3DMARK®

Technical Guide

Updated July 7, 2020

3DMARK – THE GAMER'S BENCHMARK

3DMark is a popular benchmarking app that helps you test and compare the performance of smartphones and tablets.

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.

At the end of the test, you get a score, which you can use to compare models. Be sure to use the most appropriate test for the device's capabilities and report your results using the full name of the benchmark, for example:

✓ " Smartphone scores 2,000 in the 3DMark Sling Shot Extreme benchmark."
× "The smartphone scores 2,800 in 3DMark."

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.

More than a score

3DMark is built around data-driven stories that help you learn more about your smartphone and tablet. With its unique charts, lists, and rankings, 3DMark gives you unrivalled insight into the performance of your device.

The right test every time

We've made it easy to find the right test for your device. When you open the app, 3DMark will recommend the best benchmark for your model.

Choose your tests

3DMark grows bigger every year with new tests. To save storage space and minimize download times, you can choose which tests you want to install.

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 model.

BENCHMARK	TARGET HARDWARE	ENGINE	RENDERING RESOLUTION[1]
SLING SHOT EXTREME	High-end smartphones and tablets	OpenGL ES 3.1 Metal	2560 × 1440
SLING SHOT	Mainstream smartphones and tablets	OpenGL ES 3.0	1920 × 1080

[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.

TEST COMPATIBILITY

	WINDOWS	ANDROID	IOS
SLING SHOT EXTREME	×	•	•
SLING SHOT	×	•	•
API OVERHEAD	•	•	•

LEGACY BENCHMARK TESTS

Benchmarks have a natural lifespan that ends when they no longer provide meaningful results on modern hardware.

When old benchmarks are used with new hardware, the results can be skewed or limited in ways that reduce their accuracy and relevance.

3DMark Ice Storm

Support for 3DMark Ice Storm benchmarks ended on January 14, 2020.

Ice Storm and Ice Storm Extreme are OpenGL ES 2.0 benchmarks that were released in 2013. They were originally designed for testing and comparing mainstream tablets and mobile devices. We now recommend 3DMark Sling Shot for benchmarking the latest Android devices.

LATEST VERSION NUMBERS

	WINDOWS	ANDROID	IOS
3DMARK APP	2.12.6964	2.0.4661	See table below
SLING SHOT USING OPENGL 3.0	×	2.4	2.2
SLING SHOT EXTREME USING OPENGL ES 3.1	×	2.4	2.2
SLING SHOT EXTREME USING VULKAN	×	3.1	×
API OVERHEAD	1.5	1.1	1.0

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

IOS APP	VERSION
3DMARK SLING SHOT	1.0.745
3DMARK API OVERHEAD	1.0.147

GOOD TESTING GUIDE

To get accurate and consistent benchmark results you should test clean devices without third party software installed. It is a good idea to close other apps that may be running in the background and disable notifications before running the benchmark.

Some high-powered mobile devices use thermal throttling to avoid overheating the CPU, which can lead to lower scores on successive runs. To reduce this effect, we recommended waiting 15 minutes before and after 3DMark runs to allow the device to cool down.

- Running other apps during the benchmark can affect the results.
- Don't touch the screen while running tests.
- You can cancel a test by pressing the Back Button.

Recommended process

1. Ensure your operating system is up to date.
2. Close other programs.
3. Run the benchmark.

Expert process

1. Ensure your operating system is up to date.
2. Restart the device.
3. Wait 2 minutes for startup to complete.
4. Close other app, including those running in the background.
5. Wait for 15 minutes.
6. Run the benchmark.
7. Repeat from step 3 at least three times to verify your results.

SUPPORTED LANGUAGES

The 3DMark Android app supports the following languages:

- English
- Simplified Chinese
- German
- Russian

You can change the language used in the 3DMark app by changing your device language from the main Android settings.

HOW TO USE THE 3DMARK APP

In December 2017, we released a completely redesigned app. The new app is built around data-driven stories that help you learn more about your smartphone or tablet. These stories provide you with a wealth of insights into the performance of your device, highlighting its strengths and showing you how it compares with other models.

The new app has four main sections, which you can move between using the navigation bar at the bottom of the screen.

- My tests
- My results
- My device
- Compare

Tutorial

After opening 3DMark on your device for the first time, a short tutorial will explain the four main parts of the app.

You can skip the tutorial by pressing **Skip** in the upper-right corner of the screen. You can open the tutorial again from the Settings screen.

