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3DMARK – THE GAMER'S BENCHMARK

3DMark is a tool for measuring the performance of PCs and mobile devices. It includes many different benchmarks, each designed for a specific class of hardware from smartphones to laptops to high-performance gaming PCs.

⚠ This guide is for the Windows version. There are separate guides for the Android version and the iOS version.

3DMark works by running intensive graphical and computational tests. The more powerful your hardware, the smoother the tests will run. Don't be surprised if frame rates are low. 3DMark benchmarks are very demanding.

Each benchmark gives a score that you can use to compare similar systems. When testing devices or components, be sure to use the most appropriate test for the hardware's capabilities and report your results using the full name of the benchmark test, for example:

 ✓ "Video card scores 5,800 in 3DMark Fire Strike benchmark."
 ✗ "Video card scores 5,800 in 3DMark benchmark."

3DMark is used by millions of gamers, hundreds of hardware review sites and many of the world's leading manufacturers. We are proud to say that 3DMark is the world's most popular and widely used benchmark.

The right test every time

We've made it easy to find the right test for your hardware. When you open the 3DMark app, the Home screen will recommend the most suitable benchmark. You can find and run other tests on the Benchmarks screen.

Choose your tests

3DMark grows bigger every year with new tests. When you buy 3DMark from Steam, you can choose to install only the tests you need. In 3DMark Advanced and Professional Editions, tests can be installed and updated independently.
Complete Windows benchmarking toolkit

3DMark includes benchmarks for DirectX 12, DirectX 11, DirectX 10, and DirectX 9 compatible hardware. All tests are powered by modern graphics engines that use Direct3D feature levels to target compatible hardware.

Cross-platform benchmarking

You can measure the performance of Windows, Android, and iOS devices and compare scores across platforms.
3DMARK BENCHMARKS AT A GLANCE

3DMark includes many benchmarks, each designed for specific class of hardware capabilities. You will get the most useful and relevant results by choosing the most appropriate test for your system.

<table>
<thead>
<tr>
<th>BENCHMARK</th>
<th>TARGET HARDWARE</th>
<th>ENGINE</th>
<th>RENDERING RESOLUTION¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time Spy Extreme</td>
<td>4K gaming with DirectX 12</td>
<td>DirectX 12 feature level 11</td>
<td>3840 × 2160 (4K UHD)</td>
</tr>
<tr>
<td>Time Spy</td>
<td>High-performance DirectX 12 gaming PCs</td>
<td>DirectX 12 feature level 11</td>
<td>2560 × 1440</td>
</tr>
<tr>
<td>Night Raid</td>
<td>PCs with integrated graphics</td>
<td>DirectX 12 feature level 11</td>
<td>1920 × 1080</td>
</tr>
<tr>
<td>Port Royal</td>
<td>Graphics cards with Microsoft DirectX Raytracing support</td>
<td>DirectX 12 feature level 12_1</td>
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</tr>
<tr>
<td>Fire Strike Ultra</td>
<td>4K gaming with DirectX 11</td>
<td>DirectX 11 feature level 11</td>
<td>3840 × 2160 (4K UHD)</td>
</tr>
<tr>
<td>Fire Strike Extreme</td>
<td>Multi-GPU systems and overclocked PCs</td>
<td>DirectX 11 feature level 11</td>
<td>2560 × 1440</td>
</tr>
<tr>
<td>Fire Strike</td>
<td>High-performance DirectX 11 gaming PCs</td>
<td>DirectX 11 feature level 11</td>
<td>1920 × 1080</td>
</tr>
<tr>
<td>Sky Diver</td>
<td>Gaming laptops and mid-range PCs</td>
<td>DirectX 11 feature level 11</td>
<td>1920 × 1080</td>
</tr>
<tr>
<td>Cloud Gate</td>
<td>Notebooks and typical home PCs</td>
<td>DirectX 11 feature level 10</td>
<td>1280 × 720</td>
</tr>
</tbody>
</table>

¹ The resolution shown in the table is the resolution used to render the Graphics tests. In most cases, the Physics test or CPU test will use a lower rendering resolution to ensure that GPU performance is not a limiting factor.
<table>
<thead>
<tr>
<th>BENCHMARK</th>
<th>TARGET HARDWARE</th>
<th>ENGINE</th>
<th>RENDERING RESOLUTION</th>
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</thead>
<tbody>
<tr>
<td>Ice Storm Extreme</td>
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<td>Ice Storm</td>
<td></td>
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<tr>
<td>Ice Storm Unlimited</td>
<td>Older smartphones and tablets</td>
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<td>1280 × 720</td>
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<tr>
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## 3DMARK EDITION FEATURES

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<tbody>
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<tr>
<td>Port Royal</td>
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<tr>
<td>Sky Diver</td>
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<td>VRS feature test</td>
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<td>Install tests independently</td>
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## LATEST VERSION NUMBERS

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<th>ANDROID</th>
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<td>2.10.6799</td>
<td>2.0.4573</td>
<td>See table below</td>
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<tr>
<td>TIME SPY</td>
<td>1.1</td>
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<tr>
<td>NIGHT RAID</td>
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<tr>
<td>PORT ROYAL</td>
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<td>×</td>
<td>×</td>
</tr>
<tr>
<td>FIRE STRIKE</td>
<td>1.1</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>SKY DIVER</td>
<td>1.0</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>CLOUD GATE</td>
<td>1.1</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>SLING SHOT</td>
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<tr>
<td>ICE STORM</td>
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<td>PCI EXPRESS</td>
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<td>×</td>
</tr>
<tr>
<td>VRS</td>
<td>1.0</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>NVIDIA DLSS</td>
<td>1.1</td>
<td>×</td>
<td>×</td>
</tr>
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</table>

On iOS, 3DMark benchmarks are separate apps due to platform limitations.

<table>
<thead>
<tr>
<th>IOS APP</th>
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<tbody>
<tr>
<td>3DMARK SLING SHOT</td>
<td>1.0.745</td>
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<td>3DMARK ICE STORM</td>
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<td>3DMARK API OVERHEAD</td>
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## TEST COMPATIBILITY

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Windows</th>
<th>Android</th>
<th>iOS</th>
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<tbody>
<tr>
<td>TIME SPY EXTREME</td>
<td>✔️</td>
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<td>✗</td>
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<tr>
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<td>✗</td>
</tr>
<tr>
<td>NIGHT RAID</td>
<td>✔️</td>
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<td>✗</td>
</tr>
<tr>
<td>PORT ROYAL</td>
<td>✔️</td>
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<td>FIRE STRIKE ULTRA</td>
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<td>✔️</td>
</tr>
<tr>
<td>PCI EXPRESS</td>
<td>✔️</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>VRS</td>
<td>✔️</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>NVIDIA DLSS</td>
<td>✔️</td>
<td>✗</td>
<td>✗</td>
</tr>
</tbody>
</table>
GOOD TESTING GUIDE

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

- Running other programs during the benchmark can affect the results.
- Don't touch the mouse or keyboard while running tests.
- Do not change the window focus while the benchmark is running.
- You can cancel a test by pressing the ESC key.

Recommended process
1. Install all critical updates to ensure your operating system is up to date.
2. Install the latest approved 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 approved 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

The settings on the Options screen apply to all available benchmark tests.

License

Register / Unregister

If you have a 3DMark Advanced or Professional Edition upgrade key, copy it into the box and press the Register button. If you wish to unregister your key, so you can move your license to a different machine for example, press the Unregister button.

Version details

Here you see the current version number and status of the various benchmark tests available in 3DMark. If a newer version is available, you will be able to update from this screen.

General

Language

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

- English
- German
- Japanese
- Korean
- Russian
- Simplified Chinese
- Spanish

GPU count

You can use this drop down to tell 3DMark how many GPUs are present in the system you are testing. The default choice, Automatic, is fine in most cases and should only be changed in the rare instances when SystemInfo is unable to correctly identify the system's hardware.

Scaling mode

This option controls how the rendered output of each test, which is at a fixed resolution regardless of hardware, is scaled to fit the system's Windows desktop resolution.

The default option is Centered, which maintains the aspect ratio of the rendered output and, if needed, adds bars around the image to fill the remainder of the screen.
Selecting Stretched will stretch the rendered output to fill the screen without preserving the original aspect ratio. This option does not affect the test score.

Output resolution
3DMark tests are rendered at a fixed resolution regardless of hardware – the rendering resolution. The resulting frames are then scaled to fit the system’s Windows desktop resolution – the output resolution. The default option is automatic, which sets the output resolution to the Windows desktop resolution. Change this option if you wish to display the benchmark at some other resolution. This option does not affect the test score.

Demo audio
Uncheck this box if you wish to turn off the soundtrack while a demo is running. This option is selected by default.

Result
Validate result online
This option is only available in 3DMark Professional Edition where it is disabled by default. In 3DMark Basic and Advanced Editions, all results are validated online automatically.

Automatically hide results online
Check this box if you wish to keep your 3DMark test scores private. Hidden results are not visible to other users and do not appear in search results. Hidden results are not eligible for competitions or the Hall of Fame.

- 3DMark Basic Edition, disabled by default and cannot be selected.

SystemInfo
Scan SystemInfo
SystemInfo is a component used by 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 to get a valid benchmark test score.

SystemInfo hardware monitoring
This option controls whether SystemInfo monitors your CPU temperature, clock speed, power, and other hardware information during the benchmark run. This option is selected by default.
CUSTOM BENCHMARK SETTINGS

Each benchmark test has its own settings, found on the Custom Run tab on the Test Details screen. Use custom settings to explore the limits of your PC’s performance by making tests more or less demanding.

Custom settings are only available in the Advanced and Professional Editions.

You will only get an official 3DMark test score when you run a test with the default settings. When using custom settings you will still get the results from individual sub-tests as well as hardware performance monitoring information.
NOTES ON DIRECTX 11.1

3DMark does use DirectX 11.1, but only in a minor way and with a fall-back for DirectX 11 to ensure compatibility with the widest range of hardware and to ensure that all tests work with Windows 7 and Windows 8.

DirectX 11.1 API features were evaluated and those that could be utilized to accelerate the rendering techniques in the tests designed to run on DirectX 11.0 were used.

**Discard resources and resource views**

In cases where subsequent Direct3D draw calls will overwrite the entire resource or resource view and the application knows this, but it is not possible for the display driver to deduce it, a discard call is made to help the driver in optimizing resource usage. If DirectX 11.1 is not supported, a clear call or no call at all is made instead, depending on the exact situation. This DX11.1 optimization may have a performance effect with multi-GPU setups or with hardware featuring tile based rendering, which is found in some tablets and entry-level notebooks.

**16 bpp texture formats**

The 16 bpp texture formats supported by DirectX 11.1 are used on Ice Storm game tests to store intermediate rendering results during post processing steps. If support for those formats is not found, 32 bpp formats are used instead. This optimization gives a noticeable performance effect on hardware such as tablets, entry-level notebooks for which the Ice Storm tests provide a suitable benchmark.

There are no visual differences between the tests when using DirectX 11 or DirectX 11.1 in 3DMark and the practical performance difference from these optimizations is limited to Ice Storm on very low-end Windows hardware.
TIME SPY

Time Spy is a DirectX 12 benchmark test for high-performance gaming PCs running Windows 10. Time Spy includes two Graphics tests, a CPU test, and a demo. The demo is for entertainment only and does not influence the score.

With its pure DirectX 12 engine, which supports features like asynchronous compute, explicit multi-adapter, and multi-threading, Time Spy is the ideal benchmark for testing the DirectX 12 performance of modern graphics cards.

3DMark Advanced and Professional Editions include Time Spy Extreme, a more demanding 4K benchmark test designed for the latest graphics cards and multi-core processors.

Scores from 3DMark Time Spy and Time Spy Extreme should not be compared with each other - they are separate tests with their own scores, even though they share similar content.

Time Spy benchmarks are only available in the Windows editions of 3DMark.

Time Spy

Time Spy is a DirectX 12 benchmark test for Windows 10 gaming PCs. The Graphics tests are rendered at 2560 × 1440 resolution.

Time Spy Extreme

Time Spy Extreme is a 4K gaming benchmark that raises the rendering resolution to 3840 × 2160. A 4K monitor is not required, but your graphics card must have at least 4 GB of memory. The enhanced CPU test is ideal for processors with 8 or more cores.
DIRECTX 12

DirectX 12, introduced with Windows 10, is a low-level graphics API that reduces processor overhead. With less overhead and better utilization of modern GPU hardware, a DirectX 12 game engine can draw more objects, textures and effects to the screen. How much more? Take a look at the table below that compares Time Spy with Fire Strike, a high-end DirectX 11 test.

**Average amount of processing per frame**

<table>
<thead>
<tr>
<th></th>
<th>Vertices</th>
<th>Triangles</th>
<th>Tessellation patches</th>
<th>Compute shader invocations</th>
</tr>
</thead>
<tbody>
<tr>
<td>3DMark Fire Strike</td>
<td>3,900,000</td>
<td>5,100,000</td>
<td>500,000</td>
<td>1,500,000</td>
</tr>
<tr>
<td>Graphics test 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3DMark Fire Strike</td>
<td>2,600,000</td>
<td>5,800,000</td>
<td>240,000</td>
<td>8,100,000</td>
</tr>
<tr>
<td>Graphics test 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3DMark Time Spy</td>
<td>30,000,000</td>
<td>13,500,000</td>
<td>800,000</td>
<td>29,000,000</td>
</tr>
<tr>
<td>Graphics test 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3DMark Time Spy</td>
<td>40,000,000</td>
<td>14,000,000</td>
<td>2,400,000</td>
<td>31,000,000</td>
</tr>
<tr>
<td>Graphics test 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

With DirectX 12, developers can significantly improve the multi-thread scaling and hardware utilization of their titles. But it requires a considerable amount of graphics expertise and memory-level programming skill. The programming investment is significant and must be considered from the start of a project.

3DMark Time Spy was developed with expert input from AMD, Intel, Microsoft, NVIDIA, and the other members of the **UL Benchmark Development Program**. It is one of the first DirectX 12 apps to be built "the right way" from the ground up to fully realize the performance gains that DirectX 12 offers.
DIRECT3D FEATURE LEVELS

DirectX 11 introduced a paradigm called Direct3D feature levels. A feature level is a well-defined set of GPU functionality. For instance, the 9_1 feature level implements the functionality in DirectX 9.

With feature levels, 3DMark tests can use modern DirectX 12 and DirectX 11 engines and yet still target older DirectX 10 and DirectX 9 level hardware. For example, 3DMark Cloud Gate uses a DirectX 11 feature level 10 engine to target DirectX 10 compatible hardware.

Time Spy uses DirectX 12 feature level 11_0. This lets Time Spy leverage the most significant performance benefits of the DirectX 12 API while ensuring wide compatibility with DirectX 11 hardware through DirectX 12 drivers.

Game developers creating DirectX 12 titles are also likely to use this approach since it offers the best combination of performance and compatibility.
## SYSTEM REQUIREMENTS

<table>
<thead>
<tr>
<th></th>
<th>TIME SPY</th>
<th>TIME SPY EXTREME</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OS</strong></td>
<td>Windows 10, 64-bit</td>
<td>Windows 10, 64-bit</td>
</tr>
<tr>
<td><strong>PROCESSOR</strong></td>
<td>1.8 GHz dual-core CPU with SSSE3 support</td>
<td>1.8 GHz dual-core CPU with SSSE3 support</td>
</tr>
<tr>
<td><strong>STORAGE</strong></td>
<td>2 GB free disk space</td>
<td>2 GB free disk space</td>
</tr>
<tr>
<td><strong>GPU</strong></td>
<td>DirectX 12</td>
<td>DirectX 12</td>
</tr>
<tr>
<td><strong>VIDEO MEMORY</strong></td>
<td>1.7 GB (2 GB or more recommended)</td>
<td>4 GB</td>
</tr>
</tbody>
</table>

Time Spy will not run on multi-GPU systems with Windows 10 build 10240, but this is due to an issue with Windows. You must use Windows 10 build 10586 (“November Update”) or later to enable multi-GPU configurations to work.
GRAPHICS TEST 1

Graphics tests are designed to stress the GPU while minimizing the CPU workload to ensure that CPU performance is not a limiting factor.

Graphics test 1 focuses more on rendering of transparent elements. It utilizes the A-buffer heavily to render transparent geometries and big particles in an order-independent manner. Graphics test 1 draws particle shadows for selected light sources. Ray-marched volumetric illumination is enabled only for the directional light. All post-processing effects are enabled.

Processing performed in an average frame

<table>
<thead>
<tr>
<th></th>
<th>VERTICES</th>
<th>TESSELLATION PATCHES</th>
<th>TRIANGLES</th>
<th>PIXEL SHADER INVOCATIONS</th>
<th>COMPUTE SHADER INVOCATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>TIME SPY</td>
<td>30 million</td>
<td>0.8 million</td>
<td>13.5 million</td>
<td>80 million</td>
<td>29 million</td>
</tr>
<tr>
<td>TIME SPY EXTREME</td>
<td>30 million</td>
<td>0.9 million</td>
<td>13.5 million</td>
<td>220 million</td>
<td>63 million</td>
</tr>
</tbody>
</table>

³ This figure is the average number of pixels processed per frame before the image is scaled to fit the native resolution of the device being tested. If the device's display resolution is greater than the test's rendering resolution, the actual number of pixels processed per frame will be even greater.
GRAPHICS TEST 2

Graphics tests are designed to stress the GPU while minimizing the CPU workload to ensure that CPU performance is not a limiting factor.

Graphics test 2 focuses more on ray-marched volume illumination with hundreds of shadowed and unshadowed spot lights. The A-buffer is used to render glass sheets in an order-independent manner. Also, lots of small particles are simulated and drawn into the A-buffer. All post-processing effects are enabled.

Processing performed in an average frame

<table>
<thead>
<tr>
<th></th>
<th>VERTICES</th>
<th>TESSELLATION PATCHES</th>
<th>TRIANGLES</th>
<th>PIXEL SHADER INVOCATIONS⁴</th>
<th>COMPUTE SHADER INVOCATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>TIME SPY</td>
<td>40 million</td>
<td>2.4 million</td>
<td>14 million</td>
<td>50 million</td>
<td>31 million</td>
</tr>
<tr>
<td>TIME SPY EXTREME</td>
<td>40 million</td>
<td>2.4 million</td>
<td>14 million</td>
<td>220 million</td>
<td>68 million</td>
</tr>
</tbody>
</table>

⁴ This figure is the average number of pixels processed per frame before the image is scaled to fit the native resolution of the device being tested. If the device’s display resolution is greater than the test’s rendering resolution, the actual number of pixels processed per frame will be even greater.
TIME SPY CPU TEST

The CPU test measures processor performance using a combination of physics computations and custom simulations. It is designed to stress the CPU while minimizing GPU load to ensure that GPU performance is not a limiting factor.

The CPU test uses a fixed time step. This means that the speed at which the timeline advances is constant. As a result, the same frames are simulated and rendered on every system but the time taken to complete the test will vary.

The two main components of the test workload are an implementation of a boid system to simulate flocking behaviour and a physics simulation. The boids use a simple, highly optimized simulation whereas the physics simulation is performed with the x86 path of the Bullet Open Source Physics library (v2.83) using rigid bodies and a Featherstone solver. Of the two, the boids are more dominant and make up between 40% and 70% of the workload.

In the Time Spy CPU test, the boids are implemented with SSSE3 vectorization, which is common practice in games.

The test metric is the average frame rate reported in frames per second. A higher value means better performance.
TIME SPY EXTREME CPU TEST

In 2017, both AMD and Intel introduced new processors with more cores than had ever been seen in a consumer-level CPU before.

The Time Spy CPU test does not scale well on processors with 10 or more threads. It simply doesn't have enough workload for the large-scale parallelization that high-end CPUs provide. A new test is needed.

Enhanced test design

The Time Spy Extreme CPU test also features a combination of physics computations and custom simulations, but it is three times more demanding than the Time Spy CPU test.

Adding more simulation requires more visualization, however, which can make rendering the bottleneck in some cases. This issue was solved by changing the metric for the test.

Instead of calculating the time taken to execute an entire frame, in the Extreme CPU test we only measure the time taken to complete the simulation work. The rendering work in each frame is done before the simulation and doesn't affect the score.

The test metric is average simulation time per frame reported in milliseconds. Unlike frame rate, with this metric a lower number means better performance.

CPU instruction sets

In the Time Spy test, the boids simulation is implemented with SSSE3.

In the Extreme CPU test, half of the boids systems can use more advanced CPU instruction sets, up to AVX2 if supported by the processor. The remaining half use the SSSE3 code path.

The split makes the test more realistic since games typically have several types of simulation or similar tasks running at once and would be unlikely to use a single instruction set for all of them.

Custom run

With Custom run settings, you can choose which CPU instruction set to use, up to AVX512. The selected set will be used for all boid systems, provided it is supported by the processor under test.

You can evaluate the performance gains of different instruction sets by comparing custom run scores, but note that the choice of set doesn't affect
the physics simulations, which always use SSSE3 and are 15-30% of the workload.
SCORING

Time Spy produces an overall Time Spy score, a Graphics test sub-score, and a CPU test sub-score. The scores are rounded to the nearest integer. The better a system’s performance, the higher the score.

Overall Time Spy score

The 3DMark Time Spy score formula uses a weighted harmonic mean to calculate the overall score from the Graphics and CPU test scores.

\[
\text{Time Spy score} = \frac{W_{\text{graphics}} + W_{\text{cpu}}}{\frac{W_{\text{graphics}}}{S_{\text{graphics}}} + \frac{W_{\text{cpu}}}{S_{\text{cpu}}}}
\]

Where:

\[
W_{\text{graphics}} = \text{The Graphics score weight, equal to 0.85}
\]
\[
W_{\text{cpu}} = \text{The CPU score weight, equal to 0.15}
\]
\[
S_{\text{graphics}} = \text{Graphics test score}
\]
\[
S_{\text{cpu}} = \text{CPU test score}
\]

For a balanced system, the weights reflect the ratio of the effects of GPU and CPU performance on the overall score. Balanced in this sense means the Graphics and CPU test scores are roughly the same magnitude.

For a system where either the Graphics or CPU score is substantially higher than the other, the harmonic mean rewards boosting the lower score. This reflects the reality of the user experience. For example, doubling the CPU speed in a system with an entry-level graphics card doesn’t help much in games since the system is already limited by the GPU. Likewise for a system with a high-end graphics card paired with an underpowered CPU.

Graphics test scoring

Each Graphics test produces a raw performance result in frames per second (FPS). We take a harmonic mean of these raw results and multiply it by a scaling constant to reach a Graphics score (\(S_{\text{graphics}}\)) as follows:

\[
S_{\text{graphics}} = 164 \times \frac{2}{\frac{1}{F_{gt1}} + \frac{1}{F_{gt2}}}
\]
Where:

\[
F_{gt1} = \text{The average FPS result from Graphics test 1}
\]
\[
F_{gt2} = \text{The average FPS result from Graphics test 2}
\]

The scaling constant is used to bring the score in line with traditional 3DMark score levels.

**Time Spy CPU test scoring**

The CPU test consists of three increasingly heavy levels, each of which has a ten second timeline. The third, and heaviest, level produces a raw performance result in frames per second (FPS) which is multiplied by a scaling constant to give a CPU score \(S_{cpu}\) as follows:

\[
S_{cpu} = 298 \times F_{cpu3}
\]

Where:

\[
F_{cpu3} = \text{The average FPS from the CPU test's third level}
\]

The scaling constant is used to bring the score in line with traditional 3DMark score levels.