Sharing your results

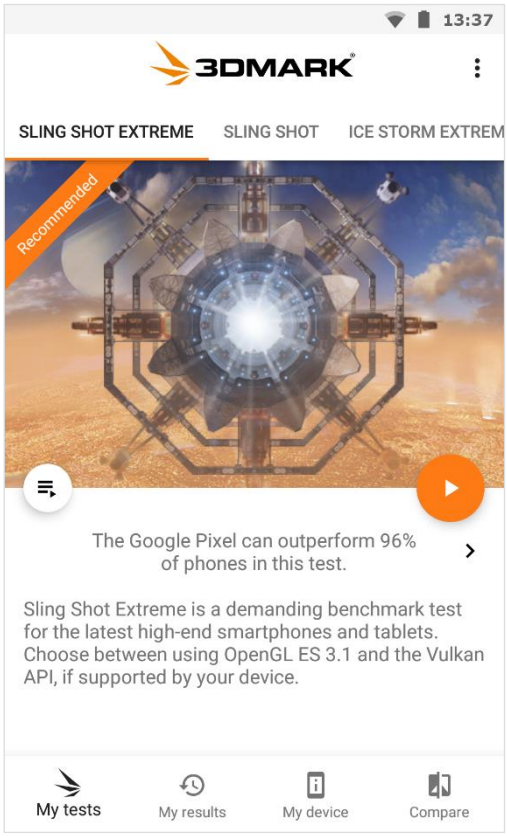
3DMark makes it easy to save and share your results, comparisons, charts, and many of the other screens in the app. Whenever you see the share icon, tap it to share an image of the current card.

MY TESTS

Choose and install your tests

There are several benchmark tests in 3DMark. Each one is designed for a specific class of device.

The recommended benchmark for your device appears first. Swipe left to see other tests. Your device may not be compatible with some tests. It may also be too powerful for others.



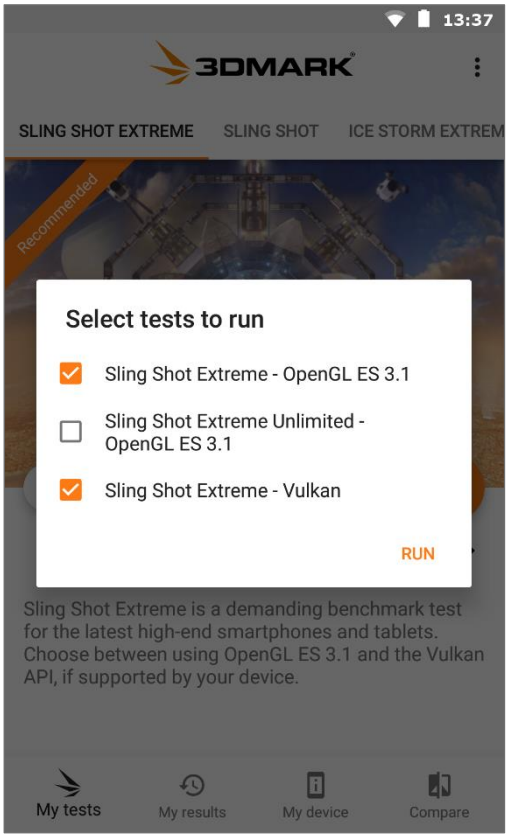
To save storage space and minimize download times, you can choose which tests you want to install.

Tests that are not installed have a monochrome image. To install a test, tap the orange download icon. After a test is installed, its image is shown in full color.

You can uninstall individual tests on the Settings screen. You won't lose your scores if you later decide to uninstall a test to free up some storage space.

Run your tests

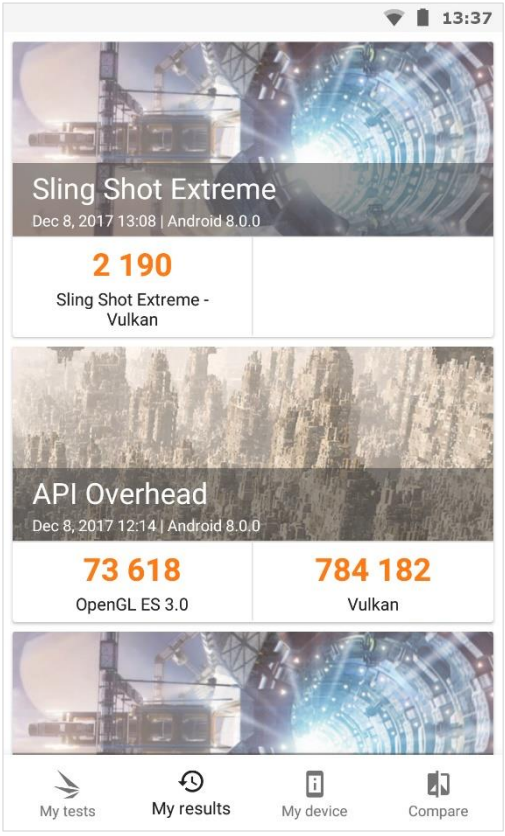
Some benchmarks have multiple versions. For example, Sling Shot Extreme has an OpenGL ES 3.1 version and a Vulkan version. Unlimited versions run off-screen. See later in this guide for details.

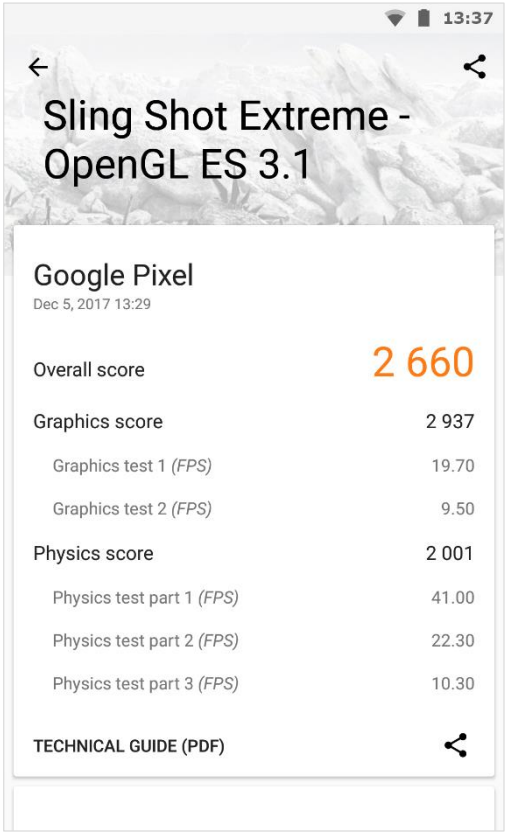


You can choose which versions to include in your run by tapping the gray icon on the left of the screen. Start your benchmark run by tapping **Run** on this screen or the orange **Run** button on the My Tests screen.

MY RESULTS

This screen lists all of your benchmark runs from your device. Tap on a result card to open it and see the detailed result view.





Detailed result view

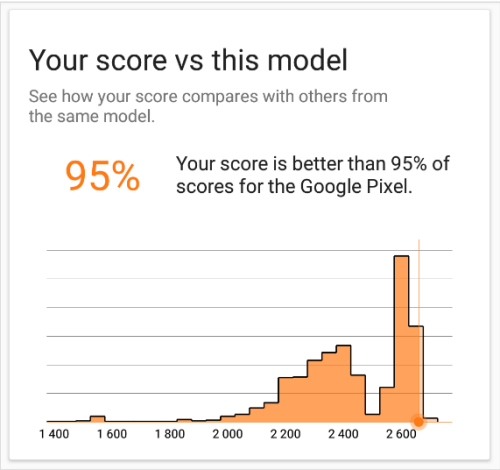
The first card in the detailed results view shows you your main score and sub-scores. See later in this guide for an explanation of how these scores are calculated.

3DMark also gives you much more. We use our extensive database of results to show you exactly where your device stands in terms of performance. Popular devices have tens of thousands of results from the real world, where 3DMark is often run under less than ideal conditions. These results provide a unique insight into your device's everyday performance outside of the test lab.

Your score vs this model

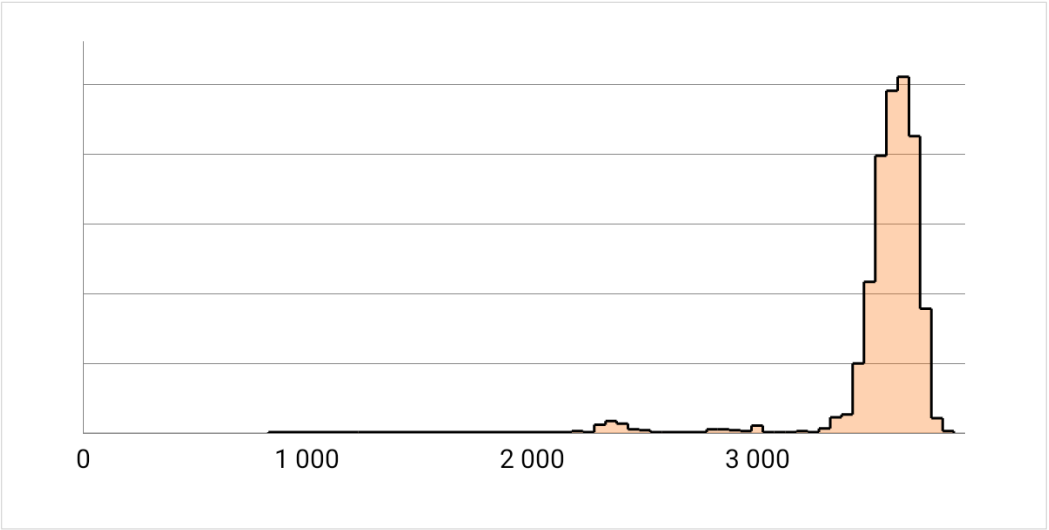
This card shows you how your score compares with others from the same model. It helps you answer the question, "Is my score a good score for this device?" and "Is my device performing properly?"