**Time Spy Extreme CPU test scoring**

In the Extreme CPU test we only measure the time taken to complete the simulation work. The rendering work in each frame is done before the simulation and does not affect the score.\(^5\)

The CPU score \(S_{cpu}\) is calculated from the average simulation time per frame reported in milliseconds.

\[
S_{CPU} = \frac{T_{Reference} \times S_{Reference}}{T_{Simulation}}
\]

---

\(^5\) Note that Time Spy Extreme is not a suitable test for systems with integrated graphics. The rendering will affect the simulation time on such systems due to shared resources.
Where:

\[ T_{\text{Reference}} = \text{Reference time constant set to 70} \]

\[ S_{\text{Reference}} = \text{Reference score constant set to 5,000} \]

\[ T_{\text{Reference}} = \text{The average simulation time per frame} \]

The scaling constants are used to bring the score in line with traditional 3DMark score levels.
Command lists and asynchronous compute

Unlike the Draw/Dispatch calls in DirectX 11 (with immediate context), In DirectX 12, the recording and execution of command lists are decoupled operations. There is no thread limitation on recording command lists. Recording can happen as soon as the required information is available.

Quoting from MSDN:

"Most modern GPUs contain multiple independent engines that provide specialized functionality. Many have one or more dedicated copy engines, and a compute engine, usually distinct from the 3D engine. Each of these engines can execute commands in parallel with each other. Direct3D 12 provides granular access to the 3D, compute and copy engines, using queues and command lists.

“The following diagram shows a title’s CPU threads, each populating one or more of the copy, compute and 3D queues. The 3D queue can drive all three GPU engines, the compute queue can drive the compute and copy engines, and the copy queue simply the copy engine."
Command list execution

For GPU work to happen, command lists are executed on queues, which come in variants called DIRECT (commonly known as graphics or 3D as in the diagram above), COMPUTE and COPY. Submission of a command list to a queue can happen on any thread. The D3D runtime serializes and orders the lists within a queue.

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIRECT command list</td>
<td>This command list type supports all types of commands including Draw calls, compute Dispatches and Copies.</td>
</tr>
<tr>
<td>COMPUTE command list</td>
<td>This command list type supports compute Dispatch and Copy commands.</td>
</tr>
<tr>
<td>DIRECT queue</td>
<td>This queue can be used for executing all types of command lists supported by DirectX 12.</td>
</tr>
<tr>
<td>COMPUTE queue</td>
<td>This queue accepts compute and copy command lists.</td>
</tr>
<tr>
<td>COPY command list and queues</td>
<td>This command list and queue type accepts only copy commands and lists respectively.</td>
</tr>
</tbody>
</table>
Once initiated, multiple queues can execute in parallel. This parallelism is commonly known as ‘asynchronous compute’ when COMPUTE queue work is performed at the same time as DIRECT queue work.

It is up to the driver and the hardware to decide how to execute the command lists. The application cannot affect this decision through the DirectX 12 API.

Please see MSDN for an introduction to the Design Philosophy of Command Queues and Command Lists, and for more information on Executing and Synchronizing Command Lists.

In Time Spy, the engine uses two command queues: a DIRECT queue for graphics and compute and a COMPUTE queue for asynchronous compute. The implementation is the same regardless of the capabilities of the hardware being tested. It is ultimately the decision of the underlying driver whether the work in the COMPUTE queue is executed in parallel or in serial.

There is a large amount of command lists as many tasks have their own command lists, (several copies so that frames can be pre-recorded).

---

6 The COPY queue is generally used for streaming assets. It is not needed in Time Spy as we load all assets before the benchmark run begins to ensure the test does not gain a dependency on storage or main memory.
Each task encapsulates a complex task substructure that is omitted in this simplified graph for clarity. If there are no dependencies, tasks are executed on the CPU in parallel.

**Grey** tasks are CPU tasks. The `async_illumination_commands` task contains light culling and tiling, environment reflections, HBAO, and unshadowed surface illumination.

**Green** tasks are submissions to the DIRECT (graphics) queue. G-buffer draws, shadow map draws, shadowed illumination resolve, and post-processing are executed on the DIRECT queue. G-buffer draws, shadow maps and some parts of the post-processing are done with graphics shaders, while illumination resolve and the rest of the post processing is done in compute shaders.

**Red** tasks are submissions to the COMPUTE queue. Particle simulation, light culling and tiling, environment reflections, HBAO and unshadowed surface illumination resolve are executed on the COMPUTE queue. All tasks in the compute queue must be done in compute shaders.

---

7 Directed Acyclic Graph (DAG), see [https://en.wikipedia.org/wiki/Directed_acyclic_graph](https://en.wikipedia.org/wiki/Directed_acyclic_graph).
**Yellow** tasks are submissions of synchronization points. The significance of these can be seen by noting that `execute_async_illumination_commands` cannot be executed on the GPU before `execute_gbuffer_commands` is completed, but the submission happens ahead of the execution, (unless we are CPU bound). The GPU needs to know that it should wait for a task to complete execution before a dependent task can begin executing. When the execution is split between queues then this operation should be done by the engine otherwise a RAW hazard occurs. There is another dependency between particle simulation and completion of particle illumination in the previous frame. The simulation happens on the compute queue, which will cause a WAR hazard if it is not synchronized with the Present occurring on the graphics queue.

The order of submission can be obtained from the dependency graph. However, it is entirely up to the driver and the hardware to decide when to actually execute the given list as long as it is executed in order in its queue.

**Compute queue work items (in order of submission)**

1. Particle simulation

   This pass is recorded and executed at the beginning of a frame because it doesn't depend on the G-buffer. Thus its recording and submission is done in parallel with recording and submission of geometry draws (G-Buffer construction).

2. Light culling and tiling
3. Environment reflections
4. Horizon based ambient occlusion
5. Unshadowed surface illumination

   These passes are recorded and submitted in parallel with G-Buffer recording and submission, but executed only after the G-Buffer is finished executing and in parallel with shadow maps execution. This is because they depend on the G-Buffer, but not on the shadow maps.

**Disabling asynchronous compute in benchmark settings**

The asynchronous compute workload per frame in Time Spy varies between 10% and 20%. To observe the benefit on your own hardware, you can optionally choose to disable asynchronous compute using the Custom run settings in 3DMark Advanced and Professional Editions.

Running with asynchronous compute disabled in the benchmark forces all work items usually associated with the COMPUTE queue to instead be put in the DIRECT queue.
**Explicit multi-adapter**

In DirectX 11, control of GPU adapters is implicit - the drivers use multiple GPUs on behalf of an application.

In DirectX 12, control of multiple GPUs is explicit. The developer can control what work is done on each GPU and when. With explicit multi-adapter control, one can implement more complex multi-GPU models, for example choosing to execute partial workloads for a frame across different GPUs.

A GPU adapter can be any graphics adapter, from any manufacturer, that supports D3D12. Each adapter is referred to as a node. There are two multi-adapter modes called linked-node adapter and multi-node adapter.

With linked-node (LDA) the programmer has access to and control over an SLI/Crossfire configuration of similar GPUs through one device interface. LDA enables some extra features over multi-node, such as faster transfers between GPUs, cross-node resource sharing and shared swap-chain (backbuffer).

With multi-node (MDA) each GPU appears as a separate device, even if they are similar and linked. With MDA, the programmer can control any and all GPUs available in the system. But the programmer must explicitly declare which GPU should execute the recorded work. MDA allows much more fine-grained control over rendering and work submission, allowing you to divide work between a discrete graphics card and an integrated GPU for example.

**Time Spy** uses explicit alternate frame rendering on linked-node configurations to improve performance on the most common multi-GPU setups used by gamers today. MDA configurations of heterogeneous adapters are not supported.

**Multi-threaded GPU work recording and submission**

DirectX 11 offers multi-threaded (deferred) context support, but not all vendors implement it in hardware, so it is slow. And overall, it is quite limited.

DirectX 12 really takes multi-threaded rendering to the next level. With DirectX 12, the programmer is in the control of everything. There are a few operations that cannot be executed at the same time on multiple threads, but otherwise, there are not many rules.

Resources must be manually transitioned to the correct states, progress within a frame must be tracked explicitly, and any potential hazards must be handled explicitly. All synchronization of CPU and GPU workloads must be
done using fences and barriers, as there is no validation or checks in the driver.

**In Time Spy**, the rendering is heavily multithreaded. Command lists are recorded on all logical cores.

**Improved resource allocation, explicit state tracking, and persistent mapping**

In DirectX 11, there are no heaps. The driver manages everything, including all states. Transfers to GPU memory must go through the API layer.

In DirectX 12, there are multiple ways to allocate resources. Programmers can create heaps, big piles of data that can later be filled with textures and buffers. Heaps also save memory by allowing resources to be placed on top of each other, for example render target surfaces.

All resource states must be explicitly declared. Resources have an initial state, and they must be transitioned to the correct state before the rendering commands are executed. For example, if a resource is going to be written to, it must be transitioned to a write state. The same applies for all other operations.

Since all state is explicit, the driver no longer has 'guess' the intent of the programmer, which allows faster execution. State can be changed across different work packets (command lists).

Some buffers can be persistently mapped to CPU memory to mirror the same buffer in GPU memory. This allows transfers to GPU memory with less stalls and also removes the need to invalidate buffers. But on the other hand, it puts the responsibility of managing the buffer on the programmer.

**In Time Spy**, all features are used, including heaps with overlapping resources to save memory. States are explicitly handled as they should be. Persistently mapped (streaming) buffers are used for all dynamic data with custom resource hazard prevention using fences.

**Pre-built GPU state objects**

In DirectX 11, individual states (like bound shaders) can be changed at any time. There are no limitations. But the driver must optimize during runtime if necessary, which can lead to stalled rendering.

In DirectX 12, the GPU pipeline state is managed by separate pipeline state objects that encapsulate the whole state of the graphics/compute engine. In the graphics case, this encompasses things like the rasterizer state, different shaders (e.g. vertex and pixel shader), and the blending mode. State switching is done in one step by replacing the whole pipeline at once.
Since pipelines are pre-built before they are bound, the driver can optimize them beforehand. During runtime, only the GPU state reconfiguration is required based on the already optimized state. This allows very fast state switching. It removes the need for ‘warm-up’ before rendering, since the drivers don't cache state as often as with DirectX 11.

Pipelines can also be compiled during runtime, of course. Games can compile only the necessary pipelines during startup. If a new pipeline object is required later, it can be created easily in a separate thread without halting any of the application logic threads.

**In Time Spy**, all pipelines are built during startup. State changes are minimized by sorting by pipeline state object during rendering.

**Resource binding**

As mentioned in the previous section on pipelines, when a new state is bound to the GPU everything about it is already known. This also applies for resource bindings. Pipeline state objects also contain information about the resources that will be bound to the shader and how they will reside in the GPU memory.

DirectX 12 uses descriptors and descriptor tables to bind resources. Descriptors are very lightweight objects that contain information about the resource that is to be bound. Descriptors can be arranged in tables for easy binding of multiple resources at once. This operation is also very fast, as the table can be described by binding only one pointer.

**In Time Spy**, resource binding is used as it should be to optimize performance.

**Explicit synchronization between CPU, GPU, multiple GPUs, and multiple GPU queues**

In DirectX 12, synchronization won't happen without programmer intervention. All possible resource hazards must be handled by the programmer by using various synchronization objects.

And since multiple GPU queues are supported, fences must also be used on the GPU side to make sure queues execute work when they should. It's programmer's responsibility to handle all synchronization.

**In Time Spy**, synchronization is used as it should be to optimize performance.
TIME SPY ENGINE

To fully take advantage of the performance improvements that DirectX 12 offers, Time Spy uses a custom game engine developed in-house from the ground up. The engine was created with the input and expertise of AMD, Intel, Microsoft, NVIDIA, and the other members of the UL Benchmark Development Program.

Multi-threading

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. This reduces CPU load by utilizing multiple cores.

Multi-GPU support

The engine supports the most common type of multi-GPU configuration, i.e. two identical GPU adapters in Crossfire/SLI, by using explicit multi-adapter with a linked-node configuration to implement explicit alternate frame rendering. Heterogeneous adapters are not supported.

Visibility solution

The Umbra occlusion library (version 3.3.17 or newer) is used to accelerate and optimize object visibility evaluation for all cameras, including the main camera and light views used for shadow map rendering. The culling runs on the CPU and does not consume GPU resources.

Descriptor heaps

One descriptor heap is created for each descriptor type when the scene is loaded. 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 created by ID3D12Device::CreateCommittedResource() are used for most resources. Explicitly created heaps are used for some target resources to reduce memory consumption by placing resources that not needed at the same time on top of each other.
Asynchronous compute

Asynchronous compute is utilized heavily to overlap multiple rendering passes for maximum utilization of the GPU. Async compute workload per frame varies between 10-20%.

Tessellation

The engine supports Phong tessellation and displacement-map-based detail tessellation.

Tessellation factors are adjusted to achieve the desired edge length for the output geometry on the render target (G-buffer, shadow map or other). Additionally, patches that are back-facing and patches that are outside of the view frustum are culled by setting the tessellation factor to zero.

Tessellation is turned entirely off by disabling hull and domain shaders when the size of an object’s bounding box on the render target drops below a given threshold.

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 the G-buffer. In the second step, transparent objects are rendered to an A-buffer, which is then resolved on top of surface illumination later on.

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

The material system uses physically based materials. The following textures can be used as input to materials. Not all textures are used on all materials.

<table>
<thead>
<tr>
<th>MATERIAL TEXTURE</th>
<th>FORMAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albedo (RGB) + metalness (A)</td>
<td>BC3 or BC7</td>
</tr>
<tr>
<td>Roughness (R) + Cavity (G)</td>
<td>BC5</td>
</tr>
<tr>
<td>Normal (RG)</td>
<td>BC5</td>
</tr>
<tr>
<td>Ambient Occlusion (R)</td>
<td>BC4</td>
</tr>
</tbody>
</table>
Opaque objects

Opaque objects are rendered directly to the G-buffer. The G-buffer is composed of textures shown in the table below. A material might not use all target textures. For example, a luminance texture is only written into when drawing geometries with luminous materials.

<table>
<thead>
<tr>
<th>G-BUFFER TEXTURE</th>
<th>FORMAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth</td>
<td>D24_UNORM_S8_UINT</td>
</tr>
<tr>
<td>Normal</td>
<td>R10G10B10A2_UNORM</td>
</tr>
<tr>
<td>Albedo</td>
<td>R8G8B8A8_UNORM_SRGB</td>
</tr>
<tr>
<td>Material Attributes</td>
<td>R10G10B10A2_UNORM</td>
</tr>
<tr>
<td>Luminance</td>
<td>R11G11B10_FLOAT</td>
</tr>
</tbody>
</table>

Transparent objects

For rendering transparent geometries, the engine uses a variant of an order-independent transparency technique called Adaptive Transparency (Salvi et al. 2011). Simply put, a per-pixel list of fragments is created for which a visibility function (accumulated transparency) is approximated. The fragments are blended according to the visibility function and illuminated in the lighting pass to allow them to be rendered in any order. The A-buffer is drawn after the G-buffer to fully take advantage of early depth tests.

In addition to the per-pixel lists of fragments, per 2x2 quad lists of fragments are created. The per-quad lists can be used for selected renderables instead of the per pixel lists. This saves memory when per pixel information is not required for a visually satisfying result. When rendering
to per quad lists, a half resolution viewport and depth texture is used to ignore fragments behind opaque surfaces. When resolving the A-buffer fragments for each pixel, both per pixel list and per quad list are read and blended in the correct order. Each per quad list is read for four pixels in the resolve pass.

**Lighting**

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

Before the main illumination passes, asynchronous compute shaders are used to cull lights, evaluate illumination from prebaked environment reflections, compute screen-space ambient occlusion, and calculate unshadowed surface illumination. These tasks are started right after G-buffer rendering has finished and are executed alongside shadow rendering. All frustum lights, omni-lights and reflection capture probes are culled to small tiles (16x16 pixels) and written to an intermediate buffer. Reflection illumination is evaluated for the opaque surfaces by sampling the precomputed reflection cubes. The results are written out to a separate texture. Ambient occlusion and unshadowed illumination results are written out to their respective targets.

Second, illumination from all lights and GI data is evaluated for the surface. The A-buffer is also resolved in a separate pass and then composed on top of surface illumination. This produces the final illumination that is sampled in the screen space reflection step, which also blends in previously computed environment illumination based on SSR quality. Reflections are applied on top of surface illumination. Surface illumination is also masked with SSAO results.

Third, volume illumination is computed. This includes two passes. The first one evaluates volume illumination from global illumination data and the second one calculates illumination from direct lights. The evaluation is done by raymarching the light ranges.

Finally, surface illumination, GI volume illumination, and direct volume illumination are composed into one final texture with some blurring, which is then fed to post-processing stages.

Shadows are sampled in both surface and volume illumination shaders. For shadow casting lights, the textures in the table below can be rendered.

<table>
<thead>
<tr>
<th>SHADOW TEXTURE</th>
<th>FORMAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shadow Depth</td>
<td>D16_UNORM</td>
</tr>
</tbody>
</table>
Particles

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

Particle illumination

Particles are rendered by inserting particle fragments into an A-buffer. The engine utilizes a separate half-resolution A-buffer for low-frequency particles to allow more of them to be visible in the scene at once. They are blended together with the main A-buffer in the combination step. Particles can be illuminated with scene lights or they can be self-illuminated. The output buffers of the GPU light-culling pass and the global illumination probes are used as inputs for illuminated particles. The illuminated particles are drawn without tessellation and they are illuminated in the pixel shader.

Particle shadows

Particles can cast shadows. Shadow casting particles are rendered into transmittance 3D textures for lights that have particle shadows enabled. Before being used as an input to illumination shaders, an accumulated version of the transmittance texture is created. If typed UAV loads are supported, the transmittance texture is accumulated in-place. Otherwise the accumulated result is written to an additional texture. The accumulated transmittance texture is sampled when rendering surface, particle and volume illumination by taking one sample with bilinear filtering per pixel or per ray marching step. Resolution of the transmittance texture for each spotlight is evaluated on each frame based on screen coverage of the light. For directional light, fixed resolution textures are used.

**Table: SHADOW TEXTURE FORMAT**

<table>
<thead>
<tr>
<th>Shadow Texture</th>
<th>Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particle Transmittance</td>
<td>R8G8B8A8_UNORM</td>
</tr>
</tbody>
</table>
POST-PROCESSING

Depth of field

The effect is computed by scattering the illumination in the out-of-focus parts of the input image using the following procedure.

1. Using CS, circle of confusion radius is computed for all screen pixels based on depth texture. The information is additionally reduced to half and quarter resolutions. In the same CS pass, a splatting primitive (position, radius and color) for out-of-focus pixels whose circle of confusion radius exceeds a predefined threshold is appended to a buffer. For pixel quads and 4x4 tiles that are strongly out of focus, a splatting primitive per quad or tile is appended to the buffer instead of per pixel primitives.

2. The buffer with splatting primitives for the out-of-focus pixels is used as point primitive vertex data and, using Geometry Shader, an image of a bokeh is splatted to the positions of these primitives. Splatting is done to a texture that is divided into regions with different resolutions using multiple viewports. First region is screen resolution and the rest are a series of halved regions down to 1x1 texel resolution. The screen space radius of the splatted bokeh determines the used resolution. The larger the radius the smaller the used splatting resolution.

3. The different regions of the splatting texture are combined by upscaling the data in the smaller resolution regions step by step to the screen resolution region.

4. Finally, the out-of-focus illumination is combined with the original illumination.

Bloom

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

Lens Reflections

The effect is computed by first applying a filter to the computed illumination in frequency domain like in the bloom effect. The filtered result is then splatted in several scales and intensities on top of the input image using additive blending. The effect is computed in the same resolution as the bloom effect and therefore the forward FFT needs to be performed only once for both effects. The filtering and inverse FFT are performed using the CS and floating point textures.
## TIME SPY VERSION HISTORY

<table>
<thead>
<tr>
<th>VERSION</th>
<th>Windows</th>
<th>Android</th>
<th>Apple</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>●</td>
<td>✗</td>
<td>✗</td>
<td>Added Time Spy Extreme</td>
</tr>
<tr>
<td>1.0</td>
<td>●</td>
<td>✗</td>
<td>✗</td>
<td>Launch version</td>
</tr>
</tbody>
</table>
3DMark Night Raid is a DirectX 12 benchmark for laptops, notebooks, tablets and other mobile computing devices with integrated graphics.

You can also use Night Raid to benchmark and compare the performance of Always Connected PCs, a new category of devices that aim to combine the performance and functionality of a PC, with the all-day battery life, and always-on connectivity of a smartphone.

3DMark Night Raid has native ARM support, which means you can benchmark and compare Always Connected PCs powered by Qualcomm Snapdragon processors.

3DMark Night Raid includes two Graphics tests, a CPU test, and a Demo. The Graphics tests measure GPU performance. The CPU test measures CPU performance. The demo is for entertainment. It does not affect the score.

Scores from Night Raid should not be compared with scores from other 3DMark tests.

Night Raid is only available in the Windows editions of 3DMark.

⚠ Night Raid is a benchmark for PCs with integrated graphics hardware. For testing PCs with discrete graphics cards, you should use Time Spy or Time Spy Extreme.
NATIVE SUPPORT FOR WINDOWS 10 ON ARM

Night Raid has native ARM support for devices with ARM processors.

3DMark Night Raid scores from devices powered by Windows 10 on ARM are comparable with scores from traditional PCs running Windows 10.

On PCs running on Windows 10, the Night Raid CPU Test uses advanced instructions sets, up to AVX2 if supported, and the SSSE3 code path.

On devices running Windows 10 on ARM, the CPU Test uses the NEON instruction set.
# SYSTEM REQUIREMENTS

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>OS</td>
<td>Windows 10</td>
</tr>
<tr>
<td>PROCESSOR</td>
<td>1.8 GHz dual-core CPU with SSSE3 or NEON support</td>
</tr>
<tr>
<td>STORAGE</td>
<td>2 GB free disk space</td>
</tr>
<tr>
<td>GPU</td>
<td>DirectX 12</td>
</tr>
<tr>
<td>VIDEO MEMORY</td>
<td>1 GB</td>
</tr>
</tbody>
</table>

⚠ Windows 10 64-bit is strongly recommended to run Night Raid. To benchmark on a Windows 10 32-bit system, you need to enable the 3 GB option by running `bcdedit /set IncreaseUserVa 3072` in the Administrator Command Prompt. Reboot the system after the command. To revert, run `bcdedit /deletevalue IncreaseUserVa` in the Administrator Command Prompt.
GRAPHICS TEST 1

Graphics tests are designed to stress the GPU while minimizing the CPU workload to ensure that CPU performance is not a limiting factor.

Night Raid Graphics Test 1 uses deferred rendering. The main source of illumination is the shadowed directional light shining in through the windows. There are a few dynamic frustum lights. Unshadowed omni lights contribute to illumination as well. The scene contains tiny, scattered particle systems. Screen-space dynamic reflection and ambient occlusion are enabled. Post-processing effects include lens reflections and bloom.

Processing performed in an average frame

<table>
<thead>
<tr>
<th>VERTICES</th>
<th>TESSELLATION PATCHES</th>
<th>TRIANGLES</th>
<th>PIXEL SHADER INVOCATIONS</th>
<th>COMPUTE SHADER INVOCATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>NIGHT RAID</td>
<td>5.4 million</td>
<td>-</td>
<td>1.8 million</td>
<td>9.2 million</td>
</tr>
</tbody>
</table>

This figure is the average number of pixels processed per frame before the image is scaled to fit the native resolution of the device being tested. If the device’s display resolution is greater than the test’s rendering resolution, the actual number of pixels processed per frame will be even greater.
GRAPHICS TEST 2

Graphics tests are designed to stress the GPU while minimizing the CPU workload to ensure that CPU performance is not a limiting factor.

Night Raid Graphics Test 2 uses forward rendering. Tessellated objects appear in almost all frames. There are a few shadowed frustum lights and a small number of point lights. The scene contains large particle systems with depth complexity. Post-processing adds a depth of field effect.

Processing performed in an average frame

<table>
<thead>
<tr>
<th>VERTICES</th>
<th>TESSELLATION PATCHES</th>
<th>TRIANGLES</th>
<th>PIXEL SHADER INVOCATIONS</th>
<th>COMPUTE SHADER INVOCATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>NIGHT RAID</td>
<td>2.0 million</td>
<td>0.032 million</td>
<td>0.7 million</td>
<td>19.6 million</td>
</tr>
</tbody>
</table>

9 This figure is the average number of pixels processed per frame before the image is scaled to fit the native resolution of the device being tested. If the device’s display resolution is greater than the test’s rendering resolution, the actual number of pixels processed per frame will be even greater.
CPU TEST

The CPU test measures processor performance. It is designed to stress the CPU while minimizing GPU load to ensure that GPU performance is not a limiting factor.

The Night Raid CPU test features a combination of physics computations and custom simulations.

The simulations require visualization, which can make rendering a bottleneck in some cases. To avoid this, the test only measures the time taken to complete the simulation work. The rendering work in each frame is done before the simulation and doesn't affect the score.

The result of the test is the average simulation time per frame reported in milliseconds. A lower number means better performance.

CPU instruction sets

On Windows 10 devices, half of the boids systems in the Night Raid CPU use advanced CPU instruction sets, up to AVX2 if supported. The remaining half use the SSSE3 code path. This split makes the test more realistic since games typically have several types of simulation or similar tasks running at once and would be unlikely to use a single instruction set for all of them.

On devices powered by Windows 10 on ARM, the CPU test always uses the NEON instruction set.

Custom run

With Custom run settings, you can choose which CPU instruction set to use, up to AVX512. The selected set will be used for all boids systems, provided it is supported by the processor under test.

You can evaluate the performance gains of different instruction sets by comparing custom run scores. Note that the choice of set does not affect the physics simulations, which always use SSSE3 and are 15-30% of the workload.

This settings is not available on devices powered by Windows 10 on ARM.
SCORING

3DMark Night Raid produces an overall Night Raid score, a Graphics test sub-score, and a CPU test sub-score. The scores are rounded to the nearest integer. The better a system's performance, the higher the score.

Overall Night Raid score

The 3DMark Night Raid score formula uses a weighted harmonic mean to calculate the overall score from the Graphics and CPU test scores.

\[
\text{Night Raid score} = \text{floor}\left(\frac{1}{W_{\text{graphics}} S_{\text{graphics}} + W_{\text{cpu}} S_{\text{cpu}}}\right)
\]

Where:

- \( W_{\text{graphics}} \) = The Graphics score weight, equal to 0.85
- \( W_{\text{cpu}} \) = The CPU score weight, equal to 0.15
- \( S_{\text{graphics}} \) = Graphics test score
- \( S_{\text{cpu}} \) = CPU test score

For a balanced system, the weights reflect the ratio of the effects of GPU and CPU performance on the overall score. Balanced in this sense means the Graphics and CPU test scores are roughly the same magnitude.

For a system where either the Graphics or CPU score is substantially higher than the other, the harmonic mean rewards boosting the lower score. This reflects the reality of the user experience. For example, doubling the CPU speed in a system with an entry-level graphics processor doesn't help much in games since the system is already limited by the GPU. Likewise, for a system with a high-end GPU paired with an underpowered CPU.

Graphics test scoring

Each Graphics test produces a raw performance result in frames per second (FPS). We take a harmonic mean of these raw results and multiply it by a scaling constant to reach a Graphics score \( S_{\text{graphics}} \) as follows:

\[
S_{\text{graphics}} = \text{floor}\left(C_{\text{graphics}} \times \frac{2}{F_{\text{gt}1} F_{\text{gt}2}}\right)
\]
Where:

\[ C_{\text{graphics}} = \text{Scaling constant set to 208.33} \]
\[ F_{gt1} = \text{The average FPS result from Graphics test 1} \]
\[ F_{gt2} = \text{The average FPS result from Graphics test 2} \]

The scaling constant is used to bring the score in line with traditional 3DMark score levels.

**CPU test scoring**

The Night Raid CPU test performs rendering and simulation, but only the simulation time affects the score. The time is measured for Bullet Physics and boid simulations, from start to finish of all simulations. Task priorities are set so that only simulations are executed when measuring time, thus eliminating other factors except the minor overhead of the task system.

Note that on systems with integrated GPUs the rendering will affect simulation time due to shared resources. On systems with discrete GPUs rendering should not affect scores except marginally.

\[ S_{\text{cpu}} = \text{floor} \left( \frac{T_{\text{Reference}} \times S_{\text{Reference}}}{T_{\text{Simulation}}} \right) \]

Where:

\[ T_{\text{Reference}} = \text{Reference time constant set to 115} \]
\[ S_{\text{Reference}} = \text{Reference score constant set to 5,000} \]
\[ S_{\text{Reference}} = \text{The average simulation time per frame} \]

The scaling constant is used to bring the score in line with traditional 3DMark score levels.
NIGHT RAID ENGINE

3DMark Night Raid uses a DirectX 12 graphics engine that is optimized for integrated graphics hardware. The engine was developed in-house with input from members of the UL Benchmark Development Program.

Engine features

Multi-threading
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. This reduces CPU load by utilizing multiple cores.

Multi-GPU support
The engine implements multi-GPU support using explicit alternate frame rendering on linked-node configuration. Heterogeneous adapters are not supported.

Visibility solution
The Umbra occlusion library (version 3.3.17 or newer) is used to accelerate and optimize object visibility evaluation for all cameras, including the main camera and light views used for shadow map rendering. The culling runs on the CPU and does not consume GPU resources.

Descriptor heaps
One descriptor heap is created for each descriptor type when the scene is loaded. Hardware Tier 1 is sufficient for containing all the required descriptors in the heaps.

Resource heaps
Implicit resource heaps are used for most resources. Explicitly created heaps are used for some resources to reduce memory consumption by placing resources that are not needed at the same time on top of each other.

Asynchronous compute
Asynchronous compute is used heavily to overlap multiple rendering passes for maximum utilization of the GPU. Async compute workload per frame varies between 10-20%. The forward-rendering path uses less async compute as there are fewer compute passes to run along the shadow map and G-buffer passes.
**Tessellation**

The engine supports Phong tessellation and displacement-map-based detail tessellation.

Tessellation factors are adjusted to achieve the desired edge length for the output geometry on the render target (G-buffer, shadow map or other). For shadow maps, 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.

Additionally, patches that are back-facing and patches that are outside of the view frustum are culled by setting the tessellation factor to zero.

Tessellation is turned entirely off by disabling hull and domain shaders when the size of an object's bounding box on the render target drops below a given threshold.

If an object has several geometry LODs, tessellation is used on the most detailed LOD.

**Deferred rendering**

Graphics Test 1 uses a deferred rendering pipeline. Objects are first rendered into a G-buffer that contains all the geometry attributes that are required for the illumination. Illumination is computed in multiple passes and the final result is blended with transparents and fed to the post-processing stages.

**Geometry rendering**

Objects are rendered in two steps depending on the attributes of the geometries. First, all non-transparent objects are drawn into the 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 a LOD system to reduce the number of vertices and triangles for objects that are far away. This also results in bigger on-screen triangle size.

The material system uses physically based materials. The system supports the following material textures: Albedo (RGB) + metalness (A), Roughness (R) + Cavity (G), Normal (RG), Ambient Occlusion (R), Displacement, Luminance, Blend, and Opacity. A material might not use all these textures.
Opaque objects

Opaque objects are rendered directly to the G-buffer. The G-buffer is composed of textures for Depth, Normal, Albedo, Material Attributes, and Luminance. A material might not use all these textures.

Transparent objects

When rendering transparent geometries, the engine uses a technique called “Weighted Order-Independent Transparency” (McGuire & Bavoil, 2013). The technique only requires two render targets and the special blending settings to achieve a good approximation of real transparency. Transparents are blended on top of the final surface illumination.

Illumination

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

Before the main illumination passes, asynchronous compute shaders are used to cull lights, compute screen-space ambient occlusion and evaluate unshadowed illumination. These tasks are started right after G-buffer rendering has finished and are executed alongside shadow rendering. All omni-lights are culled to small tiles (16x16 pixels) and written to an intermediate buffer. Frustum lights and environment cubes are culled for every pixel, because there are only a couple of them. Ambient occlusion and unshadowed illumination results are written out to their respective textures.

Illumination for shadowed lights is calculated after the completion of the shadow map rendering. This is also written out to its respective texture.

These results are combined in the global illumination pass while adding probe-based global illumination for objects that do not use light maps.

Reflection illumination is evaluated for the opaque surfaces by combining Screen Space Reflections (SSR) and sampling the precomputed reflection cubes for those surfaces that are rough (above a fixed threshold). Reflections are blended into the illumination in the SSR combination pass.

Final illumination is passed into post-processing.

Forward rendering

Graphics Test 2 uses a forward rendering pipeline.

In forward rendering mode the geometry is rendered in the same order as in the deferred mode. The same input textures are used and the illumination is computed similarly. The difference is that the outputs do not contain all material information, but rather the results of the illumination which is done in the same pixel shader. There is only one color render
target where the illumination information is stored and a depth target which is used for post-processing effects. There is no depth pre-pass. All the lights in the scene are iterated and there is no culling step.

Particles

Particles are simulated on the GPU using the asynchronous compute queue. Rendering is performed using indirect draw calls with inputs coming from the simulation buffers.

Particle simulation

Simulation is executed with multiple compute shader passes in the asynchronous queue alongside shadow map rendering. The following steps are executed per frame for each particle system:

- Alive count of particles is cleared
- New particles are emitted
- Particles are simulated
- Particles that are alive are counted and the count is written into a buffer that is used as indirect argument buffer in the draw phase.

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 either the vertex or pixel shader. Particles are blended together with the same order-independent technique as transparent geometries.

Post-processing

Depth of field

The effect is based on a separable blur filter that is used to create an out-of-focus texture in the following manner.

1. Circle of confusion radius is computed for all screen pixels based on the half-resolution depth. Output texture is obtained by multiplying the illumination with the corresponding radii. Average radius is stored to output alpha channel.
2. The result of the previous step is blurred in two passes using a separable filter and two work textures so that we get hexagonal bokehs when the outputs are combined.
3. Upon summing the work textures together in the combination step, they are divided by the stored average radii to renormalize the illumination.
4. The final result is obtained by linearly interpolating between the original illumination and the out-of-focus illumination based on the radius calculated from the full-resolution depth.

**Bloom**

Bloom is based on a compute shader FFT that evaluates several effects with one filter kernel. The effects are blur, streaks, anamorphic flare and lenticular halo. Bloom is computed in half resolution to make it faster.

**Lens Reflections**

The effect is computed by first applying a filter to the computed illumination in frequency domain like in the bloom effect. The filtered result is then splatted in several scales and intensities on top of the input image using additive blending. The effect is computed in the same resolution as the bloom effect and therefore the forward FFT needs to be performed only once for both effects. The filtering and inverse FFT are performed using compute shaders.
# NIGHT RAID VERSION HISTORY

<table>
<thead>
<tr>
<th>VERSION</th>
<th>Windows</th>
<th>Android</th>
<th>Apple</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>✔️</td>
<td>✗</td>
<td>✗</td>
<td>Launch version</td>
</tr>
</tbody>
</table>
PORT ROYAL

Port Royal is a graphics card benchmark for testing real-time ray tracing performance. Port Royal complements Time Spy by providing a dedicated test that focuses on ray tracing performance.

You can use Port Royal to test and compare the real-time ray tracing performance of any graphics card that supports Microsoft DirectX Raytracing—including multi-GPU systems.

Port Royal includes a Graphics test and a Demo. The Graphics Test combines real-time ray tracing and traditional rendering techniques to test GPU performance. The demo is for entertainment only and does not affect the benchmark score.

Port Royal is only available in 3DMark Advanced and Professional Editions for Windows PCs.

⚠ To run Port Royal, you need the Windows 10 October 2018 Update (1809) and a graphics card with drivers that support Microsoft DirectX Raytracing.
MICROSOFT DIRECTX RAYTRACING

Real-time ray tracing promises to bring new levels of realism to in-game graphics.

Ray tracing is not a new technique, but until recently it has been too computationally demanding to use in real-time.

With modern GPUs, it's now possible to use rasterization for most of the rendering while using ray tracing selectively to enhance reflections, shadows, and other effects that are difficult to achieve with traditional techniques.

Microsoft DirectX Raytracing is a new DirectX component that enables developer to use ray tracing in DirectX 12 applications. For more details, please see the following posts on the Microsoft DirectX Developer Blog:

- [Announcing Microsoft DirectX Raytracing!](#)
- [DirectX Raytracing and the Windows 10 October 2018 Update](#)

Ray tracing in Port Royal

Port Royal uses DirectX Raytracing for reflections and shadows.

Port Royal uses DirectX Raytracing to produce realistic specular reflections with correct perspective. Ray tracing overcomes a limitation of traditional techniques by accurately reflecting objects that appear outside of the screen space and those that are occluded by other objects in the view.

Port Royal uses DirectX Raytracing to render pixel-perfect hard shadows.
HOW TO MEASURE RAY TRACING PERFORMANCE

Ray tracing is very computationally demanding. You can also use Port Royal Custom run settings to make the test more, or less, demanding by changing the rendering resolution and other quality settings.

You can also disable ray tracing effects to see how it affects performance.

Set Reflection mode to Traditional or Disabled to turn off ray traced reflections.

Traditional reflection mode disables the DirectX Raytracing part of the reflection pipeline and keeps the rest of the pipeline as is. The performance and quality of the traditional reflections is not directly comparable with the state-of-the-art in games. This feature is only meant to let you compare performance when the DirectX Raytracing part is removed.

When reflections are Disabled, all parts of the reflection pipeline are removed from execution, including the traditional reflection parts.

Set Disable ray traced shadows to Yes to turn off ray traced shadows. When DirectX Raytracing is disabled, a traditional shadow map is used for the sunlight.

Custom benchmark runs do not produce an overall score, but you can use the Graphics test score to compare performance with ray tracing on and off.
# SYSTEM REQUIREMENTS

<table>
<thead>
<tr>
<th>OS</th>
<th>Windows 10, 64-bit with October 2018 Update (version 1809)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PROCESSOR</td>
<td>1.8 GHz dual-core with SSSE3 support</td>
</tr>
<tr>
<td>GPU</td>
<td>DirectX 12 with DirectX Raytracing support</td>
</tr>
<tr>
<td>MEMORY</td>
<td>4 GB RAM</td>
</tr>
<tr>
<td>VIDEO MEMORY</td>
<td>6 GB</td>
</tr>
<tr>
<td>STORAGE</td>
<td>0.8 GB free disk space</td>
</tr>
</tbody>
</table>

10 To run Port Royal, you must have a graphics card with drivers that support Microsoft DirectX Raytracing. Compatible cards include NVIDIA GeForce RTX series, NVIDIA Quadro RTX series, NVIDIA TITAN X, XP, V, and RTX, and NVIDIA GeForce GTX series cards starting with the GeForce GTX 1060 6GB and all higher models.
GRAPHICS TEST

Port Royal is a graphics card benchmark. The test measures graphics card performance with a combination of real-time ray tracing and traditional rendering techniques. Port Royal does not have a CPU test.

The scene features ray traced reflections, shadows (ray traced and shadow mapped), transparent surfaces with ray traced reflections, volumetric lighting, particles, and post-processing effects. The rendering resolution is $2560 \times 1440$.

CPU factors

The main role of the CPU in the rendering process is to compose the command lists that the GPU executes. The Port Royal engine is multi-threaded and divides the work between all logical cores.

If the CPU cannot submit work to the GPU fast enough, it will be the limiting factor in the benchmark, effectively invalidating the result of the Graphics test. Port Royal requires a multi-core CPU to run at high frame rates.

The exact point at which the benchmark becomes bound by the CPU depends on the configuration of the system.
SCORING

3DMark Port Royal produces an overall Port Royal score and a Graphics test score. These scores are the same given that the benchmark is based on a single Graphics test. The scores are rounded to the nearest integer. The better a system’s performance, the higher the score.

Overall Port Royal score

The overall 3DMark Port Royal score is the same as the Graphics test score.

\[ S_{3DMark} = S_{graphics} \]

Where:

\[ S_{graphics} = \text{The Port Royal Graphics score} \]

Graphics test scoring

The Graphics Test produces a raw performance result in frames per second. We multiply this result by a scaling constant to produce the Graphics score \((S_{graphics})\) as follows:

\[ S_{graphics} = C_{graphics} \times Fgt \]

Where:

\[ C_{graphics} = \text{Scaling constant set to 216} \]
\[ Fgt = \text{The average FPS result from the Graphics test} \]

The scaling constant is used to bring the score in line with traditional 3DMark score levels.
PORT ROYAL ENGINE

3DMark Port Royal uses a custom engine developed in-house with input from UL Benchmark Development Program members including AMD, Intel, and NVIDIA. We worked especially closely with Microsoft to create a first-class implementation of the DirectX Raytracing API.

Port Royal improves on the Time Spy/Night Raid rendering engine by implementing new effects and integrating DirectX Raytracing.

CPU side

Since Port Royal does not have a CPU test, the main role of the CPU in the test is to compose command lists for the GPU to execute. The task system allows heavy parallel execution. 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. This shortens the CPU rendering time and reduces the chance of the CPU becoming a bottleneck.

GPU side

The GPU side of the rendering is composed of multiple rasterization, compute, and ray tracing passes. Some passes run in an asynchronous compute queue.

The engine supports multi-GPU in the form of alternate frame rendering for linked node setups (homogenous adapters).
Rendering passes

The image below shows the high-level construction of a typical frame in the Port Royal benchmark. Tasks are color-coded by work type. Arrows show task relationships. The position of each task indicates the queue in which the task is executed.
Shadow map draw

Frustum lights can be shadowed. For each shadowed light, a shadow map is allocated for each frame based on heuristics that determine which resolution is required. The maximum resolution is 1k. The shadow map is used for surface illumination and for generating light shafts for volume illumination.

Shadows are sampled in illumination, cube rendering, and ray tracing shaders.

G-buffer draw

Opaque objects are drawn into the G-buffer in two passes, separating luminous and non-luminous geometries.

The material system uses physically based materials. The system supports the following material textures: Albedo (RGB) + metalness (A), Normal (RG) + Roughness (B) + Height (A), Luminance, Blend, Opacity, and Light Map. A material might not use all these textures.

The G-buffer is composed of five textures: depth, albedo + metalness, normal + roughness, luminance, and motion vectors for TAA.

Volume illumination

Volume illumination is computed using the tessellated light volume approach. The volume mesh of a light is computed by extruding the shadow map of a light, using the tessellation pipeline and adaptation heuristics to reduce the amount of mesh data. The fragment shader then computes the volumetric illumination using additive blending to sum up the airlight integral for the view ray corresponding to the pixel.

This is only used for frustum lights, and each fragment computes its own contribution to the airlight integral numerically to include the influence of the radial mask and attenuation of the light. The algorithm is explained in this paper.

This pass is the only pass that uses tessellation in this benchmark. The normal geometry pipeline does not use tessellation.

Cubemap update

Cubemaps are used to cache the radiance for both perspective-correct and traditional specular reflections for static geometries.
Illumination

Cubemaps include static geometries that are drawn once into a G-buffer. The illumination of the cubes is dynamically updated in a compute pass similar to the normal surface illumination each frame. The lights are queried from the world-space clusters in the illumination pass. The view ray direction is set to the main camera view direction to match the specular highlights to the screen space illumination texture that is also sampled for reflections.

Filtering

The mip levels of the cube maps are calculated in compute passes by taking the average of each quad in the lower mip. Each cube is halved in this way until the highest possible mip level is computed.

Transparent geometry draw

For rendering transparent geometries we use a variant of an order-independent transparency technique called Order-Independent Transparency Approximation with Raster Order Views. Simply put, transparent geometry is rendered and a per-pixel visibility function (accumulated transparency) is approximated by merging pixels into the compressed function. Then the transparent geometry is re-rendered, illuminated and additively blended according to the visibility function.

Ambient occlusion

Ambient occlusion uses an adaptive screen-space technique. It is computed using a group of compute shader passes.

Lighting

All frustum lights, omni lights, reflection probes, and decals are clustered in the world space to a uniform grid. This is done CPU side and then transferred to the GPU in advance.

The main camera lighting is evaluated using a tiled method in multiple, separate passes. Dynamic light evaluation is split into shadowed and unshadowed parts and computed separately.

Before the main illumination passes, asynchronous compute shaders are used to compute screen-space ambient occlusion and calculate unshadowed surface illumination. These tasks are started right after G-buffer rendering has finished and are executed alongside shadow and
environment rendering. Ambient occlusion and unshadowed illumination results are written out to their respective targets.

**Reflections**

Reflection rendering is a combination of multiple rendering passes containing cube rendering, ray tracing of reflection rays, reflection sampling of the cubes, and filtering of the reflection result. The illumination of the reflection cubes is updated in a compute pass as explained earlier.

We cast rays to the importance sampled direction for each screen space pixel that is over a roughness threshold. The resulting hitpoints (or one if only a single ray is used per pixel) are stored and the results are used to sample reflections from the environment maps. In cases of pixels being non-visible from the cubes or with mirror like surfaces that require pixel-perfect reflections, we compute the reflection separately to render a correct reflection (re-shade). For reflections of glass, we always run the full shading.

**Reflect**

The reflect pass uses the ray tracing pipeline to generate a reflection ray for each pixel above a predetermined roughness threshold. The direction is importance sampled according to the same specular BRDF as used in direct illumination. The hit shader writes the ray length, instance ID, primitive index and barycentric coordinates of the hit. The ray generation shader then stores these into textures.

**Cube sampling**

The reflection cubes are used for glossy reflections to find the radiance of a ray intersection generated by the ray tracing pass. The intersection point is reconstructed using the same importance sampling routine as in the reflect pass and reading the ray length stored by the reflect pass. This position is then projected into the reflection cubes. The world space position of the projected point in each cube is tested to determine if it corresponds to the same intersection point, or if it was occluded by another geometry.

In case the point is not found from any cubes or screen space illumination texture, the instance ID, primitive index and barycentric coordinates stored by the reflection pass are read and used to recompute the radiance for the given ray.

If the roughness of the surface is above a certain threshold, the cube sampling is skipped since the resolution is generally not enough for sharp reflections.
Filtering

Finally, we execute a spatial-temporal filtering pass for the reflection result and combine it with illumination.