The chart shows the range of scores for your device. The peaks show the most common scores from other people with the same model.



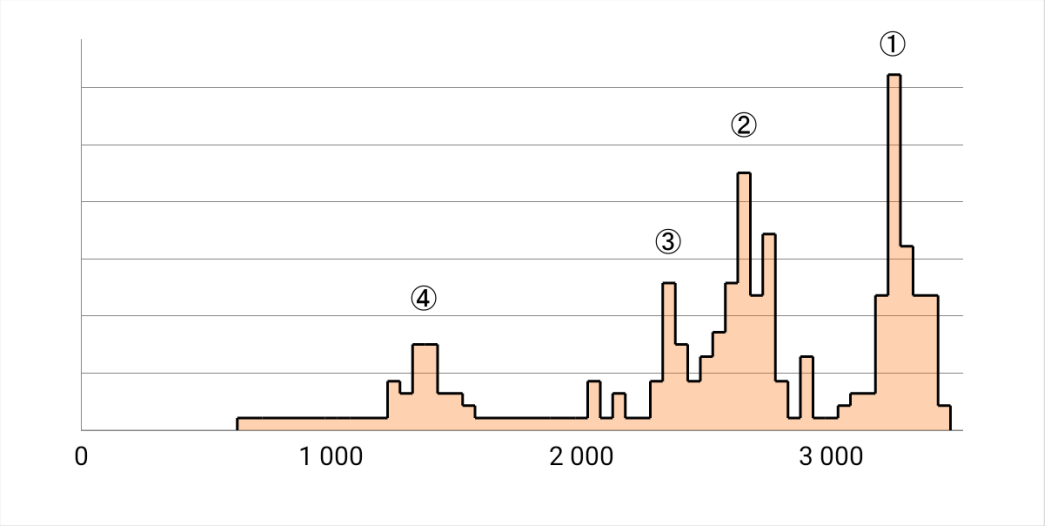
The shape of the chart tells you a lot about the performance of your device.

Looking at the chart below, for example, the peak shows the most common scores for the device. The higher the peak, the more results there are around that score value. In this case, you can see that all the results tend to fall in the same narrow range. This means the device performs consistently even when the benchmark is running under less than ideal conditions.



Score range for a device with consistent performance.

In the next chart, however, we see a different performance profile. There are four distinct peaks spread over a wide range of scores. A chart with this shape tells you that, even though the device can score nearly as well as the first device, it cannot perform to that level consistently in real-world use.



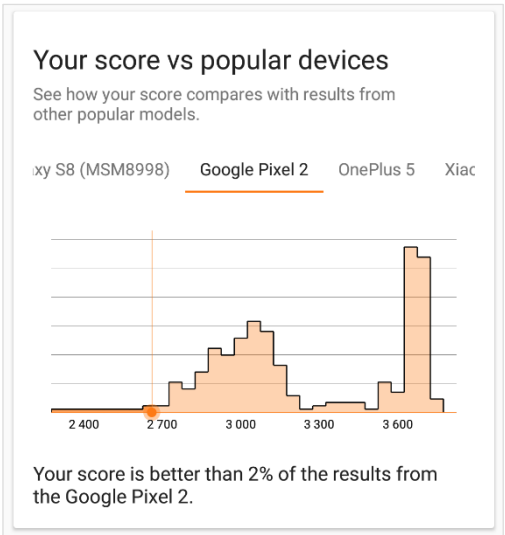
Score range for a device with inconsistent real-world performance.