Pre-TAA combine pass

This pass, shown in the GPU task structure as “Combine” inside the “Illumination” block, evaluates the reflection illumination by evaluating a preintegrated specular BRDF, and modulating the reflection filtering results with it. The reflection is then added with surface illumination. Ambient occlusion is also applied here since it has to be before TAA and after the reflection sampling phase as the screen space illumination texture is also sampled there.

Decals

The Port Royal engine implements a deferred decal system for increased visual quality and easier scene variation.

Decals are skewed prisms that are applied on top of the rendered G-buffer using a compute shader in the asynchronous compute queue. Decals are clustered similarly to lights to speed up the apply pass. For each pixel, active decals are fetched from the matching cluster and applied on top of the G-buffer using one of the implemented blending modes. Various modes allow changing different attributes in the G-buffer (such as normal only or all channels).

Ray-traced shadows

Ray traced shadows are implemented in a separate pass running in an async compute queue. For each fragment, there is a shadow ray cast from this fragment in the world space towards the direction of the light source. The any-hit shader is then used to detect whether the ray has been occluded on its way from light towards the fragment.

The output of the ray generation shader is shadow modulation map, which is a float32 texture filled with values ranging from 0 to 1. The values are generated per-fragment by dividing the energy flux that has reached this fragment by the total energy flux present in the scene (i.e. from all the lights).

One shadow ray is cast from each fragment towards the light source. Post-process filter is not employed for the shadow mask, so the implementation only supports hard-edged shadows.
Particles

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

Particle illumination

Particles are rendered as transparent surfaces with approximated visibility.

Fluids

⚠ Fluid simulation is only used in the Port Royal demo. It does not contribute to the Graphics Test score.

Simulation

Fluids are simulated on the GPU using the asynchronous compute queue. The simulation is based on the Position Based Fluids method. Radix sort is used in each step to order the fluid particles using the Z-order curve to achieve locality of memory access when calculating interactions. Additionally, spatial hashing is used to accelerate the neighbor search.

Illumination

The liquid surface is constructed in screen-space by splatting ellipsoids, doing most of the computation in vertex shader, and smoothing the result. The illumination of the surface is done in a compute pass after the surface is illuminated, and the surface illumination is used to apply approximate screen space refractions.

Post-processing

Temporal anti-aliasing

Temporal anti-aliasing (TAA) is applied for the surface illumination texture that already has reflections applied. The projection matrix used for the G-buffer is jittered for each frame so that the sampled subpixel position varies according to a determined pattern. TAA then blends these subpixel-jittered samples together using exponential average. To fetch a sample from a previous frame, motion vectors written by the G-buffer pass are used. Additionally, variance clipping is used to reduce ghosting.
Post-TAA resolve
This pass applies parts that do not use TAA on top of the illumination resolved by TAA. Since TAA only applies to opaque objects, transparent elements within the scene such as volumetric illumination, particles and transparent meshes are directly resolved in this pass, on top of the TAA results.

Depth of field
The effect is computed by scattering the illumination in the out of focus parts of the input image by using multiple passes. First, a compute shader is used to compute confusion radiuses based on depth texture, and splatting primitives are added to a buffer. Then, these primitives are rendered to various resolution textures using the normal rasterization pipeline. Last, the out-of-focus illumination is combined with the original illumination.

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

Lens Reflections
The effect is computed by first applying a filter to the computed illumination in frequency domain like in the bloom effect. The filtered result is then splatted in several scales and intensities on top of the input image using additive blending. The effect is computed in the same resolution as the bloom effect and therefore the forward FFT needs to be performed only once for both effects. The filtering and inverse FFT are performed using the CS and floating point textures.

Tone mapping
Tone mapping is executed as the last pass of the rendering pipeline. It applies various two-dimensional camera effects (such as vignette) to the final texture and controls the tone reproduction.

Dynamic Global Illumination: Ray traced photon mapping
⚠ Dynamic Global Illumination is only used in the Port Royal demo. It does not contribute to the Graphics Test score.

We have implemented a dynamic global illumination solution using real-time photon mapping. This is a multi-pass algorithm with components of
rasterization, ray tracing and compute work. The main passes of the algorithm are sample generation from reflective shadow maps, photon tracing, photon splatting and irradiance filtering.
## PORT ROYAL VERSION HISTORY

<table>
<thead>
<tr>
<th>VERSION</th>
<th>Windows</th>
<th>Android</th>
<th>Apple</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>✔️</td>
<td>✗</td>
<td>✗</td>
<td>Improved multi-GPU support. Scores improve on multi-GPU systems.</td>
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<td>✔️</td>
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FIRE STRIKE

Fire Strike is a DirectX 11 benchmark for high-performance gaming PCs. Fire Strike includes two graphics tests, a physics test and a combined test that stresses both the CPU and GPU.

3DMark Advanced and Professional Editions include Fire Strike Extreme and Fire Strike Ultra, two benchmarks designed for high-end systems with multiple GPUs (SLI / Crossfire).

Scores from 3DMark Fire Strike, Fire Strike Extreme and Fire Strike Ultra should not be compared to each other - they are separate tests with their own scores, even though they share the same content.

Fire Strike benchmarks are only available in the Windows editions of 3DMark.

⚠ Fire Strike tests are demanding benchmarks designed for high-end hardware. If your system scores less than 2800 in Fire Strike you should run Sky Diver instead.

Fire Strike

Fire Strike is a DirectX 11 benchmark for high-performance gaming PCs and overclocked systems. Fire Strike is very demanding, even for the latest graphics cards. If your frame rate is low, use Sky Diver instead.

Fire Strike Extreme

Fire Strike Extreme is designed for testing PCs with multiple GPUs (minimum 1.5 GB graphics card memory required). It raises the rendering resolution from 1920 × 1080 to 2560 × 1440 and improves the visual quality.

Fire Strike Ultra

Fire Strike Ultra is a dedicated test for 4K gaming. It raises the rendering resolution to 3840 × 2160 (4K UHD), four times larger than 1080p. A 4K monitor is not required, but your graphics card must have at least 3GB of memory.
# SYSTEM REQUIREMENTS

<table>
<thead>
<tr>
<th></th>
<th>FIRE STRIKE</th>
<th>FIRE STRIKE EXTREME</th>
<th>FIRE STRIKE ULTRA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OS</strong>(^{11})</td>
<td>Windows 7 or later</td>
<td>Windows 7 or later</td>
<td>Windows 7 or later</td>
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<td><strong>PROCESSOR</strong></td>
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<td>6 GB free space</td>
<td>6 GB free space</td>
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<td><strong>GPU</strong></td>
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<td>DirectX 11</td>
<td>DirectX 11</td>
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<td>3 GB RAM</td>
<td>5.5 GB RAM</td>
<td>7 GB RAM</td>
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<tr>
<td><strong>FOR SYSTEMS WITH A DISCRETE GRAPHICS CARD</strong></td>
<td>2 GB RAM</td>
<td>4 GB RAM</td>
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\(^{11}\) Windows 7 users must install Service Pack 1.
## DEFAULT SETTINGS

<table>
<thead>
<tr>
<th></th>
<th>FIRE STRIKE</th>
<th>EXTREME</th>
<th>ULTRA</th>
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<tbody>
<tr>
<td><strong>RESOLUTION</strong></td>
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<td><strong>PARTICLE ILLUMINATION QUALITY</strong></td>
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<td><strong>DEPTH OF FIELD QUALITY</strong></td>
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<td><strong>BLOOM RESOLUTION</strong></td>
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</table>
GRAPHICS TEST 1

3DMark Fire Strike Graphics test 1 focuses on geometry and illumination. Particles are drawn at half resolution and dynamic particle illumination is disabled. There are 100 shadow casting spot lights and 140 non-shadow casting point lights in the scene. Compute shaders are used for particle simulations and post processing. Pixel processing is lower than in Graphics test 2 as there is no depth of field effect.

Processing performed in an average frame

<table>
<thead>
<tr>
<th></th>
<th>VERTICES</th>
<th>TESSELLATION PATCHES</th>
<th>TRIANGLES</th>
<th>PIXELS¹²</th>
<th>COMPUTE SHADER INVOCATIONS</th>
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</thead>
<tbody>
<tr>
<td>FIRE STRIKE</td>
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<tr>
<td>FIRE STRIKE EXTREME</td>
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<td>9.9 million</td>
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<td>650,000</td>
<td>12.4 million</td>
<td>330 million</td>
<td>3.4 million</td>
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</table>

¹² This figure is the average number of pixels processed per frame before the image is scaled to fit the native resolution of the device being tested. If the device’s display resolution is greater than the test’s rendering resolution, the actual number of pixels processed per frame will be even greater.
GRAPHICS TEST 2

3DMark Fire Strike Graphics test 2 focuses on particles and GPU simulations. Particles are drawn at full resolution and dynamic particle illumination is enabled. There are two smoke fields simulated on GPU. Six shadow casting spot lights and 65 non-shadow casting point lights are present. Compute shaders are used for particle and fluid simulations and for post processing steps. Post processing includes a depth of field effect.

Processing performed in an average frame

<table>
<thead>
<tr>
<th></th>
<th>VERTICES</th>
<th>TESSELLATION PATCHES</th>
<th>TRIANGLES</th>
<th>PIXELS (^1)</th>
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</table>

\(^1\) This figure is the average number of pixels processed per frame before the image is scaled to fit the native resolution of the device being tested. If the device’s display resolution is greater than the test’s rendering resolution, the actual number of pixels processed per frame will be even greater.
PHYSICS TEST

3DMark Fire Strike Physics test benchmarks the hardware’s ability to run gameplay physics simulations on the CPU. The GPU load is kept as low as possible to ensure that only the CPU is stressed. The Bullet Open Source Physics Library is used as the physics library for the test.

The test has 32 simulated worlds. One thread per available logical CPU core is used to run simulations. All physics are computed on CPU with soft body vertex data updated to GPU each frame.
COMBINED TEST

3DMark Fire Strike Combined test stresses both the GPU and CPU simultaneously. The GPU load combines elements from Graphics test 1 and 2 using tessellation, volumetric illumination, fluid simulation, particle simulation, FFT based bloom and depth of field.

The CPU load comes from the rigid body physics of the breaking statues in the background. There are 32 simulation worlds running in separate threads each containing one statue decomposing into 113 parts. Additionally there are 16 invisible rigid bodies in each world except the one closest to camera to push the decomposed elements apart. The simulations run on one thread per available CPU core.

The 3DMark Fire Strike Combined test uses the Bullet Open Source Physics Library.

Processing performed in an average frame

<table>
<thead>
<tr>
<th></th>
<th>VERTICES</th>
<th>TESSELLATION PATCHES</th>
<th>TRIANGLES</th>
<th>PIXELS¹</th>
<th>COMPUTE SHADER INVOCATIONS</th>
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</thead>
<tbody>
<tr>
<td>FIRE STRIKE</td>
<td>7.5 million</td>
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¹ This figure is the average number of pixels processed per frame before the image is scaled to fit the native resolution of the device being tested. If the device’s display resolution is greater than the test’s rendering resolution, the actual number of pixels processed per frame will be even greater.
SCORING

Scores from different benchmarks should not be compared to each other. Fire Strike, Fire Strike Extreme, and Fire Strike Ultra are separate tests with their own scores, even though they share the same content.

Overall Fire Strike score

The 3DMark Fire Strike score formula uses a weighted harmonic mean to calculate the overall score from the Graphics, Physics, and Combined scores.

\[
\text{Fire Strike score} = \frac{W_{\text{graphics}} + W_{\text{physics}} + W_{\text{combined}}}{\frac{1}{S_{\text{graphics}}} + \frac{1}{S_{\text{physics}}} + \frac{1}{S_{\text{combined}}}}
\]

Where:

- \( W_{\text{graphics}} \) = The Graphics score weight, equal to 0.75
- \( W_{\text{physics}} \) = The Physics score weight, equal to 0.15
- \( W_{\text{combined}} \) = The Combined score weight, equal to 0.10
- \( S_{\text{graphics}} \) = Graphics score
- \( S_{\text{physics}} \) = Physics score
- \( S_{\text{combined}} \) = Combined score

For a balanced system, the weights reflect the ratio of the effects of GPU and CPU performance on the overall score. Balanced in this sense means the Graphics, Physics and Combined scores are roughly the same magnitude.

For a system where either the Graphics or Physics score is substantially higher than the other, the harmonic mean rewards boosting the lower score. This reflects the reality of the user experience. For example, doubling the CPU speed in a system with an entry-level graphics card doesn't help much in games since the system is already limited by the GPU. Likewise for a system with a high-end graphics card paired with an underpowered CPU.

Graphics score

Each Graphics test produces a raw performance result in frames per second (FPS). We take a harmonic mean of these raw results and multiply it by a scaling constant to reach a Graphics score \( S_{\text{graphics}} \) as follows:
\[ S_{\text{graphics}} = 230 \times \frac{2}{\frac{1}{F_{\text{gt1}}} + \frac{1}{F_{\text{gt2}}}} \]

Where:

\[ F_{\text{gt1}} = \text{The average FPS result from Graphics test 1} \]
\[ F_{\text{gt2}} = \text{The average FPS result from Graphics test 2} \]

The scaling constant is used to bring the score in line with traditional 3DMark score levels.

**Physics score**

\[ S_{\text{physics}} = 315 \times F_{\text{physics}} \]

Where:

\[ F_{\text{physics}} = \text{The average FPS result from the Physics Test} \]

The scaling constant is used to bring the score in line with traditional 3DMark score levels.

**Combined score**

\[ S_{\text{combined}} = 215 \times F_{\text{combined}} \]

Where:

\[ F_{\text{combined}} = \text{The average FPS result from the Combined Test} \]

The scaling constant is used to bring the score in line with traditional 3DMark score levels.
FIRE STRIKE ENGINE

Fire Strike benchmarks require graphics hardware with full DirectX 11 feature level 11 support.

Multithreading

The multithreading model is based on DX11 deferred device contexts and command lists. The engine utilizes one thread per available logical CPU core. One of the threads is considered as the main thread, which uses both immediate device context and deferred device context. The other threads are worker threads, which use only deferred device contexts.

Rendering workload is distributed between the threads by distributing items (e.g. geometries and lights) in the rendered scene to the threads. Each thread is assigned roughly equal amount of scene items.

When rendering a frame, each thread does the work associated to items assigned to the thread. That includes, for example, computation of transformation matrix hierarchies, computation of shader parameters (constants buffer contents and dynamic vertex data) and recording of DX API calls to a command list. When the main thread is finished with the tasks associated to its own items, it executes the command lists recorded by worker threads.

Tessellation

The engine supports rendering with and without tessellation. The supported tessellation techniques are PN Triangles, Phong, and displacement map based detail tessellation. Both triangle and quad based tessellation is supported.

Tessellation factors are adjusted to achieve desired edge length for output geometry on the render target. Additionally, patches that are back facing and patches that are outside of the view frustum are culled by setting the tessellation factor to zero.

Tessellation is turned entirely off by disabling hull and domain shaders when size of object's bounding box on render target drops below a given threshold. This applies both to g-buffer and shadow map drawing.

Lighting

Lighting is done in deferred style. Geometry attributes are first rendered to a set of render targets. Ambient occlusion is then computed from depth and normal data. Finally illumination is rendered based on those attributes.
Surface illumination

Two different surface shading models and g-buffer compositions are supported. The more complex model uses four textures and depth texture as the g-buffer. The simpler model uses two textures and depth texture.

Surface illumination model is either combination of Oren-Nayar diffuse reflectance and Cook-Torrance specular reflectance or basic Blinn Phong reflectance model. Simple surface shading model is used on Feature Level 10 demo and tests while the complex model is used on Feature Level 11 demo and tests. Optionally atmospheric attenuation is also computed.

Horizon based screen space ambient occlusion can be applied to the surface illumination.

Point, spot and directional lights are supported. Spot and directional lights can be shadowed. For spot lights, shadow texture size is selected based on size of the light volume in screen space. Shadow maps are sampled using best candidate sample distribution. Sample pattern is dithered with $4 \times 4$ pixel pattern.

Volumetric illumination

The renderer supports volume illumination. It is computed by approximating the light scattered towards the viewer by the medium between eye and the visible surface on each lit pixel. The approximation is based on volume ray casting and the Rayleigh-Mie scattering and attenuation model.

One ray is cast on each lit pixel for each light. The cast ray is sampled at several depth levels. Sampling quality is improved by dithering sampling depths with a $4 \times 4$ pixel pattern. The achieved result is blurred to combine the different sampling depths on neighboring pixels before combining the volume illumination with the surface illumination.

When rendering illumination, there are two high dynamic range render targets. One is for surface illumination and the other for volume illumination.

Particle illumination

Particle effects are rendered on top of opaque surface illumination with additive or alpha blending. Particles are simulated on the GPU. Particles can be either simply self-illuminated or receive illumination from scene lights.

Lights that participate in particle illumination can be individually selected. To illuminate particles, the selected lights are rendered to three volume
textures that are fitted into view frustum. The textures contain incident radiance in each texel stored as spherical harmonics. Each of the three textures holds data for one color channel storing four coefficients. Incident radiance from each light is rendered to these volume textures as part of light rendering.

When rendering illuminated particles, hull and domain shaders are enabled. Incident radiance volume texture sampling is done in the domain shader. Tessellation factors are set to produce fixed size triangles in screen pixels. Tessellation is used to avoid sampling incident radiance textures in the pixel shader.

Particles can cast shadows on opaque surface and on other particles. For generating particle shadows, particle transmittance is first rendered to a 3D texture. The transmittance texture is rendered from the shadow casting light like a shadow map. After particles have been rendered to the texture, an accumulated transmittance 3D texture is generated by accumulating values of each depth slice in the transmittance texture. The accumulated transmittance texture can then be sampled when rendering illumination or incident radiance that is used to illuminate particles.
POST-PROCESSING

Particle based distortion

Particles can be used to generate a distortion effect. For particles that generate the effect, a distortion field is rendered to a texture using a 3D noise texture as input. This field is then used to distort the input image in post processing phase.

Depth of field

The effect is computed using the following procedure:

1. Circle of confusion radius is computed for all screen pixels and stored in a full resolution texture.
2. Half and quarter resolution versions are made from the radius texture and the original illumination texture.
3. Positions of out-of-focus pixels whose circle of confusion radius exceeds a predefined threshold are appended to a buffer.
4. The position buffer is used as point primitive vertex data and, using Geometry Shaders, the image of a hexagon-shaped bokeh is splatted to the positions of these vertices. Splatting is done to a texture that is divided into regions with different resolutions using multiple viewports. First region is screen resolution and the rest are a series of halved regions down to 1x1 texel resolution. The screen space radius of the splatted bokeh determines the used resolution. The larger the radius the smaller the used splatting resolution.
5. Steps 3 and 4 are performed separately for half and quarter resolution image data with different radius thresholds. Larger bokehs are generated from lower resolution image data.
6. The different regions of the splatting texture are combined by up-scaling the data in the smaller resolution regions step by step to the screen resolution region.
7. The out-of-focus illumination is combined with the original illumination.

Lens reflections

The effect is computed by first applying a filter to the computed illumination in frequency domain like in the bloom effect. The filtered result is then splatted in several scales and intensities on top of the input image using additive blending. The effect is computed in the same resolution as the bloom effect and therefore the forward FFT needs to be performed only once for both effects. As in the bloom effect, the forward and inverse FFTs are performed using the CS and 32bit floating point textures.
Bloom

The effect is computed by transforming the computed illumination to frequency domain using Fast Fourier Transform (FFT) and applying bloom filter to the input in that domain. An inverse FFT is then applied to the filtered image. The forward FFT, applying the bloom filter and inverse FFT are done with the CS. The effect is computed in reduced resolution. The input image resolution is halved two or three times depending on settings and then rounded up to nearest power of two. The FFTs are computed using 32bit floating point textures. A procedurally pre-computed texture is used as the bloom filter. The filter combines blur, streak, lenticular halo and anamorphic flare effects.

Anti-aliasing

MSAA and FXAA anti-aliasing methods are supported.

In MSAA method G-buffer textures are multisampled with the chosen sample count. Edge mask is generated based on differences in G-buffer sample values. The mask is used in illumination phase to select for which pixels illumination is evaluated for all G-buffer samples. For pixels that are not considered edge pixels, illumination is evaluated only for the first G-buffer sample. Volume illumination is always evaluated only for the first G-buffer sample due to its low frequency nature.

FXAA is applied after tone mapping making it the final step in post processing.

Smoke simulation

The implementation of the smoke simulation is based on Ronald Fedkiw's paper "Visual Simulation of Smoke" with the addition of viscous term as in Jos Stam's "Stable Fluids" but without a temperature simulation. Thus the smoke is simulated in a uniform grid where velocity is modeled with incompressible Euler equations. Advection is solved with a semi-Lagrangian method.

Vorticity confinement method is then applied to the velocity field to reinforce vortices. Diffusion and projection is then computed by the Jacobi iteration method. The simulation is done entirely with Compute Shaders. Cylinders that interact with the smoke are implicit objects which are voxelized into the velocity and density field in Compute Shaders.
# FIRE STRIKE VERSION HISTORY

<table>
<thead>
<tr>
<th>VERSION</th>
<th>Windows</th>
<th>Android</th>
<th>iOS</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>●</td>
<td>×</td>
<td>×</td>
<td><strong>Fixed issues when benchmarking systems with multiple GPUs. Scores improve significantly on systems with multiple GPUs.</strong></td>
</tr>
<tr>
<td>1.0</td>
<td>●</td>
<td>×</td>
<td>×</td>
<td><strong>Launch version</strong></td>
</tr>
</tbody>
</table>

Fire Strike Ultra, added in 3DMark v1.4.775, uses the Fire Strike v1.1.0 workload.

3DMark v2.1.2852, released July 14, 2016, used an incorrect setting for Fire Strike Custom runs that resulted in slightly lower than expected scores. Results from Fire Strike Custom runs using that version should not be compared with any other version of 3DMark. The issue was fixed in 3DMark v2.1.2969 released August 18, 2016. The standard Fire Strike benchmark was not affected, nor were Fire Strike Extreme and Fire Strike Ultra.
SKY DIVER

Sky Diver is a DirectX 11 benchmark for mid-range gaming PCs and laptops.

Use 3DMark Sky Diver to benchmark gaming PCs and laptops with mid-range graphics cards, mobile GPUs, or integrated graphics. It is especially suitable for DirectX 11 compatible systems that struggle to run the more demanding Fire Strike test.

⚠️ If your system scores more than 12000 in Sky Diver, you should run Fire Strike.

Use 3DMark Sky Diver to benchmark:

- Integrated GPUs like AMD A10-7850K and Intel i5-4570R
- Mobile integrated GPUs like AMD A10-5757M and Intel i7-4750HQ
- Mobile discrete GPUs like AMD R7 M265 and NVIDIA GT 840M
- Entry level discrete GPUs like AMD R7 240

Sky Diver includes two Graphics tests, a Physics test and a Combined test designed to stress the CPU and GPU at the same time.

Sky Diver is compatible with Windows 8 and Windows 7. A DirectX 11 compatible GPU is required. 3DMark Sky Diver runs on all DirectX 11 feature level 11_0 compatible hardware and uses optimized code paths on feature level 11_1 devices.

Sky Diver is only available in the Windows editions of 3DMark.

How is Sky Diver different from Fire Strike?

Sky Diver and Fire Strike are complementary benchmarks designed to cover the full performance range of DirectX 11 graphics hardware. Fire Strike is equivalent to a modern DirectX 11 game running on ultra-high settings. Sky Diver is equivalent to running a game on normal settings.

Scores from Sky Diver and Fire Strike are not directly comparable.
## SYSTEM REQUIREMENTS

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Requirement Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OS</strong></td>
<td>Windows 7 or later</td>
</tr>
<tr>
<td><strong>PROCESSOR</strong></td>
<td>1.8 GHz dual-core Intel or AMD CPU</td>
</tr>
<tr>
<td><strong>STORAGE</strong></td>
<td>6 GB free disk space</td>
</tr>
<tr>
<td><strong>GPU</strong></td>
<td>DirectX 11</td>
</tr>
<tr>
<td><strong>FOR SYSTEMS WITH INTEGRATED GRAPHICS</strong></td>
<td>2.5 GB RAM&lt;sup&gt;16&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>FOR SYSTEMS WITH A DISCRETE GRAPHICS CARD</strong></td>
<td>2 GB RAM + 512 MB video card memory&lt;sup&gt;17&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

---

<sup>15</sup> Windows 7 users must install Service Pack 1.

<sup>16</sup> The benchmark tests require 2.5 GB of RAM. The demo requires 3 GB of RAM.

<sup>17</sup> The benchmark tests require 512 MB of video card memory. The demo requires 1 GB of video card memory.
### DEFAULT SETTINGS

<table>
<thead>
<tr>
<th>Setting</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution</td>
<td>1920 × 1080</td>
</tr>
<tr>
<td>GPU Memory Budget</td>
<td>1 GB</td>
</tr>
<tr>
<td>Tessellation Detail</td>
<td>Medium(^{18})</td>
</tr>
</tbody>
</table>

\(^{18}\) The tessellation detail setting is relative. Sky Diver's medium value is roughly the same as Fire Strike's low value.
GRAPHICS TEST 1

3DMark Sky Diver Graphics test 1 focuses on tessellation. The test uses a forward lighting method with one shadow casting directional light. The test utilizes a depth of field post processing effect, which is not used in the other tests.

Processing performed in an average frame

<table>
<thead>
<tr>
<th>VERTICES</th>
<th>TESSELLATION PATCHES</th>
<th>TRIANGLES</th>
<th>PIXELS(^\text{19})</th>
<th>COMPUTE SHADER INVOCATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>SKY DIVER</td>
<td>1.6 million</td>
<td>150,000</td>
<td>3.9 million</td>
<td>30.3 million</td>
</tr>
</tbody>
</table>

\(^{19}\) This figure is the average number of pixels processed per frame before the image is scaled to fit the native resolution of the device being tested. If the device’s display resolution is greater than the test’s rendering resolution, the actual number of pixels processed per frame will be even greater.
GRAPHICS TEST 2

This test focuses on pixel processing and compute shader utilization. The test uses a compute shader-based deferred tiled lighting method with screen space ambient occlusion. Post processing creates a lens reflection effect, which is not used in Graphics test 1.

Processing performed in an average frame

<table>
<thead>
<tr>
<th>VERTICES</th>
<th>TESSELLATION PATCHES</th>
<th>TRIANGLES</th>
<th>PIXELS</th>
<th>COMPUTE SHADER INVOCATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>SKY DIVER</td>
<td>0.9 million</td>
<td>90,000</td>
<td>1.5 million</td>
<td>13.9 million</td>
</tr>
</tbody>
</table>

>> This figure is the average number of pixels processed per frame before the image is scaled to fit the native resolution of the device being tested. If the device’s display resolution is greater than the test’s rendering resolution, the actual number of pixels processed per frame will be even greater.
PHYSICS TEST

3DMark Sky Diver Physics test benchmarks the hardware’s ability to run gameplay physics simulations on the CPU. The GPU load is kept as low as possible to ensure that only the CPU is stressed. The test uses the Bullet Open Source Physics Library.

Sky Diver Physics test introduces a new approach to CPU testing in 3DMark designed to extend the performance range for which the test is relevant. With this new approach, the test has four levels of work. The first level is the lightest and the last is the heaviest.

The test starts with the first level and continues to the fourth level unless the frame rate drops below a minimum threshold. The score is calculated from the last two completed levels.

There are 96 simulation worlds with identical structure in total. In the first level, 8 worlds are triggered. On the second level, 16 more. On the third level, a further 24, and on the fourth and final level, another 48 so that all 96 worlds are being simulated at once.

Each world contains a statue that collapses when struck by a hammer swinging from a chain. Each statue contains 49 fragments. Each fragment is a mesh collision shape and, together, the 49 fragments have 6590 triangles. The hammer piece hangs on a chain with 39 links simulated using the Featherstone articulated body algorithm.
COMBINED TEST

This test contains both graphics workloads and physics simulations to stress the CPU and GPU.

The test uses the compute shader based deferred tiled lighting method from Graphics test 2. The CPU workload is similar to the third level of the Physics test where 48 worlds are being simulated at once.

The workloads are designed to be of equal weight so that on balanced systems both the GPU and CPU are well utilized.

The 3DMark Sky Diver Combined test uses the Bullet Open Source Physics Library.

Processing performed in an average frame

<table>
<thead>
<tr>
<th>VERTICES</th>
<th>TESSELLATION PATCHES</th>
<th>TRIANGLES</th>
<th>PIXELS²</th>
<th>COMPUTE SHADER INVOCATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>SKY DIVER</td>
<td>1.3 million</td>
<td>100,000</td>
<td>1.6 million</td>
<td>29.6 million</td>
</tr>
</tbody>
</table>

² This figure is the average number of pixels processed per frame before the image is scaled to fit the native resolution of the device being tested. If the device’s display resolution is greater than the test’s rendering resolution, the actual number of pixels processed per frame will be even greater.
**SCORING**

Sky Diver produces an overall Sky Diver score, a Graphics test sub-score, a Physics test sub-score, and a Combined test sub-score. The scores are rounded to the nearest integer. The higher the score, the better the performance.

**Overall Sky Diver score**

The 3DMark Sky Diver score formula uses a weighted harmonic mean to calculate the overall score from the Graphics, Physics, and Combined scores.

\[
\text{Sky Diver score} = \frac{W_{\text{graphics}} + W_{\text{physics}} + W_{\text{combined}}}{\frac{W_{\text{graphics}}}{S_{\text{graphics}}} + \frac{W_{\text{physics}}}{S_{\text{physics}}} + \frac{W_{\text{combined}}}{S_{\text{combined}}}}
\]

Where:

- \(W_{\text{graphics}}\) = The Graphics score weight, equal to 0.75
- \(W_{\text{physics}}\) = The Physics score weight, equal to 0.15
- \(W_{\text{combined}}\) = The Physics score weight, equal to 0.10
- \(S_{\text{graphics}}\) = Graphics score
- \(S_{\text{physics}}\) = Physics score
- \(S_{\text{combined}}\) = Combined score

For a balanced system, the weights reflect the ratio of the effects of graphics and physics performance on the overall score. Balanced in this sense means the Graphics, Physics and Combined scores are roughly the same magnitude.

For a system where either the Graphics or Physics score is substantially higher than the other, the harmonic mean rewards boosting the lower score. This reflects the reality of the user experience. For example, doubling the CPU speed in a system with an entry-level graphics card doesn't help much in games since the system is already limited by the GPU. Likewise for a system with a high-end graphics card paired with an underpowered CPU.
Graphics score

Each Graphics test produces a raw performance result in frames per second (FPS). We take a harmonic mean of these raw results and multiply it with a scaling constant to reach a Graphics score ($S_{graphics}$) as follows:

$$S_{graphics} = 219 \times \frac{2}{\frac{1}{F_{gt1}} + \frac{1}{F_{gt2}}}$$

Where:

- $F_{gt1} = \text{The average FPS result from Graphics Test 1}$
- $F_{gt2} = \text{The average FPS result from Graphics Test 2}$

The scaling constant is used to bring the score in line with traditional 3DMark score levels.

Physics score

3DMark Sky Diver Physics test uses a different approach to testing than that used in Fire Strike, Cloud Gate and Ice Storm. The aim of the new approach is to extend the performance range for which the test is relevant.

The test has four levels of work. The first level is the lightest and the last is the heaviest. The test begins with the first level and continues until the frame rate drops below a minimum threshold $L_{low}$, or until the last available level is run.

Each level produces a raw performance result in frames per second (FPS). The score is defined as a weighted average of the two highest successfully completed levels.

$$S_{physics} = 56 \times \left( (1 - W_i)N_{i-1}F_{i-1} + W_iN_iF_i \right)$$

Where:

- $W = \text{The weighting factor for a level}$
- $i = \text{The index of the last level to run}$
- $N = \text{The frame rate normalization factor for a level}$
- $F = \text{The frame rate of a level}$
The weight $W$ for a level is defined as:

$$W_i = \min(1, \frac{F_{i-1} - L_{low}}{L_{high} - L_{low}})$$

Where:

$L_{low} = $ The minimum frame rate threshold, set to 30 FPS
$L_{high} = $ Upper frame rate threshold used for weighting, set to 40 FPS

When the first level is the last level to run above $L_{low}$ then the score is defined as follows:

$$S_{physics} = 56 \times F_1$$

Frame rate normalization factors are used to normalize the frame rates of different levels before using them in the score calculation. A set of reference CPUs was used to define the factors.

<table>
<thead>
<tr>
<th>REFERENCE CPUS FOR $N_2$</th>
<th>LEVEL 1 FRAME RATE</th>
<th>LEVEL 2 FRAME RATE</th>
<th>RELATIVE DIFFERENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMD A4-5150M</td>
<td>30.53</td>
<td>17.14</td>
<td>1.78</td>
</tr>
<tr>
<td>INTEL CORE i5-4200U</td>
<td>56.49</td>
<td>33.43</td>
<td>1.69</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>REFERENCE CPUS FOR $N_3$</th>
<th>LEVEL 2 FRAME RATE</th>
<th>LEVEL 3 FRAME RATE</th>
<th>RELATIVE DIFFERENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMD A10-7850K</td>
<td>51.48</td>
<td>28.84</td>
<td>1.79</td>
</tr>
<tr>
<td>INTEL CORE i5-4430</td>
<td>68.58</td>
<td>39.62</td>
<td>1.73</td>
</tr>
</tbody>
</table>
REFERENCE CPUS FOR

\( N_4 \)

<table>
<thead>
<tr>
<th>LEVEL 3 FRAME RATE</th>
<th>LEVEL 4 FRAME RATE</th>
<th>RELATIVE DIFFERENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMD A10-7850K</td>
<td>28.84</td>
<td>16.57</td>
</tr>
<tr>
<td>INTEL CORE I7-4770K</td>
<td>55.30</td>
<td>31.87</td>
</tr>
</tbody>
</table>

The following table defines values for the frame rate normalization factors. \( N_1 \) is always set to 1. \( N_{i+1} \) is the average relative frame rate difference of levels \( i \) and \( i+1 \) on the reference CPUs multiplied by \( N_i \).

<table>
<thead>
<tr>
<th>( N_1 )</th>
<th>( N_2 )</th>
<th>( N_3 )</th>
<th>( N_4 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.000</td>
<td>1.735</td>
<td>3.054</td>
<td>5.314</td>
</tr>
</tbody>
</table>

Combined score

\[ S_{combined} = 243 \times F_{combined} \]

Where:

\[ F_{combined} = \text{The average FPS result from the Combined Test} \]

The scaling constant is used to bring the score in line with traditional 3DMark score levels.
SKY DIVER ENGINE

Multithreading
The engine utilizes one thread per available CPU core, less one physical core that is left free for the display driver. Draw calls are issued through immediate device context only.

Tessellation
The engine supports rendering with and without tessellation. The supported tessellation techniques are Phong tessellation and displacement map based detail tessellation.

Tessellation factors are adjusted to achieve desired edge length for output geometry on the render target. Additionally, patches that are back facing and patches that are outside of the view frustum are culled by setting the tessellation factor to zero.

Tessellation is turned entirely off by disabling hull and domain shaders when size of object's bounding box on render target drops below a given threshold.

Lighting
The engine supports two alternative methods of lighting the scene.

Forward lighting
The forward lighting method is used for the first part of the Demo and Graphics test 1.

It supports one shadow casting directional light and a limited number of additional un-shadowed point lights as well as cube map-based ambient illumination. All lights are rendered in one pass to DXGI_FORMAT_R11G11B10_FLOAT texture.

Compute shader-based tiled deferred lighting
The compute shader based tiled deferred lighting method is used the second part of the Demo, Graphics test 2 and the Combined test.

It supports point lights, spot lights and cube map-based ambient illumination. The geometry is first rendered to gbuffer that contains depth, normal and surface illumination parameters stored in three textures with DXGI_FORMAT_D24_UNORM_S8_UINT, DXGI_FORMAT_R10G10B10A2_UNORM and DXGI_FORMAT_R8G8B8A8_UNORM_SRGB formats. Screen space ambient occlusion is computed to a DXGI_FORMAT_R8_UNORM texture.
Lighting is evaluated in one compute shader pass that splits the screen to tiles and culls scene lights for each tile evaluating the illumination for visible lights on each tile. Lighting is rendered to a DXGI_FORMAT_R11G11B10_FLOAT texture.

**Particles**

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

Depth of field

The effect is computed using the following procedure:

1. Using Compute Shader, the circle of confusion radius is computed for all screen pixels based on depth texture and the information is reduced to half and quarter resolutions. In the same CS pass, data about out-of-focus pixels whose circle of confusion radius exceeds a predefined threshold is appended to a buffer.

2. The buffer with information about the out-of-focus pixels is used as point primitive vertex data and, using Geometry Shader, the image of a hexagon-shaped bokeh is splatted to the positions of these vertices. Splatting is done to a texture that is divided into regions with different resolutions using multiple viewports. First region is screen resolution and the rest are a series of halved regions down to 1x1 texel resolution. The screen space radius of the splatted bokeh determines the used resolution. The larger the radius the smaller the used splatting resolution.

3. The different regions of the splatting texture are combined by up-scaling the data in the smaller resolution regions step by step to the screen resolution region.

4. The out-of-focus illumination is combined with the original illumination.

Bloom

The effect is computed by transforming the computed illumination to frequency domain using Fast Fourier Transform (FFT) and applying bloom filter to the input in that domain. An inverse FFT is then applied to the filtered image. The forward FFT, applying the bloom filter and inverse FFT are done with the Compute Shader. The effect is computed in reduced resolution. The input image resolution is halved three times and rounded up to nearest power of two. With the 1920 × 1080 screen resolution, 256 × 256 resolution is used to perform the FFT. DXGI_FORMAT_R16G16B16A16_FLOAT textures are used to store the frequency domain data. A procedurally precomputed texture is used as the bloom filter. The filter combines blur, streak, lenticular halo and anamorphic flare effects.

Windows

3DMark Sky Diver runs on all DirectX 11 feature level 11_0 compatible hardware and uses optimized code paths on feature level 11_1 devices.
## SKY DIVER VERSION HISTORY

<table>
<thead>
<tr>
<th>VERSION</th>
<th>Windows</th>
<th>Android</th>
<th>Apple</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0.0</td>
<td>●</td>
<td>×</td>
<td>×</td>
<td>Launch version</td>
</tr>
</tbody>
</table>
CLOUD GATE

Cloud Gate is a new test designed for Windows notebooks and typical home PCs. It is a particularly good benchmark for systems with integrated graphics. Cloud Gate includes two graphics tests and a physics test. The benchmark uses a DirectX 11 engine limited to Direct3D feature level 10 making it suitable for testing DirectX 10 compatible hardware. Cloud Gate is only available in the Windows edition of 3DMark.

- Designed for typical home PCs and notebooks.
- DirectX 11 engine supporting DirectX 10 hardware.
- Includes two graphics tests and a physics test.

3DMark Cloud Gate and 3DMark Vantage compared

3DMark Vantage and 3DMark Cloud Gate are both benchmarks for DirectX 10 compatible hardware. The difference is in the engine powering each benchmark.

3DMark Vantage, released in April 2008, uses a DirectX 10 engine. 3DMark Cloud Gate uses a DirectX 11 engine limited to Direct3D feature level 10. Using Direct3D feature levels is the modern approach to game engine design as it allows developers to use a DirectX 11 engine and still support older generation hardware all the way down to DirectX 9 level models.

We recommend using 3DMark Cloud Gate for testing DirectX 10 based systems. Scores from 3DMark Vantage and 3DMark Cloud Gate cannot be directly compared.
# SYSTEM REQUIREMENTS

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OS</strong></td>
<td>Windows 7 or later</td>
</tr>
<tr>
<td><strong>PROCESSOR</strong></td>
<td>1.8 GHz dual-core Intel or AMD CPU</td>
</tr>
<tr>
<td><strong>MEMORY</strong></td>
<td>2 GB</td>
</tr>
<tr>
<td><strong>STORAGE</strong></td>
<td>6 GB free disk space</td>
</tr>
<tr>
<td><strong>GPU</strong></td>
<td>DirectX 10</td>
</tr>
<tr>
<td><strong>VIDEO CARD MEMORY</strong></td>
<td>256 MB</td>
</tr>
</tbody>
</table>

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22 Windows 7 users must install Service Pack 1.
# DEFAULT SETTINGS

<table>
<thead>
<tr>
<th>Setting</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>RENDERING RESOLUTION</td>
<td>1280 × 720</td>
</tr>
<tr>
<td>GPU MEMORY BUDGET</td>
<td>256 MB</td>
</tr>
<tr>
<td>SHADOW SAMPLE COUNT</td>
<td>4</td>
</tr>
<tr>
<td>SHADOW MAP RESOLUTION</td>
<td>1024</td>
</tr>
<tr>
<td>DEPTH OF FIELD QUALITY</td>
<td>Low</td>
</tr>
<tr>
<td>BLOOM RESOLUTION</td>
<td>1/8</td>
</tr>
</tbody>
</table>
GRAPHICS TEST 1

Cloud Gate Graphics test 1 has an emphasis on geometry processing while having simple shaders. Volumetric illumination is disabled, but the scene contains particle effects. FFT based bloom effects and a depth of field effect are added as post processing steps.

Processing performed in an average frame

<table>
<thead>
<tr>
<th></th>
<th>VERTICES</th>
<th>TRIANGLES</th>
<th>PIXELS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLOUD GATE</td>
<td>3.0 million</td>
<td>1.1 million</td>
<td>15.6 million</td>
</tr>
</tbody>
</table>

23 This figure is the average number of pixels processed per frame before the image is scaled to fit the native resolution of the device being tested. If the device's display resolution is greater than the test's rendering resolution, the actual number of pixels processed per frame will be even greater.
**GRAPHICS TEST 2**

Cloud Gate Graphics test 2 has shaders that are more mathematically complex than Graphics test 1, but has less geometry to process. Simple volumetric illumination is used, but the scene has no particle effects. Post processing steps are similar to Graphics test 1.

**Processing performed in an average frame**

<table>
<thead>
<tr>
<th></th>
<th>VERTICES</th>
<th>TRIANGLES</th>
<th>PIXELS(^{24})</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLOUD GATE</td>
<td>1.8 million</td>
<td>690,000</td>
<td>16.3 million</td>
</tr>
</tbody>
</table>

\(^{24}\)This figure is the average number of pixels processed per frame before the image is scaled to fit the native resolution of the device being tested. If the device's display resolution is greater than the test's rendering resolution, the actual number of pixels processed per frame will be even greater.
PHYSICS TEST

The Cloud Gate Physics test benchmarks the hardware's ability to run gameplay physics simulations on CPU. The GPU load is kept as low to ensure that only the CPU is stressed.

The test has 32 simulated worlds. Each world has 4 soft bodies, 4 joints and 20 rigid bodies colliding with each other. The rigid bodies are invisible and are there to cause the blast effect on the soft bodies.

The simulations run on one thread per available CPU core. All physics are computed on the CPU with soft body vertex data updated to the GPU each frame. Each world also has one CPU simulated particle system. The Physics test uses a forward renderer for minimum GPU load.

The test duration is 20 seconds but the score calculation begins after 8 seconds. The first 8 seconds skipped to allow all simulated objects to actively participate in simulation.

The Cloud Gate Physics test uses the Bullet Open Source Physics Library.
SCORING

Overall Cloud Gate score

The 3DMark Cloud Gate score formula uses a weighted harmonic mean to calculate the overall score from the Graphics and Physics scores.

\[
\text{Cloud Gate score} = \frac{W_{\text{graphics}} + W_{\text{physics}}}{\frac{W_{\text{graphics}}}{S_{\text{graphics}}} + \frac{W_{\text{physics}}}{S_{\text{physics}}}}
\]

Where:

- \( W_{\text{graphics}} \) = The Graphics score weight, equal to 7/9
- \( W_{\text{physics}} \) = The Physics score weight, equal to 2/9
- \( S_{\text{graphics}} \) = Graphics score
- \( S_{\text{physics}} \) = Physics score

For a balanced system, the weights reflect the ratio of the effects of graphics and physics performance on the overall score. Balanced in this sense means the Graphics and Physics sub-scores are roughly the same magnitude.

For a system where either the Graphics or Physics score is substantially higher than the other, the harmonic mean rewards boosting the lower score. This reflects the reality of the user experience. For example, doubling the CPU speed in a system with an entry-level graphics card doesn't help much in games since the system is already limited by the GPU. Likewise for a system with a high-end graphics card paired with an underpowered CPU.

Graphics score

Each Graphics test produces a raw performance result in frames per second (FPS). We take a harmonic mean of these raw results and multiply it with a scaling constant to reach a Graphics score (\( S_{\text{graphics}} \)) as follows:

\[
S_{\text{graphics}} = 230 \times \frac{2}{\frac{1}{F_{\text{gt1}}} + \frac{1}{F_{\text{gt2}}}}
\]

Where:
\[ F_{gt1} = \text{The average FPS result from Graphics test 1} \]
\[ F_{gt2} = \text{The average FPS result from Graphics test 2} \]

The scaling constant is used to bring the score in line with traditional 3DMark score levels.

**Physics score**

The Physics score is calculated from the raw performance result in frames per second (FPS) of the Physics test.

\[ S_{physics} = 315 \times F_{physics} \]

Where:

\[ F_{physics} = \text{The average FPS result from the Physics Test} \]

The scaling constant is used to bring the score in line with traditional 3DMark score levels.
CLOUD GATE ENGINE

Cloud Gate tests use same engine as Fire Strike, but with a reduced set of features including a simplified lighting model and some fall-backs implemented for Direct3D feature level 10.

Cloud Gate requires graphics hardware with support for Direct3D feature level 10 or greater.
## CLOUD GATE VERSION HISTORY

<table>
<thead>
<tr>
<th>VERSION</th>
<th>Windows</th>
<th>Android</th>
<th>iOS</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1.0</td>
<td>●</td>
<td>×</td>
<td>×</td>
<td>Fixed issues when benchmarking systems with multiple GPUs. Scores improve significantly on systems with multiple GPUs.</td>
</tr>
<tr>
<td>1.0.0</td>
<td>●</td>
<td>×</td>
<td>×</td>
<td>Launch version</td>
</tr>
</tbody>
</table>

---

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ICE STORM

Ice Storm is a cross-platform benchmark for low cost, basic smartphones and tablets and older mobile devices. We recommend using Time Spy, Fire Strike, and Sky Diver for testing modern PCs.

Ice Storm includes two Graphics tests focusing on GPU performance and a Physics test targeting CPU performance.