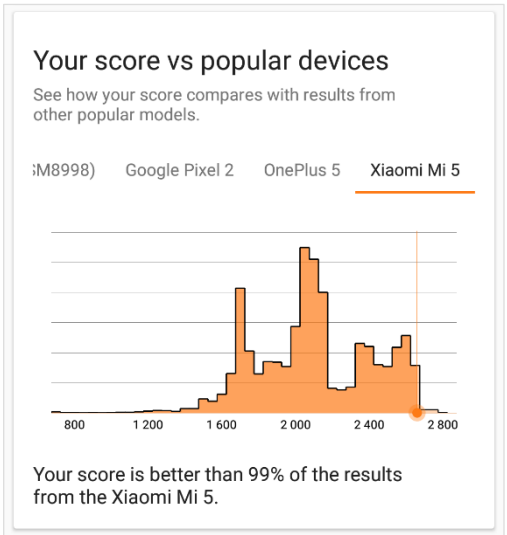
The rightmost peak (1) shows the score the device can achieve under ideal conditions. Peaks (2) and (3) tell you that this device slows down when hot or when multitasking. Many devices tend to reduce performance in steps, and those steps are visible in the chart. Lower scores may also come from devices running an older version of Android. The leftmost peak (4) shows you that the device's real-world performance can sometimes be far below the optimum.

These charts are available in the app for almost 5,000 smartphones and tablets. For each device, there is a separate chart for each benchmark test.

Your score vs popular devices

This card shows how your score compares with results from a selection of popular devices. Tap on a device above the chart to select it.





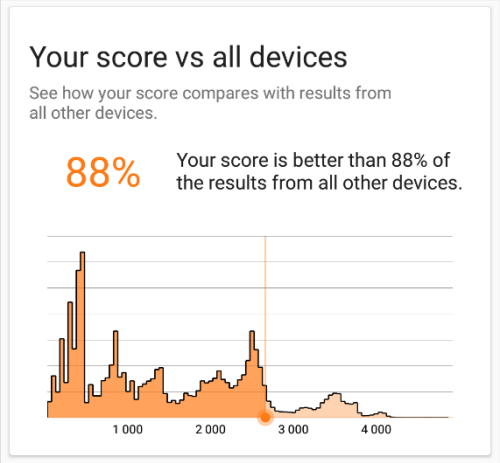
In the examples above, the user's device does not perform as well as the Google Pixel 2, but it scored higher than 99% of the results from the Xiaomi Mi 5.

This card is a useful way to see how older phones compare with the latest models. It can help you decide if it is worth upgrading.

Your score vs all devices

This card shows you how your score compares with the results from all other devices. It helps you understand where your device sits in the market from budget models on the left to high-end on the right.

As with the other charts, the peaks show the most common score ranges for the test. In this case, since the chart shows results from all devices, the peaks tend to mark the performance of the most popular SoC models.



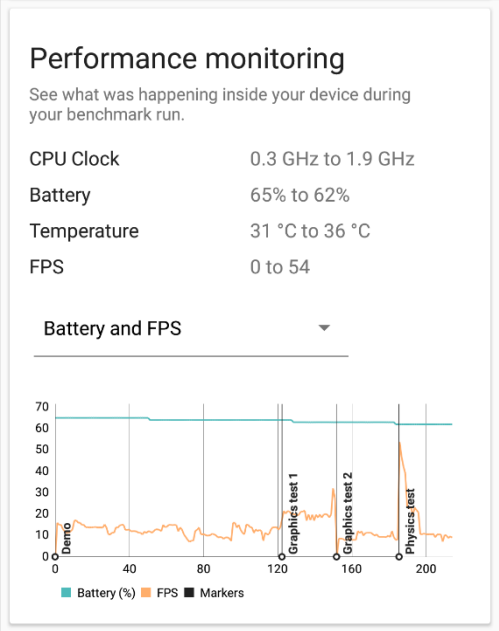
This card can be particularly helpful for seeing how older flagship phones compare with the latest models.

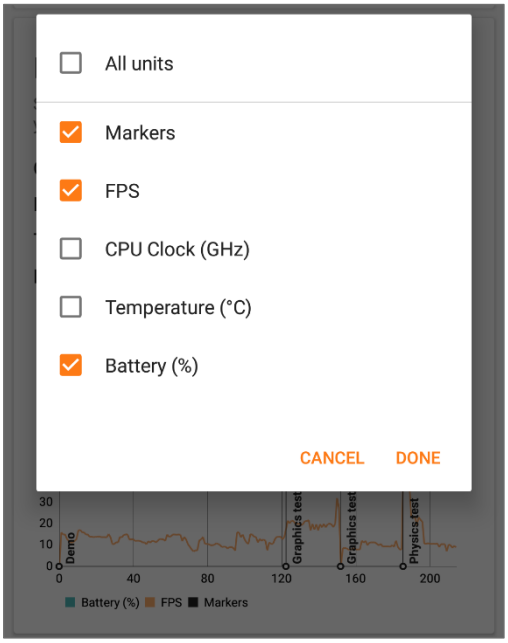
Performance monitoring

This card shows you what was happening inside your device during your benchmark run.