On Android and iOS, Ice Storm uses OpenGL ES 2.0. On Windows, Ice Storm uses a DirectX 11 engine limited to Direct3D feature level 9.

Ice Storm's test content, settings and rendering resolution are the same on all platforms and scores can be compared across Windows, Android and iOS.

- Cross-platform benchmark for older mobile devices.
- Includes two Graphics tests and a Physics test.
- Compare scores across Windows, Android and iOS.
## SYSTEM REQUIREMENTS

### Windows

<table>
<thead>
<tr>
<th></th>
<th>ICE STORM UNLIMITED</th>
<th>ICE STORM EXTREME</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OS</strong>&lt;sup&gt;25&lt;/sup&gt;</td>
<td>Windows 7 or later</td>
<td>Windows 7 or later</td>
</tr>
<tr>
<td><strong>PROCESSOR</strong></td>
<td>1.8 GHz dual-core</td>
<td>1.8 GHz dual-core</td>
</tr>
<tr>
<td></td>
<td>Intel or AMD CPU</td>
<td>Intel or AMD CPU</td>
</tr>
<tr>
<td><strong>MEMORY</strong></td>
<td>2 GB</td>
<td>4 GB</td>
</tr>
<tr>
<td><strong>STORAGE</strong></td>
<td>6 GB free disk space</td>
<td>6 GB free disk space</td>
</tr>
<tr>
<td><strong>GPU</strong>&lt;sup&gt;26&lt;/sup&gt;</td>
<td>DirectX 9</td>
<td>DirectX 9</td>
</tr>
<tr>
<td><strong>VIDEO CARD MEMORY</strong></td>
<td>128 MB</td>
<td>256 GB</td>
</tr>
</tbody>
</table>

<sup>25</sup> Windows 7 users must install Service Pack 1.

<sup>26</sup> DirectX 9 hardware needs Shader Model 3.0 support, 128 MB and WDDM 1.1 drivers. Note that ATI Radeon X1x00 series cards do not have WDDM 1.1 drivers available and cannot run 3DMark. The oldest cards confirmed to work with 3DMark are Radeon HD 2x00 series (Ice Storm, Cloud Gate), NVIDIA GeForce 7x00 series (Ice Storm) and Intel GMA X4500 (Ice Storm).
ICE STORM

<table>
<thead>
<tr>
<th>RENDERING RESOLUTION</th>
<th>1280 × 720</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPU MEMORY BUDGET</td>
<td>128 MB</td>
</tr>
<tr>
<td>TEXTURE QUALITY</td>
<td>Low</td>
</tr>
<tr>
<td>BLOOM RESOLUTION</td>
<td>1/8</td>
</tr>
</tbody>
</table>

Use Ice Storm for device-to-device comparisons of older mobile devices. Ice Storm is rendered at a fixed 1280 × 720 resolution and then scaled to the native resolution of the display. This is the best approach for ensuring that devices can be compared fairly.

Many mobile devices lock their display refresh rate to 60 Hz and force the use of vertical sync. If your device is able to run this test at more than 60 frames per second you will be prompted to run a more demanding test instead.

Ice Storm Unlimited

Use Ice Storm Unlimited to make chip-to-chip comparisons. Ice Storm Unlimited uses the same content and settings as Ice Storm but runs offscreen using a fixed time step between frames. Unlimited mode renders exactly the same frames in every run on every device. The display is updated with frame thumbnails every 100 frames to show progress.

Ice Storm Unlimited measures the performance of the device hardware without vertical sync, display resolution scaling and other operating system factors affecting the result.
ICE STORM EXTREME

<table>
<thead>
<tr>
<th>GRAPHICS TESTS RENDERING RESOLUTION</th>
<th>1920 ×1080</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYSICS TEST RENDERING RESOLUTION</td>
<td>1280 × 720</td>
</tr>
<tr>
<td>GPU MEMORY BUDGET</td>
<td>256 MB</td>
</tr>
<tr>
<td>TEXTURE QUALITY</td>
<td>High</td>
</tr>
<tr>
<td>BLOOM RESOLUTION</td>
<td>1/4</td>
</tr>
</tbody>
</table>

Use Ice Storm Extreme for device-to-device comparisons of low cost, basic model mobile devices.

Ice Storm Extreme raises the Graphics tests rendering resolution from 1280 × 720 to 1920 × 1080 and uses higher quality textures and post-processing effects to create a more demanding load. The Physics test renders at 1280 × 720 to ensure performance is not limited by the GPU.

Many mobile devices lock their display refresh rate to 60 Hz and force the use of vertical sync. If your device is able to run this test at more than 60 frames per second you will be prompted to run a more demanding test instead.
GRAPHICS TEST 1

Ice Storm Graphics test 1 stresses the hardware's ability to process lots of vertices while keeping the pixel load relatively light. Hardware on this level may have dedicated capacity for separate vertex and pixel processing. Stressing both capacities individually reveals the hardware's limitations in both aspects. Pixel load is kept low by excluding expensive post processing steps, and by not rendering particle effects.

Processing performed in an average frame

<table>
<thead>
<tr>
<th></th>
<th>VERTICES</th>
<th>TRIANGLES</th>
<th>PIXELS</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICE STORM</td>
<td>530,000</td>
<td>180,000</td>
<td>1.9 million</td>
</tr>
<tr>
<td>ICE STORM EXTREME</td>
<td>580,000</td>
<td>190,000</td>
<td>4.4 million</td>
</tr>
</tbody>
</table>

This figure is the average number of pixels processed per frame before the image is scaled to fit the native resolution of the device being tested. If the device's display resolution is greater than the test's rendering resolution, the actual number of pixels processed per frame will be even greater.
GRAPHICS TEST 2

Graphics test 2 stresses the hardware's ability to process lots of pixels. It tests the ability to read textures, do per pixel computations and write to render targets. The additional pixel processing compared to Graphics test 1 comes from including particles and post processing effects such as bloom, streaks and motion blur. The numbers of vertices and triangles are considerably lower than in Graphics test 1 because shadows are not drawn and the processed geometry has a lower number of polygons.

Processing performed in an average frame

<table>
<thead>
<tr>
<th></th>
<th>VERTICES</th>
<th>TRIANGLES</th>
<th>PIXELS(^{28})</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICE STORM</td>
<td>79,000</td>
<td>26,000</td>
<td>7.8 million</td>
</tr>
<tr>
<td>ICE STORM EXTREME</td>
<td>89,000</td>
<td>28,000</td>
<td>18.6 million</td>
</tr>
</tbody>
</table>

\(^{28}\) This figure is the average number of pixels processed per frame before the image is scaled to fit the native resolution of the device being tested. If the device's display resolution is greater than the test's rendering resolution, the actual number of pixels processed per frame will be even greater.
PHYSICS TEST

The purpose of the Physics test is to benchmark the hardware’s ability to do gameplay physics simulations on CPU. The GPU load is kept as low as possible to ensure that only the CPU’s capabilities are stressed.

The test has four simulated worlds. Each world has two soft bodies and two rigid bodies colliding with each other. One thread per available CPU core is used to run simulations. All physics are computed on the CPU with soft body vertex data updated to the GPU each frame. The background is drawn as a static image for the least possible GPU load.

The Ice Storm Physics test uses the Bullet Open Source Physics Library.
SCORING

Scores from individual Ice Storm benchmarks can be compared across platforms, for example you can compare 3DMark Ice Storm Extreme scores from Android and iOS devices.

Scores from different benchmarks should not be compared to each other. Ice Storm, Ice Storm Unlimited and Ice Storm Extreme are separate tests with their own scores, even though they share the same content.

**Overall Ice Storm score**

The 3DMark Ice Storm score formula uses a weighted harmonic mean to calculate the overall score from the Graphics and Physics scores.

\[
\text{Ice Storm score} = \frac{W_{\text{Graphics}} + W_{\text{Physics}}}{\frac{W_{\text{Graphics}}}{S_{\text{Graphics}}} + \frac{W_{\text{Physics}}}{S_{\text{Physics}}}}
\]

Where:

- \(W_{\text{Graphics}}\) = The Graphics score weight, equal to 7/9
- \(W_{\text{Physics}}\) = The Physics score weight, equal to 2/9
- \(S_{\text{Graphics}}\) = Graphics score
- \(S_{\text{Physics}}\) = Physics score

For a balanced system, the weights reflect the ratio of the effects of graphics and physics performance on the overall score. Balanced in this sense means the Graphics and Physics sub-scores are roughly the same magnitude.

For a system where either the Graphics or Physics score is substantially higher than the other, the harmonic mean rewards boosting the lower score. This reflects the reality of the user experience. For example, doubling the CPU speed in a system with an entry-level graphics card doesn't help much in games since the system is already limited by the GPU. Likewise for a system with a high-end graphics card paired with an underpowered CPU.

**Graphics score**

Each Graphics test produces a raw performance result in frames per second (FPS). We take a harmonic mean of these raw results and multiply it with a scaling constant to reach a Graphics score \(S_{\text{Graphics}}\) as follows:
\[ S_{graphics} = 230 \times \frac{2}{\frac{1}{F_{gt1}} + \frac{1}{F_{gt2}}} \]

Where:

\[ F_{gt1} = \text{The average FPS result from Graphics test 1} \]
\[ F_{gt2} = \text{The average FPS result from Graphics test 2} \]

The scaling constant is used to bring the score in line with traditional 3DMark score levels.

**Physics score**

The Physics score is calculated from the raw performance result in frames per second (FPS) of the Physics test.

\[ S_{physics} = 315 \times F_{physics} \]

Where:

\[ F_{physics} = \text{The average FPS result from the Physics Test} \]

The scaling constant is used to bring the score in line with traditional 3DMark score levels.
ICE STORM ENGINE

Ice Storm uses the same engine on all platforms. The engine supports the following features.

- Traditional forward rendering using one pass per light.
- Scene updating and visibility computations are multithreaded.
- Draw calls are issued from a single thread.
- Support for skinned and static geometries.
- Surface lighting model is basic Blinn Phong.
- Supported light types include unshadowed point light & optionally shadow mapped directional light as well as pre-computed environmental cube.
- Support for transparent geometries and particle effects.
- 16-bit color formats are used in illumination buffers if supported by the hardware.

Windows

On Windows and Windows RT, Ice Storm requires support for Direct3D feature level 9_3 or 9_1 with the optional shadow filtering support.

Android

Ice Storm does not use any vendor specific OpenGL ES 2.0 extensions. Textures are compressed using ETC. Textures that require an alpha channel are loaded uncompressed.

iOS

Textures, including those with an alpha channel, are compressed using PVRTC.
# ICE STORM VERSION HISTORY

<table>
<thead>
<tr>
<th>VERSION</th>
<th>Windows</th>
<th>RT</th>
<th>Android</th>
<th>Apple</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2.0</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>Added Ice Storm Unlimited</td>
</tr>
<tr>
<td>1.1.1</td>
<td>●</td>
<td>×</td>
<td>●</td>
<td>×</td>
<td>Ice Storm Extreme Physics test now runs at 1080 × 720 to ensure performance is not limited by the GPU. Scores may improve slightly on devices with low-end GPUs.</td>
</tr>
<tr>
<td>1.1.0</td>
<td>●</td>
<td>×</td>
<td>●</td>
<td>×</td>
<td>Added Ice Storm Extreme</td>
</tr>
<tr>
<td>1.0.0</td>
<td>●</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>Launch version</td>
</tr>
</tbody>
</table>
API OVERHEAD FEATURE TEST

Feature tests are special tests designed to highlight specific techniques, functions or capabilities. A 3DMark feature test differs from a 3DMark benchmark in that the nature of the test may be necessarily artificial rather than based on real-world uses and applications.

Even so, feature tests are designed such that performance improvements in the test should benefit other applications as well, i.e. any driver optimization that results in improved performance in the API Overhead feature test will also benefit other games and applications.

The 3DMark API Overhead feature test is an impartial test for measuring and comparing the performance of the latest graphics APIs.

<table>
<thead>
<tr>
<th></th>
<th>Windows</th>
<th>Android</th>
<th>Apple</th>
</tr>
</thead>
<tbody>
<tr>
<td>DirectX 12</td>
<td>●</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>DirectX 11</td>
<td>●</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>Vulkan</td>
<td>●</td>
<td>●</td>
<td>×</td>
</tr>
<tr>
<td>OpenGL ES 3.0</td>
<td>×</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Metal</td>
<td>×</td>
<td>×</td>
<td>●</td>
</tr>
</tbody>
</table>

New low-overhead APIs like Vulkan, DirectX 12 and Metal make better use of multi-core CPUs to streamline code execution and eliminate software bottlenecks, particularly for draw calls.

A draw call happens when the CPU tells the GPU to draw an object on the screen. Games typically make thousands of draw calls per frame, but each one creates performance-limiting overhead for the CPU.

As the number of draw calls rises, graphics engines become limited by API overhead. APIs like Vulkan, DirectX 12 and Metal reduce that overhead allowing more draw calls. With more draw calls, the graphics engine can draw more objects, textures and effects to the screen.

The 3DMark API Overhead feature test measures API performance by making a steadily increasing number of draw calls. The result of the test is
the number of draw calls per second achieved by each API before the frame rate drops below 30 FPS.

For Windows, the API Overhead feature test is only available in 3DMark Advanced Edition and 3DMark Professional Edition.
CORRECT USE OF THE API OVERHEAD FEATURE TEST

The API Overhead feature test is not a general-purpose GPU benchmark, and it should not be used to compare graphics cards or mobile devices from different vendors.

The test is designed to make API overhead the performance bottleneck. It does this by maximizing the number of draw calls in a scene, (by drawing a huge number of individual ‘buildings’), while minimizing the GPU load, (by using simple shaders and no lighting effects). This an artificial scenario that is unlikely to be found in games, which typically aim to achieve high levels of detail and exceptional visual quality.

The benefit of reducing API overhead is greatest when the CPU is the limiting factor. With modern APIs and fast CPUs, the test can become GPU bound, but not always in a way that is meaningful from a general GPU performance perspective. The point at which the test moves from being CPU-bound to GPU-bound changes from system to system. It is not easy to tell from the test results whether the run was CPU or GPU limited. And what's more, it is difficult to isolate the relative impact of GPU performance and driver performance.

As a result, you should be careful making conclusions about GPU performance when comparing API Overhead test results from different systems. For instance, we would advise against comparing the Vulkan score from an AMD GPU with the DirectX 12 score from an NVIDIA GPU. Likewise, it could be misleading to credit the GPU for any difference in DirectX 12 performance between an AMD GPU and an NVIDIA GPU.

Another scenario, for example, would be to test DirectX 12 performance with a range of CPUs in a system with a fixed GPU. Or, you could test a vendor's range of GPUs, from budget to high-end, and keep the CPU fixed. But in both cases, the nature of the test means it will not show you the extent to which the performance differences are due to the hardware and how much is down to the driver.

The proper use of the test is to compare the relative performance of each API on a single system, rather than the absolute performance of different systems.

The focus on single-system testing is one reason why the API Overhead test is called a feature test rather than a benchmark.
# SYSTEM REQUIREMENTS

<table>
<thead>
<tr>
<th></th>
<th>DirectX 11</th>
<th>DirectX 12&lt;sup&gt;29&lt;/sup&gt;</th>
<th>Vulkan</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OS</strong>&lt;sup&gt;30&lt;/sup&gt;</td>
<td>Windows 7 or later, 64-bit</td>
<td>Windows 10, 64-bit</td>
<td>Windows 7 or later, 64-bit</td>
</tr>
<tr>
<td><strong>PROCESSOR</strong></td>
<td>1.8 GHz dual-core Intel or AMD CPU</td>
<td>1.8 GHz dual-core Intel or AMD CPU</td>
<td>1.8 GHz dual-core Intel or AMD CPU</td>
</tr>
<tr>
<td><strong>MEMORY</strong></td>
<td>6 GB</td>
<td>6 GB</td>
<td>6 GB</td>
</tr>
<tr>
<td><strong>GPU</strong></td>
<td>DirectX 11 compatible</td>
<td>DirectX 12 compatible</td>
<td>Vulkan compatible</td>
</tr>
<tr>
<td><strong>VIDEO CARD MEMORY</strong></td>
<td>1 GB</td>
<td>1 GB</td>
<td>1 GB</td>
</tr>
</tbody>
</table>

<sup>29</sup> The DirectX 12 part of the API Overhead feature test requires Windows 10, graphics hardware that supports DirectX 12, and the appropriate drivers. The API Overhead feature test does not yet support multi-GPU systems, and you may need to disable Crossfire/SLI. Close other apps that tie into the DirectX stack, for example applications like FRAPS that draw overlays. Apps that are not compatible with DirectX 12 will prevent the test from running.

<sup>30</sup> Windows 7 users must install Service Pack 1.
**WINDOWS SETTINGS**

**Windowed mode**
Check this box to run the test in a window. The default is unchecked, meaning the test runs full screen.

**Rendering resolution**
Use this drop-down menu to set the rendering resolution for the test. This is the resolution used for the internal render target, before the output is scaled to the back buffer. This option is cosmetic, since changing the rendering resolution will not affect the test results on the majority of systems. The default is 1280 × 720.
TECHNICAL DETAILS

The test is designed to make API overhead the performance bottleneck. The test scene contains a large number of geometries. Each geometry is a unique, procedurally-generated, indexed mesh containing 112 -127 triangles.

The geometries are drawn with a simple shader, without post processing. The draw call count is increased further by drawing a mirror image of the geometry to the sky and using a shadow map for directional light.

The scene is drawn to an internal render target before being scaled to the back buffer. There is no frustum or occlusion culling to ensure that the API draw call overhead is always greater than the application side overhead generated by the rendering engine.

Starting from a small number of draw calls per frame, the test increases the number of draw calls in steps every 20 frames, following the figures in the table below.

To reduce memory usage and loading time, the test is divided into two parts. On Windows, the first part runs until 98,304 draw calls per frame. The second part starts from the beginning on all platforms.

<table>
<thead>
<tr>
<th>DRAW CALLS PER FRAME</th>
<th>DRAW CALLS PER FRAME INCREMENT PER STEP</th>
<th>ACCUMULATED DURATION IN FRAMES</th>
</tr>
</thead>
<tbody>
<tr>
<td>192 – 384</td>
<td>12</td>
<td>320</td>
</tr>
<tr>
<td>384 – 768</td>
<td>24</td>
<td>640</td>
</tr>
<tr>
<td>768 – 1536</td>
<td>48</td>
<td>960</td>
</tr>
<tr>
<td>1536 – 3072</td>
<td>96</td>
<td>1280</td>
</tr>
<tr>
<td>3072 – 6144</td>
<td>192</td>
<td>1600</td>
</tr>
<tr>
<td>6144 – 12288</td>
<td>384</td>
<td>1920</td>
</tr>
<tr>
<td>12288 – 24576</td>
<td>768</td>
<td>2240</td>
</tr>
<tr>
<td>24576 – 49152</td>
<td>1536</td>
<td>2560</td>
</tr>
</tbody>
</table>
### Geometry batching

To improve content streaming performance, reduce API overhead and shorten loading times, games often batch geometries together by storing the vertex data for a group of geometries in a single, large buffer.

Allocating one large buffer is faster than allocating several small buffers. And uploading the contents of one large buffer from the CPU to the GPU is faster than uploading the contents of several small buffers.

In games and other real-world applications, the extent to which batching is possible depends on many factors. API overhead is reduced if consecutive draw calls can use the same buffer and there is no buffer changing operation required between draw calls.

The 3DMark API Overhead feature test makes a vertex buffer change operation on every tenth draw call. This represents neither the worst case nor the optimal scenario and was chosen to best reflect the nature of real-world workloads.

For fairness, we use the same batching and buffer management code on all platforms. Some platforms restrict the minimum size of buffer allocations, which in practice requires applications to store the data for smaller geometries together in large buffers. Therefore, the test uses large buffers to hold the data for several geometries.
DIRECTX 12 PATH

All lighting draw calls use the same primitive topology and pipeline state object. The following DirectX 12 API calls are made, at least once, for each lighting draw call:

```
SetIndexBuffer()
SetGraphicsRootDescriptorTable()
SetGraphicsRootConstantBufferView()
DrawIndexedInstanced() with a single instance
```

All shadow map draw calls use the same primitive topology and pipeline state object. The following DirectX 12 API calls are made, at least once, for each shadow map draw call:

```
SetIndexBuffer()
SetGraphicsRootConstantBufferView()
DrawIndexedInstanced() with a single instance
```

Neither lighting nor shadow map passes use tessellator or geometry shader. The test uses one thread for each logical CPU core. Draw call recording work is divided evenly between all threads for both the shadow map and lighting passes. Each thread records draw calls for a fixed set of geometries for both passes.
DIRECTX 11 PATH

All lighting draw calls use the same primitive topology, shaders and rasterizer, depth stencil and blend states. The following DirectX 11 API calls are made for each lighting draw call:

- IASetIndexBuffer()
- IASetVertexBuffers()
- VSSetConstantBuffers()
- PSSetConstantBuffers()
- PSSetSamplers()
- PSSetShaderResources()
- DrawIndexed()

All shadow map draw calls use the same primitive topology, shaders and rasterizer, depth stencil and blend states. The following API calls are made for each shadow map draw call:

- IASetIndexBuffer()
- IASetVertexBuffers()
- VSSetConstantBuffers()
- DrawIndexed()

Neither lighting nor shadow map passes use tessellator or geometry shader.

Single-threaded

When single threaded mode is selected, draw calls for all geometries are made through ImmediateDeviceContext using a single thread, first for the shadow map pass and then for the lighting pass.

Multi-threaded

When multi-threaded mode is selected, (and there are more than two logical CPU cores available), one core is intentionally left unused to ensure it is available for the display driver. The other threads, (one less than the number of available cores), are used to record draw calls to command lists through DeferredDeviceContexts.

Draw call recording work is divided evenly across all used threads for both shadow map and lighting passes. Each thread records draw calls for a fixed set of geometries for both passes. First all command lists are recorded without synchronization points. After being recorded, the command lists are executed by the main thread in the appropriate order.
⚠ Since one thread is reserved for the display driver, running multi-threaded on a dual-core CPU will return the same result as running the single-threaded test.
VULKAN PATH

All lighting draw calls use the same primitive topology and pipeline state object. The following Vulkan API calls are made for each lighting draw call:

- `vkCmdBindDescriptorSets()`
- `vkCmdDrawIndexed()`

All shadow map draw calls use the same primitive topology and pipeline state object. The following Vulkan API calls are made for each shadow map draw call:

- `vkCmdBindDescriptorSets()`
- `vkCmdDrawIndexed()`

Neither lighting nor shadow map passes use tessellator or geometry shader. The test uses one thread for each logical CPU core. Draw call recording work is divided evenly between all threads for shadow map and lighting passes. Each thread records draw calls for a fixed set of geometries for both passes.
MANTLE PATH

⚠ Please note that the Mantle test was replaced with a Vulkan test in 3DMark v2.3.3663 released on March 23, 2017.

All lighting draw calls use the same primitive topology, shaders and rasterizer, depth stencil and blend states. The following Mantle API calls are made for each lighting draw call:

- grCmdBindDescriptorSet()
- grCmdBindIndexData()
- grCmdDrawIndexed()

All shadow map draw calls use the same primitive topology, shaders and rasterizer, depth stencil and blend states. For each shadow map draw call, the following Mantle API calls are made:

- grCmdBindDescriptorSet()
- grCmdBindIndexData()
- grCmdDrawIndexed()

Neither lighting nor shadow map passes use tessellator or geometry shader.

All shader constants are stored in one large constant buffer that is updated with a single grMapMemory() call. The memory states for the constant buffer are set with grCmdPrepareMemoryRegions().

The test uses one thread for each logical CPU core. Draw call recording work is divided evenly between all threads for shadow map and lighting passes. Each thread records draw calls for a fixed set of geometries for both passes.
SCORING

The test increases the number of draw calls per frame in steps, until the frame rate drops below 30 frames per second.

Note that if a single frame takes more than 3 times as long to render than the average time for the 20 previous frames, it is treated as an outlier and ignored. This is necessary because the first frame after raising the draw call count sometimes has a longer frame time, which would cause the test to end earlier than it should.

Once the frame rate drops below 30 frames per second, the number of draw calls per frame is kept constant and the average frame rate is measured over 3 seconds.

This frame rate value is then multiplied by the number of draw calls per frame to give the result of the test: the number of draw calls per second achieved by each API.

⚠ The API Overhead feature test is not a general-purpose GPU benchmark, and it should not be used to compare graphics cards from different vendors. The proper use of the test is to compare the relative performance of each API on a single system, rather than the absolute performance of different systems.
## API OVERHEAD VERSION HISTORY

### Windows

<table>
<thead>
<tr>
<th>VERSION</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5</td>
<td>Vulkan test replaces Mantle.</td>
</tr>
<tr>
<td>1.3</td>
<td>Minor bug fixes. Scores are not affected.</td>
</tr>
<tr>
<td>1.2</td>
<td>Minor bug fixes. Scores are not affected.</td>
</tr>
<tr>
<td>1.1</td>
<td>Updated for Windows 10 RTM. Scores are not affected.</td>
</tr>
<tr>
<td>1.0</td>
<td>Launch version</td>
</tr>
</tbody>
</table>
PCI EXPRESS FEATURE TEST

3DMark feature tests are special tests designed to highlight specific techniques, functions or capabilities.

PCI Express (PCIe) is a standard interface that provides high-bandwidth communication between devices in a computer. New PCI Express 4.0 interfaces provide up to twice the bandwidth of PCI Express 3.0. With more bandwidth, games can transfer more data, reduce loading times, and support more complex scenes.

The 3DMark PCI Express feature test is designed to measure the bandwidth available to your GPU over your computer’s PCI Express interface. This is a synthetic test. In real-world use, your PC’s gaming performance is extremely unlikely to be limited by PCIe bandwidth.

The PCI Express feature test is available in 3DMark Advanced Edition and 3DMark Professional Edition (annual license only).
# SYSTEM REQUIREMENTS

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>OS</td>
<td>Windows 10, 64-bit</td>
</tr>
<tr>
<td>PROCESSOR</td>
<td>Dual-core processor</td>
</tr>
<tr>
<td>GPU</td>
<td>DirectX 12 dedicated graphics card</td>
</tr>
<tr>
<td>VIDEO MEMORY</td>
<td>4 GB</td>
</tr>
<tr>
<td>MEMORY</td>
<td>12 GB RAM</td>
</tr>
<tr>
<td>STORAGE</td>
<td>170 MB</td>
</tr>
</tbody>
</table>

⚠ You need a DirectX 12 compatible discrete graphics card to run the 3DMark PCI Express feature test. The test will not run on systems that have only integrated graphics. In multi-GPU systems, the test will run on the primary GPU. External GPU enclosures are not supported.
TECHNICAL DETAILS

The 3DMark PCI Express feature test aims to make bandwidth the limiting factor for performance.

For each frame, the test uploads a large amount of vertex and texture data to the GPU. The goal is to transfer enough data to saturate the PCIe 4.0 interface. The geometry streaming load increases from 2,400,000 to 9,600,000 vertices per frame as the test runs. The texture streaming load remains constant.

The test uses a fixed time step between frames. This ensures that every system does the same amount of work when running the test.

Rendering

The 3DMark PCI Express feature test is rendered at 2560 × 1440 resolution.

The test is forward-rendered with simple Blinn-Phong shading. The background is rendered by blending three textures, two of which are uploaded for each frame. The test uses post-processing to add linear fog, tone mapping, and bloom effects.
SCORING

The result is the average bandwidth achieved during the test.

The amount of bandwidth available over PCI Express depends on your motherboard, your graphics card, the PCIe slot used by your graphics card, your system's BIOS settings, and other factors.

This is a synthetic test. In real-world use, your PC's gaming performance is extremely unlikely to be limited by PCIe bandwidth.
## PCI EXPRESS FEATURE TEST HISTORY

<table>
<thead>
<tr>
<th>VERSION</th>
<th>Windows</th>
<th>Android</th>
<th>Apple</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>●</td>
<td>✗</td>
<td>✗</td>
<td>Launch version</td>
</tr>
</tbody>
</table>

Page 154 of 199
VRS FEATURE TEST

3DMark feature tests are special tests designed to highlight specific techniques, functions or capabilities.

Variable-Rate Shading (VRS) is a DirectX 12 feature that allows developers to improve performance by selectively reducing the shading rate in parts of the frame where there will be little noticeable effect on image quality.

The 3DMark VRS feature test helps you compare differences in performance and image quality when using Tier 1 variable-rate shading. The test also offers an interactive mode for experimenting with different VRS settings and exporting frames for comparison.

The VRS feature test is available in 3DMark Advanced Edition and 3DMark Professional Edition (annual license only).
# SYSTEM REQUIREMENTS

<table>
<thead>
<tr>
<th>OS</th>
<th>Windows 10 version 1903 or later, 64-bit</th>
</tr>
</thead>
<tbody>
<tr>
<td>PROCESSOR</td>
<td>Dual-core processor</td>
</tr>
<tr>
<td>GPU</td>
<td>DirectX 12 GPU that supports Tier 1 Variable-Rate Shading and the <code>AdditionalShadingRatesSupported</code> capability.</td>
</tr>
<tr>
<td>VIDEO MEMORY</td>
<td>1 GB</td>
</tr>
<tr>
<td>MEMORY</td>
<td>4 GB</td>
</tr>
<tr>
<td>STORAGE</td>
<td>100 MB</td>
</tr>
</tbody>
</table>
VARIABLE-RATE SHADING

Variable-Rate Shading (VRS) is a feature in DirectX 12 that allows developers to improve performance by selectively reducing the level of detail in parts of the frame where there will be little noticeable effect on image quality.

Shading rate refers to the number of pixel shader operations called for each pixel. Higher shading rates improve accuracy but are more demanding for the GPU. Lower shading rates improve performance at the cost of visual fidelity.

With Variable-Rate Shading, developers can vary the shading rate within a single frame. Tier 1 VRS lets developers specify the per-draw shading rate, allowing different shading rates for each draw call. Tier 2 hardware can additionally support VRS within each draw call.

By using VRS to lower the shading rate for parts of the frame that are in deep shadow, far the camera, or peripheral to the player’s focus, for example, a game can run at a higher frame rate with little perceptible loss in visual quality.

For more details, please see the DirectX Developer Blog and the Windows Dev Center.
TECHNICAL DETAILS

The 3DMark VRS feature test helps you compare differences in frame rate and image quality when using Tier 1 variable-rate shading.

The test runs twice to test performance and image quality. VRS is disabled on the first pass and enabled for the second pass. The test reports the frame rate for each run.

Rendering

The default rendering resolution for the test is $1920 \times 1080$. You can change the rendering resolution using the drop-down selector on the VRS feature test tab in the UI. This is the resolution the test uses before scaling the output to your monitor's display resolution.
SCORING

The test runs in two passes. VRS is disabled on the first pass of the test to provide a baseline for comparison. Variable-Rate Shading is enabled for the second pass. The test then reports the average frame rate for each pass and calculates the performance gained with VRS.
INTERACTIVE MODE

Interactive mode lets you change variable-rate shading settings on the fly to see how they affect the frame rate and image quality.

Use the controls on the overlay to enable or disable VRS. The Time and Pause controls let you move through the timeline to specific points. The Capture frame button exports the original rendered frame with the current settings for comparison.

When VRS is enabled, the shading rate varies with camera distance. You can use the Visualizer to see how variable-rate shading is applied in the scene.

- Blue areas use a 4×4 shading rate.
- Green areas use a 2×2 shading rate.
- Red areas use a 1×1 shading rate.

You can change the threshold distance for each shading rate with the sliders. This allows you to experiment with the settings to prioritise performance or visual fidelity.
# VRS FEATURE TEST HISTORY

<table>
<thead>
<tr>
<th>VERSION</th>
<th>Windows</th>
<th>Android</th>
<th>Apple</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>✔️</td>
<td>✗</td>
<td>✗</td>
<td>Launch version</td>
</tr>
</tbody>
</table>
NVIDIA DLSS FEATURE TEST

Feature tests are special tests designed to highlight specific techniques, functions or capabilities.

The NVIDIA DLSS feature test is designed to help you test and compare the performance and image quality of DLSS processing.

DLSS (Deep Learning Super Sampling) is an NVIDIA RTX technology that uses the power of deep learning and AI to improve game performance while maintaining visual quality.

The NVIDIA DLSS feature test runs the Port Royal benchmark twice. The first run has DLSS disabled to provide a baseline. The second run uses DLSS processing. The result screen reports the frame rate for each run.

The NVIDIA DLSS feature test is only available in 3DMark Advanced Edition and 3DMark Professional Edition.

⚠ DLSS is a proprietary NVIDIA technology. To run this test, you will need an NVIDIA graphics card with drivers that support DLSS and Microsoft DirectX Raytracing, such as a GeForce RTX series, Quadro RTX series or TITAN RTX. You must also have the latest NVIDIA drivers for your graphics card and the Windows 10 October 2018 Update (1809).
# SYSTEM REQUIREMENTS

<table>
<thead>
<tr>
<th>Component</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>OS</td>
<td>Windows 10, 64-bit with October 2018 Update (version 1809)</td>
</tr>
<tr>
<td>PROCESSOR</td>
<td>1.8 GHz dual-core with SSSE3 support</td>
</tr>
<tr>
<td>GPU</td>
<td>DirectX 12 with support for DirectX Raytracing and DLSS&lt;sup&gt;31&lt;/sup&gt;</td>
</tr>
<tr>
<td>VIDEO MEMORY</td>
<td>6 GB</td>
</tr>
<tr>
<td>MEMORY</td>
<td>4 GB RAM</td>
</tr>
<tr>
<td>STORAGE</td>
<td>0.8 GB free disk space (shared with Port Royal)</td>
</tr>
</tbody>
</table>

<sup>31</sup> DLSS is a proprietary NVIDIA technology. To run NVIDIA DLSS feature test, you must have an NVIDIA graphics card that supports DLSS, such as a GeForce RTX series, Quadro RTX series or TITAN RTX. You must also have the latest NVIDIA drivers for your graphics card.
DEEP LEARNING SUPER SAMPLING

Deep Learning Super Sampling (DLSS) is an NVIDIA RTX technology that uses deep learning and AI to improve game performance while maintaining visual quality.

DLSS uses a deep neural network to extract multidimensional features of the rendered scene and intelligently combine details from multiple frames to construct a high-quality final image. This approach allows NVIDIA RTX GPUs to use fewer samples for rendering and use AI to fill in information to create the final image. The result is a clear, crisp image of a quality similar to traditional rendering but with higher performance.

Aliasing

Aliasing — a distracting jagged line on the edge of an object in a scene — is a common artifact in real-time computer graphics.

Increasing the resolution of the entire image is not always practical so a common way to remove the jagged lines is to increase the number of samples on the line which helps to smooth it. Many techniques have been developed which intelligently blend the colors of the jagged edges with the colors of nearby pixels but most of these can lead to a loss of fine detail.

Temporal Anti-aliasing

The 3DMark Port Royal benchmark uses Temporal Anti-Aliasing (TAA), a popular anti-aliasing technique used in many games today. TAA solves the aliasing problem by accumulating multiple samples temporally — instead of adding more samples to a single frame, it adds a small jitter to a rendered frame, and combines the current samples with matching samples from previous frames. This directly leads to an increased sampling rate. Unfortunately, TAA suffers from flickering and ghosting artifacts. These can be especially seen in dynamic scenes.

A deep learning solution to aliasing

To develop Deep Learning Super Sampling, NVIDIA researchers trained a neural network to find jagged edges in an image, determine the best color for each pixel, and then apply proper colors to create smoother edges and improved image quality.

DLSS provides high-quality anti-aliasing with fewer artifacts and better performance than other types of anti-aliasing. Compared with TAA, DLSS produces sharp images that are temporally stable.
Neural network training

The specific details and method of the training is NVIDIA's trade secret since DLSS is a proprietary technology.

In general terms, the training process utilizes a large set of supersampled aliased rendering results and screen-space velocity textures generated by the workload to train the weights of the convolutional autoencoder.
HOW TO TEST DLSS PERFORMANCE

The NVIDIA DLSS feature test helps you compare performance and image quality with and without DLSS processing.

The feature test runs the Port Royal benchmark twice. The first run renders Port Royal to the output resolution with DLSS disabled to measure baseline performance.

The second run renders Port Royal at a lower resolution then uses DLSS processing to create frames at the output resolution.

The result screen reports the frame rate for each run. Compare frame rates to see how DLSS affects performance.

Resolution settings

You can choose an output resolution for the test. By default, the test uses the 2560 × 1440 output resolution.

- 1920 × 1080 (1080p)
- 2560 × 1440 (1440p)
- 3840 × 2160 (4K)

Part 1 — DLSS off

The first part of the test renders the Port Royal benchmark at the output resolution with DLSS disabled. This gives you a baseline reference for Port Royal performance and image quality using TAA.

Part 2 — DLSS on

The second part of the test renders Port Royal at a lower resolution then uses DLSS processing to create frames at the output resolution. The table below shows in rendering-output resolution pairs used in the test.

<table>
<thead>
<tr>
<th>DLSS RENDERING RESOLUTION</th>
<th>DLSS OUTPUT RESOLUTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1440 × 810</td>
<td>1920 × 1080 (1080p)</td>
</tr>
<tr>
<td>1920 × 1080</td>
<td>2560 × 1440 (1440p)</td>
</tr>
<tr>
<td>2560 × 1440</td>
<td>3840 × 2160 (4K)</td>
</tr>
</tbody>
</table>

With DLSS, the internal rendering resolution is linked to the output resolution and cannot be independently changed.
Display resolution

For both parts of the test, the output resolution is scaled (if required) to the **Scaled resolution** setting on the 3DMark Options screen. By default, this is set to **Automatic**, which scales the output resolution to the display resolution of your Windows desktop. You can override this setting on the Options screen to test other scenarios based on the resolution and scaling capabilities of your monitor.

Scaling from output resolution to your display resolution has negligible effect on performance.
HOW TO COMPARE DLSS IMAGE QUALITY

In 3DMark Professional Edition, you can use the 3DMark Image Quality Tool to output and save frames from each part of the test for further analysis. But please be aware that there is a known issue with the Tool that can affect the quality of the images it generates.

TAA works by using information from previous frames. In Single frame mode the tool does not generate enough warmup frames for TAA to work properly. The lack of warmup frames in Single Frame mode results in the Tool producing low quality images.

While we are fixing this for a future update, please use Frame sequence mode to capture pixel-perfect comparison images.

Set the frame sequence to run for at least 10 frames either side of the frame you wish to capture. For example, if you want frame 500, set the frame sequence to frames 490 to 510 and use the middle frame for comparison.
RESULT SCREEN

The NVIDIA DLSS feature test produces two frame rate results.

- Average frame rate with DLSS off.
- Average frame rate with DLSS on.

Compare the two results to see how DLSS affects performance.

Hardware monitoring charts show the frame rate and other hardware metrics changed during the test.
The NVIDIA DLSS feature test uses the Port Royal engine with an additional DLSS integration. Please read the Port Royal engine section of this guide for more details.
# NVIDIA DLSS FEATURE TEST HISTORY

<table>
<thead>
<tr>
<th>VERSION</th>
<th>Windows</th>
<th>Android</th>
<th>Apple</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>✔</td>
<td>✗</td>
<td>✗</td>
<td>Updated to ensure compatibility with upcoming NVIDIA drivers.</td>
</tr>
<tr>
<td>1.0</td>
<td>✔</td>
<td>✗</td>
<td>✗</td>
<td>Launch version</td>
</tr>
</tbody>
</table>
STRESS TESTS

Stress testing is a useful way to check the reliability and stability of your system. It can also identify faulty hardware or a need for better cooling. The best time to run the stress test is after buying or building a new PC, upgrading your graphics card, or overclocking your GPU.

If your GPU crashes, hangs, or produces visual artifacts during the test, it may indicate a reliability or stability problem. If it overheats and shuts down, you may need more cooling in your computer.

Stress Tests are not available in 3DMark Basic Edition or the Steam demo.
OPTIONS

Test Selection

Use this drop down menu to choose which Stress Test to run. 3DMark offers many tests, each designed for a specific class of hardware. You should use the test most suited to the system you are testing.

⚠ Note that Fire Strike Ultra requires at least 3 GB of dedicated video card memory. A crash on a system that does not meet this requirement is not a sign of a hardware stability problem.

Number of loops

In 3DMark Professional Edition, you can use this option to set the number of loops for the test. The minimum number of loops is 2. The maximum is 5000. You can stop the test at any time by pressing the ESC key.

Enable window mode

In 3DMark Professional Edition, use this option to run the test in a window.
**TECHNICAL DETAILS**

The aim of stress testing is to place a high load on the system for an extended period of time to expose any problems with stability or cooling capability.

3DMark Stress Tests work by looping a benchmark graphics test continuously without pausing for loading screens or other breaks. A Stress Test takes around 20 minutes to run when set to the default 20 loops, which is usually enough to find any significant stability or cooling issues.

<table>
<thead>
<tr>
<th>STRESS TEST</th>
<th>TARGET HARDWARE</th>
<th>ENGINE</th>
<th>RENDERING RESOLUTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>TIME Spy Extreme</td>
<td>PC systems designed for 4K gaming with DirectX 12</td>
<td>DirectX 12 feature level 11</td>
<td>3840 × 2160 (4K UHD)</td>
</tr>
<tr>
<td>TIME Spy</td>
<td>High-performance gaming PC running Windows 10</td>
<td>DirectX 12 feature level 11</td>
<td>2560 × 1440</td>
</tr>
<tr>
<td>Night Raid</td>
<td>PCs with integrated graphics</td>
<td>DirectX 12 feature level 11</td>
<td>1920 × 1080</td>
</tr>
<tr>
<td>Port Royal</td>
<td>Graphics cards supporting Microsoft DirectX Raytracing</td>
<td>DirectX 12, feature level 12.1, DirectX Raytracing API</td>
<td>2560 × 1440</td>
</tr>
<tr>
<td>Fire Strike Ultra</td>
<td>PC systems designed for 4K gaming</td>
<td>DirectX 11 feature level 11</td>
<td>3840 × 2160 (4K UHD)</td>
</tr>
<tr>
<td>Fire Strike Extreme</td>
<td>Multi-GPU systems and overclocked PCs</td>
<td>DirectX 11 feature level 11</td>
<td>2560 × 1440</td>
</tr>
<tr>
<td>Fire Strike</td>
<td>High-performance gaming PCs</td>
<td>DirectX 11 feature level 11</td>
<td>1920 × 1080</td>
</tr>
<tr>
<td>Sky Diver</td>
<td>Gaming laptops and mid-range PCs</td>
<td>DirectX 11 feature level 11</td>
<td>1920 × 1080</td>
</tr>
</tbody>
</table>
SCORING

The main result from the Stress Test is the system's Frame Rate Stability expressed as a percentage.

\[
Frame Rate Stability = \frac{fpsLow}{fpsHigh} \times 100
\]

Where:

- \(fpsHigh\) = The average frame rate from the best performing loop of the test.
- \(fpsLow\) = The average frame rate from the worst performing loop of the test.

A high score means your PC's performance under load is stable and consistent. To pass the test, your system's frame rate stability must be at least 97% and all loops must be completed.

In the example below, the system failed the test because its average frame rate dropped noticeably after the GPU reaches its peak temperature.
HOW TO REPORT SCORES

3DMark includes many tests, each designed for a specific type of hardware. Make sure you use the most appropriate test for the hardware's capabilities.

Each test gives its own score, which you can use to compare similar systems. There is no overall 3DMark score. Scores from different tests are not comparable. Do not use 3DMark as a unit of measurement.

✓ "Video card scores 10,000 in 3DMark Fire Strike benchmark."
✗ "Video card scores 10,000 3DMarks."

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.

World record scores

UL's Hall of Fame is the only source of official 3DMark world record scores. You should not present scores from any other website or leaderboard as world records. In those cases we suggest using alternative wording such as:

"Video card takes the number one spot on [website] leaderboard."

Using 3DMark scores in reviews

We provide established and reputable publications with complimentary Professional Edition benchmarks. Contact us at UL.BenchmarkPress@ul.com to request keys for your publication.

Press can use our benchmark scores in their hardware reviews. Please include a link to https://benchmarks.ul.com/ whenever you use our benchmarks in a review, feature, or news story.

Using 3DMark scores in marketing material

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On the first mention of 3DMark in marketing text, such as an advertisement or product brochure, please write "3DMark benchmark" to protect our trademark. For example:

"We recommend 3DMark® benchmarks from UL."

Please include our legal text in your small print.

3DMark® is a registered trademark of Futuremark Corporation.
RELEASE NOTES

3DMark Windows v2.10.6799 – September 25, 2019
This is a minor update. Benchmark scores are not affected.

Fixed
• Fixed an issue with the Install button not installing test DLCs on Steam.

3DMark Windows v2.10.6797 – September 24, 2019
This is a minor update. Benchmark scores are not affected.

Fixed
• Fixed the upgrade button links in 3DMark Basic Edition and the 3DMark Demo on Steam.

3DMark Windows v2.10.6771 – September 5, 2019
This is a minor update. Benchmark scores are not affected.

Fixed
• Fixed a bug that prevented the Time Spy Stress Test from starting.

3DMark Windows v2.10.6762 – September 3, 2019
This is a minor update. Benchmark scores are not affected.

Fixed
• Fixed a rare issue in the Time Spy test.
• Fixed a folder permission issue when running Time Spy.

3DMark Windows v2.10.6751 – August 26, 2019
This major update adds the VRS feature test, a new test for comparing performance and image quality when using Tier 1 Variable-Rate Shading.

New
• VRS feature test.

Fixed
• Fixed a rare issue in the Night Raid test. Benchmark scores are not affected.
3DMark Windows v2.9.6631 – June 25, 2019
This major update adds the PCI Express feature test, a new test for measuring the bandwidth available to your GPU over your computer's PCI Express interface.

New
• PCI Express feature test.

3DMark Windows v2.8.6578 – June 6, 2019
This is a minor update. Benchmark scores are not affected.

Compatibility
• Updated DirectX 12 resource handling in Port Royal to improve compatibility with upcoming hardware and drivers.

Fixed
• Improved presentation of benchmark results when using custom run settings.

3DMark Windows v2.8.6572 – April 20, 2019
This is a minor update. Benchmark scores are not affected.

Improved
• Improved presentation of benchmark results when using custom run settings.
• License key check is no longer case-sensitive.

WeGame
3DMark Advanced Edition:
• Released 3DMark Advanced Edition as a new title in WeGame.