The data above the chart show the minimum and maximum values from your run. The chart shows you how those values changed during the run.

You can choose from a few preconfigured chart combinations, such as Battery and FPS, or create your own custom chart view.


Performance monitoring
See what was happening inside your device during your benchmark run.
CPU Clock 0.3 GHz to 1.9 GHz
Battery 65% to 62%
Temperature 31 °C to 36 °C
FPS 0 to 54
Battery and FPS
70
60
50
40
30
20
10
0
0
40
80
120
160
200
Demo
Graphics test 1
Graphics test 2
Physics test
Battery (%) FPS Markers


All units
Markers
FPS
CPU Clock (GHz)
Temperature (°C)
Battery (%)
CANCEL
DONE
30
20
10
0
0
40
80
120
160
200
Demo
Graphics test
Graphics test
Physics test
Battery (%) FPS Markers

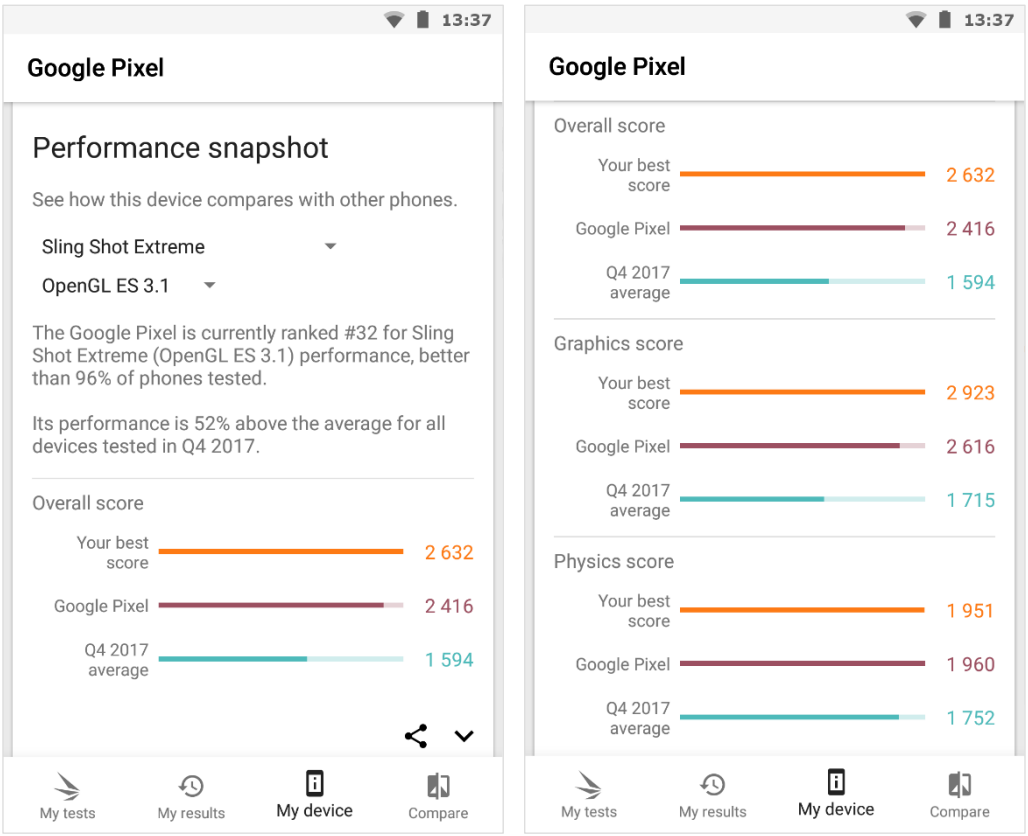
MY DEVICE

This part of the app helps you learn more about the performance of your device. It helps you answer questions like, "How does my device compare with the market?" and "Is my device sensitive to overheating?" and "How has the performance of my device changed with Android OS updates?" This section also lists the main specifications for your device.

Performance snapshot

This card tells you how your device ranks against other models and how it compares with the average score for all devices tested in the last quarter of the year.

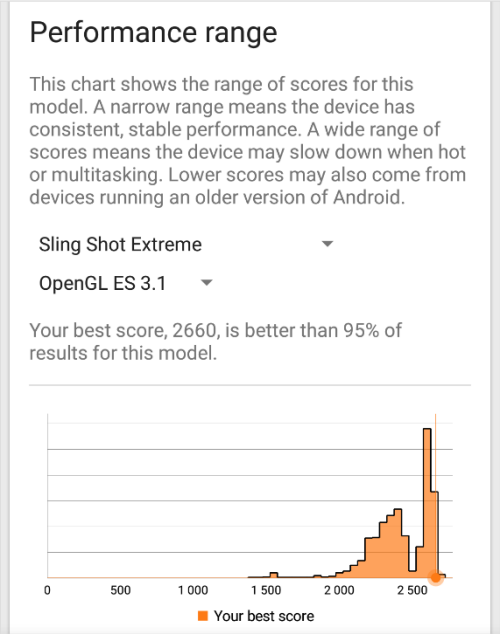
You can select different benchmark tests from the drop-down list. For some benchmarks, you can also choose the API. For example, Sling Shot Extreme has scores for OpenGL ES 3.1 and Vulkan APIs.



The Overall score chart shows how your best result compares with the average score for your model and with the average score from all devices tested in the last quarter. You can expand the card with the drop-down arrow to see the charts for the Graphics and Physics scores.

Performance range

Just like the charts in the detailed result view, the Performance Range chart shows the spread of scores for your device. The peaks show the most common scores from other people with the same model. You can also see how your best score for the test compares.



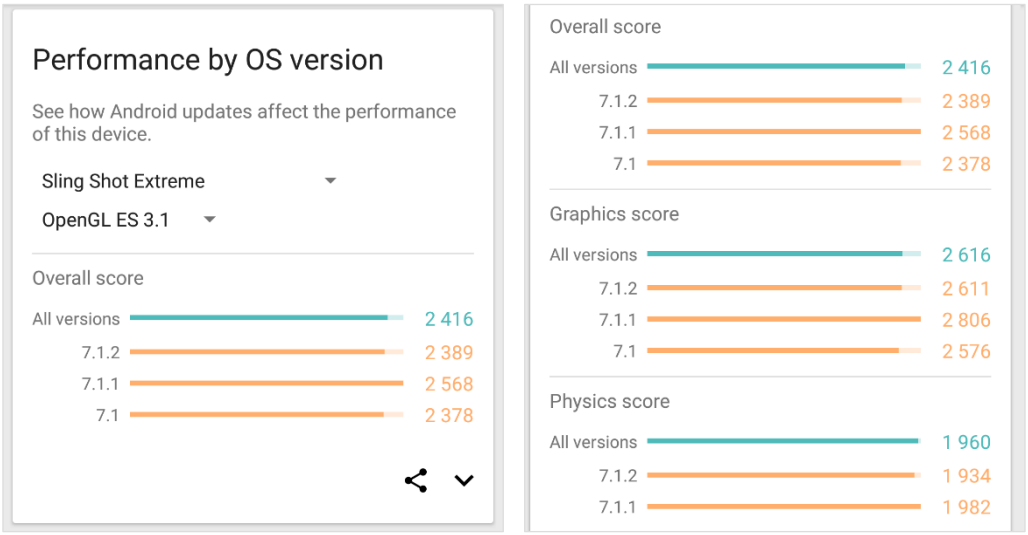
You can select different benchmark tests from the drop-down list. For some benchmarks, you can also choose the API.

The shape of the chart tells you a lot about the performance of your device. A narrow range means the device has consistent, stable performance. A wide range of scores means that the device may slow down when hot or multitasking. Lower scores may also come from devices running an older version of Android.

Performance by OS version

Android OS updates can breathe new life into older devices. New features and interface design changes can give a device a fresh, modern feel. Beneath the surface, driver optimizations and changes to the operating system can improve performance, stability, and battery life.

This card shows how Android OS updates have affected the performance of your device. The chart shows the average benchmark score for each OS version available for your device.



You can select different benchmark tests from the drop-down list. For some benchmarks, you can also choose the API. You can expand the card with the drop-down arrow to see the charts for the Graphics and Physics scores.