3DMark Experience Edition:
• Now includes the same free benchmark tests as 3DMark Basic Edition and the Steam Demo.
• Home screen now recommends the most suitable free test for your PC.
• The in-app Hall of Fame now includes hardware details.
• Removed the in-app option to purchase 3DMark Advanced Edition.

3DMark Windows v2.8.6546 – March 15, 2019
This is a minor update. Benchmark scores are not affected.
WeGame

• 3DMark now recommends the free Night Raid test on the Home screen to users who have not bought benchmark runs or a full license. If your PC cannot run Night Raid, 3DMark will recommend the best test for your system. Note that all tests other than Night Raid require a paid license.

Fixed

• Fixed an issue that could cause an error after clicking "Update all" on the update prompt when both Port Royal benchmark and NVIDIA DLSS feature test require an update.

3DMark Windows v2.8.6536 – March 12, 2019

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

Improved

• Improved license handling when unregistering 3DMark Advanced Edition.

Fixed

• The language selection dropdown again shows all available languages.
• Fixed a rare issue that could occur when looping a test with custom settings over an extended period.

WeGame

• The default value for buying individual runs is now 1 instead of 3.

3DMark Windows v2.8.6528 – March 11, 2019

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

Compatibility

• Updated the Port Royal benchmark and NVIDIA DLSS feature test to ensure compatibility with upcoming NVIDIA drivers.
• 3DMark will now warn and prevent you from installing to a path that contains non-Latin-alphabet characters.

Professional Edition

• Fixed a rare issue that could cause the UI to fail to process command line parameters.

3DMark Windows v2.8.6446 – February 12, 2019

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

- Improved the way the license information is shown on the Options screen.

Fixed

- Fixed a problem in the Steam version when trying to buy the Port Royal upgrade from the NVIDIA DLSS feature test screen.
- The API Overhead feature test no longer requires DirectX 12 to start. As in previous versions, it will now run on DirectX 11 systems and skip unsupported APIs.

Professional Edition

- The Image Quality Tool now renders frames from the NVIDIA DLSS feature test at the selected output resolution without rescaling to the desktop resolution.

3DMark Windows v2.8.6427 – February 4, 2019

This major update adds the NVIDIA DLSS feature test, a new test for comparing performance and image quality with and without DLSS processing.

New

- NVIDIA DLSS feature test.

Improved

- Redesigned Benchmarks screen adds new filters to help you find the best benchmarks for your testing requirements.

Fixed

- Port Royal v1.1 benchmark features improved multi-GPU support. Scores improve on multi-GPU systems.
- Fixed a file output issue in the Port Royal Image Quality Tool in 3DMark Professional Edition.

3DMark Windows v2.7.6296 – January 21, 2019

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

Port Royal benchmark

- Fixed a rendering issue that could cause visual artifacts at high resolutions.
- Reflections are now correctly masked by transparent surfaces.
• Fixed the rendering of surface elements when Transparents are disabled in the Custom run settings.
• Fixed the Enable Looping setting for Custom runs.
• Custom Demo runs now use ray traced photon mapping by default.

All benchmarks
• Improved algorithm for the recommended benchmark on the 3DMark Home screen.
• Fixed the Demo Audio setting on the Options screen.

3DMark Windows v2.7.6283 – January 8, 2019
This major update adds Port Royal, a new real-time ray tracing benchmark for graphics cards that support Microsoft DirectX Raytracing.

New
• Port Royal benchmark test.
• Port Royal Stress Test.

3DMark Windows v2.6.6238 – November 19, 2018
This is a minor update. Benchmark scores are not affected.

Improved
• Improved folder structure when installing to a custom location.

New
• Fixed the update notification system.

3DMark Windows v2.6. 6174 – October 8, 2018
This major update adds Night Raid, a new DirectX 12 benchmark for laptops, notebooks, tablets and other mobile computing devices with integrated graphics. Night Raid also has native ARM support for the latest Always Connected PCs powered by Windows 10 on ARM.

New
• Night Raid benchmark test.
• Night Raid Stress Test.

Fixed
• Fixed the self-update notification system
Professional Edition only

- Fixed a rare issue that could cause 3DMark to fail when running a long stress test from the command line.

3DMark Windows v2.5.5029 – 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

- Improved stability when looping Fire Strike on a PC with Intel integrated graphics.
- Fixed an issue with logging that could cause a benchmark run to fail.

3DMark Windows v2.4.4264 – February 14, 2018

Improved

- Improved score validation checks. Result submits from previous versions will no longer be eligible for the 3DMark Hall of Fame.

3DMark Windows v2.4.4254 – February 5, 2018

Improved

- The installer is now available in Japanese, Korean, and Spanish.
- To meet our improved score validation checks, hardware monitoring information is now required for competitive submissions to the 3DMark Hall of Fame.

Fixed

- Restored the 3DMark splash screen when starting the application.
- Fixed a crash that could occur when the system returns unexpected values for the amount of video RAM.

3DMark Windows v2.4.4180 – December 21, 2017

New

- 3DMark is now available in Japanese, Korean, and Spanish.
- Choose your preferred language from the Options screen.
3DMark Windows v2.4.4163 – December 12, 2017

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

Improved

• Benchmark loading screen logos and labels are now consistent across all tests. You will need to update your DLC files, but this is purely a cosmetic change. Benchmark scores are not affected.
• Use the new "Update All" button to update all DLC files to the latest version.

Fixed

• Fixed an issue with the Vulkan part of the API Overhead feature test that was caused by a change in the Vulkan specification.
• Custom Run looping now works as intended again.
• Restored the missing sub-scores on the Fire Strike result screen.
• Fixed a rare issue that could cause Fire Strike, Cloud Gate, and Ice Storm tests to fail on a few specific Intel processors when using integrated graphics.
• Fixed an issue that could cause 3DMark to hang on the splash screen.

3DMark Windows 2.4.3819 – October 11, 2017

This major update adds Time Spy Extreme, a new DirectX 12 benchmark with a 4K rendering resolution. Time Spy Extreme is an ideal benchmark test for systems with the latest graphics cards and new processors with 8 or more cores. A 4K monitor is not required, but your graphics card must have at least 4 GB of memory.

Time Spy Extreme is available as a free update for 3DMark Advanced Edition and 3DMark Professional Edition licenses purchased after July 14, 2016. For copies bought before that date, Time Spy Extreme can be added to 3DMark by purchasing the Time Spy upgrade.

New

• Time Spy Extreme benchmark test, 4K gaming with DirectX 12.
• Time Spy Extreme Stress Test.

Fixed

• Time Spy Graphics Test 2 no longer reloads between passes when looping.
• Fixed a rare issue that could cause Time Spy to fail when starting the test from a script or other background process.
• Fixed an issue in the API Overhead feature test that caused the Vulkan part to fail on Intel integrated GPUs when using non-native resolutions.

3DMark Windows 2.4.3802 – October 2, 2017
Pre-release preview of Time Spy Extreme for press publications.

3DMark Windows 2.3.3732– June 14, 2017
This is a minor update. Benchmark scores are not affected.

Fixed
• Various minor bug fixes to improve compatibility and stability.
• Fixed an issue with the shader cache that could, in rare cases, cause a crash.

3DMark Windows 2.3.3682– April 6, 2017
This is a minor update. Benchmark scores are not affected.

Fixed
• Fixed an issue that could cause the API Overhead feature test to fail at the end of the DirectX 12 test on some systems.

3DMark Windows v2.3.3663 – March 23, 2017
This is a major update that adds Vulkan support to the API Overhead feature test. Benchmark scores are not affected with the exception of API Overhead feature test, which now produces scores for Vulkan instead of Mantle.

New
• Added Vulkan support to the API Overhead feature test. Use the API Overhead feature test to compare Vulkan, DirectX 12, and DirectX 11 API performance on your PC. The Vulkan test requires compatible video drivers with Vulkan support. Check with your GPU vendor for Vulkan driver support if your hardware is unable to run the test. Note that the Vulkan test replaces the Mantle test found in previous versions of 3DMark.

Improved
• SystemInfo scan time greatly improved on X99 systems.

Fixed
• Fixed an issue that could cause the API Overhead feature test to fail to show a score at the end of an otherwise normal run on some systems.
• Fixed Time Spy test to properly recover from a corrupted shader cache - if runtime compiled shaders are found to be corrupted, they are deleted and recompiled. Uninstallation also now completely removes the shader cache folder.

• Fixed a scaling issue that could cause parts of the UI to end up outside the display area on 1080p monitors with 150% DPI scaling. UI will now scale appropriately even on high DPI scaling settings.

Professional Edition
• Fixed an issue that could cause the Command Line interface to refuse to work after registering a Time Spy Professional Edition key with an expiration date.

3DMark Windows v2.2.3509 – December 15, 2016
This update fixes a GUI issue that resulted in marginally lower than expected scores when starting a test from the Benchmark Details screen in 3DMark versions 2.1.2852 and later. Benchmark runs started from the Home screen or the Command Line were not affected.

It is normal for 3DMark scores to vary by up to 3% between runs since there are factors in a modern, multitasking operating system that cannot be completely controlled.

With this update, overall scores are expected to increase by up to 0.3%. Scores from the Physics and CPU parts of benchmark tests may improve by up to 2.5%. Scores from this version of 3DMark are consistent with results from previous versions that did not have the GUI issue.

Compatibility
• Added a two-minute timeout to the SystemInfo scan to prevent it from stalling for long periods on some specific systems.

3DMark Windows v2.2.3491 – December 10, 2016
This is a minor update. Benchmark scores are not affected.

Fixed
• Fixed an issue with the output resolution setting on the Option screen.

3DMark Windows v2.2.3488 – December 9, 2016
This is a minor update. Benchmark scores are not affected.
Improved

- 3DMark now warns you when vsync, FreeSync, or G-SYNC is enabled. For accurate results, you should disable these features in your video driver settings before benchmarking.

Fixed

- Fixed a SystemInfo timing issue that most commonly affected systems with the X99 chipset. 3DMark now waits for the SystemInfo scan to finish before starting the test.
- Fixed a rare issue that could cause the UI to open on an empty white window.

VRMark Preview

VRMark is now available from futuremark.com and Steam. You can still install and run the VRMark Preview in 3DMark, but it is no longer recommended or supported.

- Moved the Preview from the main navigation bar to the Benchmarks screen.
- Added an uninstall button to the VRMark Preview screen.

3DMark Windows v2.1.2973 – August 19, 2016

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

Fixed

- Updating 3DMark from within the app will now properly close previous versions before applying the update.

3DMark Windows v v2.1.2969 – August 18, 2016

This is a minor update to fix problems reported by some users. Benchmark scores are not affected with one exception - see the section about Fire Strike Custom runs below for details.

Improved

- SystemInfo module updated to 4.48 for improved compatibility with the latest hardware.
- The video RAM check that warns if your system may not be able to run a test now accepts extra main RAM beyond the minimum requirement as VRAM for integrated graphics.
- We've added a DETAILS button to the panel for the Recommended test on the Benchmarks screen to make it easier to find more information...
and the settings for the test. This is also where you find the option to enable or disable the demo for each test.

**Fixed Fire Strike Custom run settings**

Unfortunately, the previous version (3DMark v2.1.2852) used an incorrect setting for Fire Strike Custom runs that resulted in slightly lower than expected scores. Fire Strike Custom run results from the previous version should not be compared with this latest version nor with any other version of 3DMark. The standard Fire Strike benchmark run was not affected, nor were Fire Strike Extreme and Fire Strike Ultra.

- Restored the control for volumetric illumination sample count setting on the Fire Strike Custom run screen, which was missing in the previous version.
- Fixed the default value for volumetric illumination sample count for Fire Strike Custom runs. In 3DMark v2.1.2852, Fire Strike Custom run used an incorrect default setting of 1.5. This has been reverted to 1.0, which is the correct value for the test.

**Standalone version fixes**

- Fixed an issue that caused installation to fail if the unzipped installer content resided in a path that included a folder name with a space.
- Fixed an issue that could prevent the in-app update from working properly. If you are affected by this issue and cannot update 3DMark from within the app, you should download the full installer.

**Steam version fixes**

- Fixed a problem that could cause 3DMark to appear to be still running in the Steam client after exiting, which then blocked Steam from closing.
- Fixed an issue that prevented DLCS from installing into a custom Steam library folder when the folder name included a space.

**Other fixes**

- Fixed an issue that prevented Sky Diver from starting on 32-bit Windows.
- Fixed an issue that caused Time Spy to crash when scaling mode was set to Stretched.
- Fixed an issue that could cause result parsing to fail on complex systems with lots of devices due to the unusually large data set generated by the SystemInfo scan.

**Known Issues**

- Time Spy fails to run on multi-GPU systems with Windows 10 build 10240, but this is not the fault of the benchmark. You must upgrade
Windows 10 to build 10586 ("November Update") or later to enable multi-GPU configurations to work.

- Installing the standalone version and the DLC test data to the same folder is not a supported configuration. The latest version will prevent you from installing both to the same folder. If you currently have 3DMark and the DLC test data installed to the same custom folder you will need to uninstall 3DMark then reinstall the latest version using the full installer.

3DMark Windows v2.1.2852 – July 14, 2016

This major update adds Time Spy, a new DirectX 12 benchmark test. With its pure DirectX 12 engine, which supports new API features like asynchronous compute, explicit linked multi-adapter, and multi-threading, 3DMark Time Spy is the ideal benchmark for testing the DirectX 12 performance of the latest graphics cards.

New

- Added Time Spy Stress Test - a new dedicated Stress Test for high-performing PCs running on Windows 10. Time Spy Stress Test is not available in 3DMark Basic Edition or 3DMark Time Spy upgrade in Steam.

Fixed

- Fixed an issue that could cause all Stress Test runs to end with 0% score.
- Fixed an issue that could prevent self-update from working (standalone version only). If you are running 3DMark 2.0.2724 or 2.0.2809 Advanced Edition, you need to download and install the full 2.1 installer to update.

3DMark Windows v2.0.2809 - July 12, 2016

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

Fixed

- Fixed further compatibility issues with the Steam launcher and some specific operating system configurations that could cause the 64-bit version to refuse to start.
- Fixed an issue with result file processing that could cause the benchmark to hang with a black screen at the end of a demo or test on some systems.

3DMark Windows v2.0.2724 - July 4, 2016

This is a minor update that fixes several compatibility issues. Benchmark scores are not affected.
Improved

- SystemInfo module updated to 4.47 for improved compatibility with the latest hardware.

Fixed

- Fixed an issue that could cause the Sky Diver Stress Test to hang on a white screen on very fast systems.
- Fixed an issue that prevented 3DMark from installing on Windows 7 if UAC was disabled. You can now click 'Ignore' on the warning to continue the installation.
- Fixed compatibility issues with the Steam launcher and some specific operating system configurations that could cause the 64-bit version to refuse to start.
- Fixed an issue that could cause the benchmark to fail if your Windows user folder name contained UTF-8 characters.


This major update adds new Stress Tests for checking the stability of your PC.

New

- Use the new Stress Tests to check the stability of your system after buying or building a new PC, upgrading your graphics card, or overclocking your GPU. Stress testing can help you identify faulty hardware or the need for better cooling. Stress Tests are not available in 3DMark Basic Edition or the Steam demo.

Improved

- SystemInfo module updated to 4.46 for improved hardware detection.
- Reintroduced the option to set up a Custom run using only the Demo.

Fixed

- Fixed an issue that could cause 3DMark to fail to install test DLC files.

3DMark Windows v2.0.2067 - April 15, 2016

This minor update fixes a few issues that came to light after the v2.0.1979 release on April 6. Benchmark scores are unaffected.

Fixed

- SystemInfo module updated to 4.45 to fix a compatibility issue with Russian and Chinese language versions of Windows.
• Fixed the Unicode compatibility issue with Russian and Chinese language versions of Windows.
• Fixed the white screen issue when installing 3DMark under a NTFS Junction or Mount Point.
• Fixed the missing button text issue affecting a small number of users.

Improved
• Updated Russian localization.

3DMark Windows v2.0.1979 – April 6, 2016
This is a major update that adds a redesigned UI for all editions and a preview of VRMark for Advanced and Professional Edition users.

New
• 3DMark UI has been redesigned and rebuilt to be faster and more flexible.
• Home screen recommends the best test based on your system details.
• Run other benchmarks and feature tests from the Benchmarks screen.
• Russian localization.

Improved
• Each benchmark test can now be updated independently.
• Ice Storm Extreme and Ice Storm Unlimited are unlocked in 3DMark Basic Edition.
• SystemInfo module updated to 4.43 for improved hardware detection.

VRMark preview
• Explore two test scenes in a preview of VRMark, our new benchmark for VR systems. The preview does not produce a score.
• The preview is not available in 3DMark Basic Edition or the Steam demo.

Fixed
• Workaround for the AMD driver issue where the preview videos in the UI caused some AMD graphics cards to use low power mode and run at lower clock speeds.

3DMark Windows v1.5.915 – June 5, 2015
This is a minor update. Benchmark scores are unaffected. Note that while Windows 10 is in development there may be unforeseeable compatibility problems with some hardware configurations.
Improved

- SystemInfo module updated to 4.39 for improved detection of upcoming hardware from AMD and Intel.

Compatibility

- API Overhead feature test updated to work with Windows 10 Technical Preview build 10130.

Known issues

- AMD Catalyst Driver 15.200.1023.5 for Windows 10 has an issue that prevents the DirectX 12 API Overhead test from working on Radeon R9 280, Radeon HD 79xx series, and Radeon HD 78xx series graphics cards. We expect AMD to fix the issue with its next driver update.
- Intel HD Graphics Driver 10.18.15.4204 for Windows 10 does not appear to have working full screen DirectX 12 support. We are investigating this issue for a future update.

3DMark Windows v1.5.893 – April 24, 2015

This is a minor update. Benchmark scores are unaffected.

Compatibility

- Fixed a bug that could cause the API Overhead feature test to hang on Windows 10 Technical Preview build 10061.

Steam version only

- Fixed an issue that prevented Steam Achievements from being unlocked.

3DMark Windows v1.5.884 - March 26, 2015

This major update adds the API Overhead feature test, the world’s first independent test for comparing the performance of DirectX 12, Mantle, and DirectX 11. See how many draw calls your PC can handle with each API before the frame rate drops below 30 FPS.

New

- Added Feature Test selection screen.

Improved

- Improved formatting of larger scores to make them more readable.
• Result screen automatically shows FPS after running a single test.

Fixed

• Fixed a bug that could cause the Sky Diver demo to hang at the cave entrance scene.

3DMark Windows v1.4.828 - December 1, 2014
This is a minor update. Benchmark scores are unaffected.

Improved

• SystemInfo module updated to 4.32 for improved hardware detection.
• Reduced hardware monitoring overhead (was already negligible).
• Product key is no longer visible on the Help tab unless you choose to reveal it.

Fixed

• Fixed a memory access violation issue with Ice Storm and Cloud Gate that could occasionally cause crashes in stress testing scenarios.
• Letterboxed mode now retains 16:9 aspect ratio even when selecting a non-default Output Resolution on the Help tab.

Professional Edition only

• Fixed the "No outputs found on DXGI adapter" issue in the Command Line application affecting laptops with NVIDIA Optimus graphics switching technology.
• Fixed custom_x.3dmdef files to use the centered scaling mode by default.
• You can now change the scaling mode from a .3dmdef file and via command line.

3DMark Windows v1.4.780 - October 23, 2014
This is a minor update. Benchmark scores are unaffected.

Fixed

• Fixed the "No outputs found on DXGI adapter" issue affecting laptops with NVIDIA Optimus graphics switching technology.

3DMark Windows v1.4.778 - October 14, 2014
This is a minor update. Benchmark scores are unaffected.
Fixed
• Fixed the "Workload Single init returned error message: bad lexical cast" issue affecting some systems.

3DMark Windows v1.4.775 - October 13, 2014
This is a major update that adds Fire Strike Ultra, the world's first 4K Ultra HD benchmark. Fire Strike Ultra is available in 3DMark Advanced Edition and 3DMark Professional Edition.

New
• Added Fire Strike Ultra, a new 4K Ultra HD benchmark test. You don't need a 4K monitor to run Fire Strike Ultra, though you will need a GPU with at least 3 GB of dedicated memory.

Improved
• New design for main benchmark selection screen.
• Improved benchmark logging to assist customer support.

Fixed
• 3DMark is now more robust when there is a problem identifying or monitoring the hardware in the system.

Professional Edition only
• You can now set command line options within .3dmdef files.
• Minor syntax changes to the .3dmdef definition files. You may need to update your existing scripts if using automation. See Command Line Guide for details.
• Added command line logging options.
• Command line progress logging now includes workload names and loop numbers.
• Removed empty log lines from command line output.

3DMark Windows v1.3.708 – June 11, 2014
This update adds Sky Diver, a new DirectX 11 benchmark for gaming laptops and mid-range PCs. Sky Diver is ideal for testing systems with mainstream graphics cards, mobile GPUs, integrated graphics and other DirectX 11 hardware that cannot achieve double-digit frame rates in Fire Strike.

Improved
• You can now run benchmarks individually in 3DMark Basic Edition.
• SystemInfo module updated to 4.29 for improved hardware detection.
Compatibility

• On Windows 7, Service Pack 1 is required for 3DMark version 1.3.708 onwards.

Professional Edition only

• The filenames of the .3dmddef definition files used for running 3DMark from the command line have changed with this release. You may need to update your existing scripts if using automation.

3DMark Windows v1.2.362 - March 12, 2014

Improved

• Improved reliability when submitting results over an internet connection with very high latency.
• SystemInfo module updated to 4.26 for improved hardware detection.

Fixed

• DirectX 10 level video cards no longer attempt to run the Fire Strike benchmark.
• Fixed a rare issue that could corrupt the saved product key.

Steam version only

• Fixed a bug that prevented Steam Achievements from being unlocked.
• Fixed a rare issue with results not always being associated with a Steam ID.

Professional Edition only

• Fixed an issue with command line XML export of Ice Storm scores.

3DMark Windows v1.2.250 – December 10, 2013

New

• Added Ice Storm Unlimited test enabling comparison of Windows 8 tablets with the latest Android and iOS devices.

Improved

• 3DMark now uses technology provided by TechPowerUp for improved GPU hardware detection.

Fixed

• Hardware monitoring performance graphs show clock speeds and temperatures for the CPU and GPU again (with compatible hardware).
Tests

- Ice Storm updated to version 1.2

3DMark Windows Edition v1.1.0 – May 6, 2013

This update fixes issues when testing systems with multiple GPUs. Fire Strike and Fire Strike Extreme scores will increase slightly on systems with two GPUs and significantly on systems with three or four GPUs.

New

- Added Ice Storm Extreme benchmark to 3DMark Advanced and Professional Editions.

Fixed

- 3DMark now works correctly on systems with up to four GPUs.
- Fixed the issue caused by Windows update KB2670838, which added partial DX11.1 support to Windows 7.
- Fixed a problem with the bloom post-processing effect when using very high rendering resolutions in custom settings.

Tests

- Ice Storm updated to version 1.1.0
- Cloud Gate updated to version 1.1.0
- Fire Strike updated to version 1.1.0

3DMark Windows Editions v1.0.0 – February 4, 2013

- Launch version.

Tests

- Ice Storm version 1.0.0
- Cloud Gate version 1.0.0
- Fire Strike version 1.0.0
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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 Germany, China and Taiwan.

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