Specification

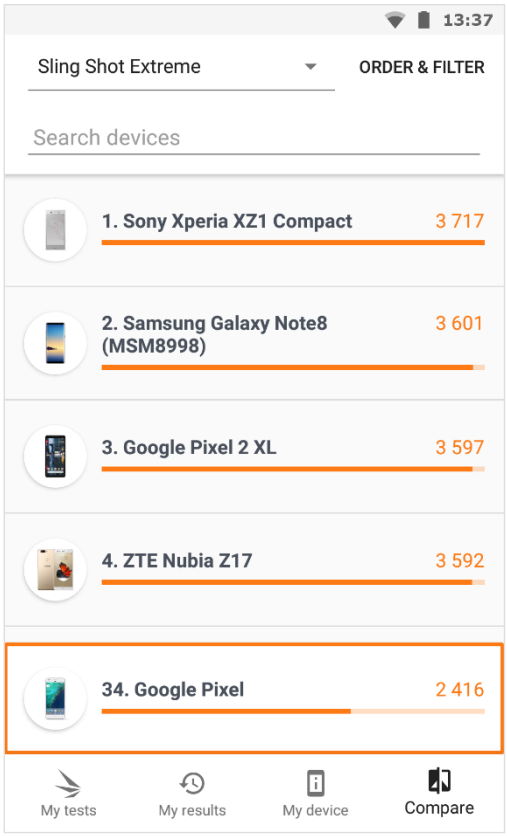
This card shows the main technical specifications of the device, from its hardware (SoC, CPU, GPU, RAM, storage) to screen (type, size, resolution) to physical properties (dimensions, weight) and much more, all on one screen.

COMPARE

This part of the app helps you choose a new phone or tablet by comparing the latest models. You can search, filter, and sort our list of the best devices. With performance data for almost 5,000 devices, it is easy to find and compare the best smartphone and tablets with 3DMark.

You can search for a device by name or by scrolling through the list. To make comparing easier, the average score and rank for your own device is always visible near the bottom of the screen.

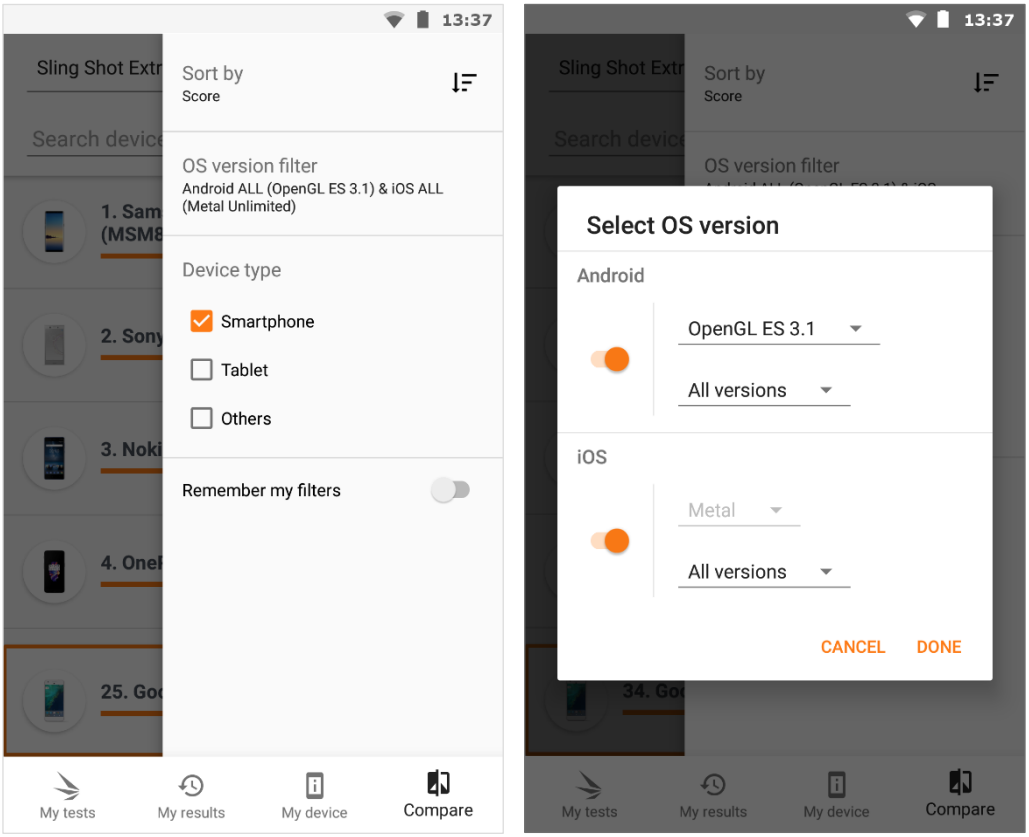
To find out more about a device, tap on its row to open a detailed view that is similar to the My Device screen.



Compare list options

There is a separate list for each benchmark. You can select the benchmark used for the list from the drop-down menu at the top-left of the screen.

Tap on **Order & Filter** to open an options menu for the list. From the top, you can choose to sort the list by **score** or alphabetically by device **name**. Tap the sort icon in the top-right to swap between ascending and descending order.

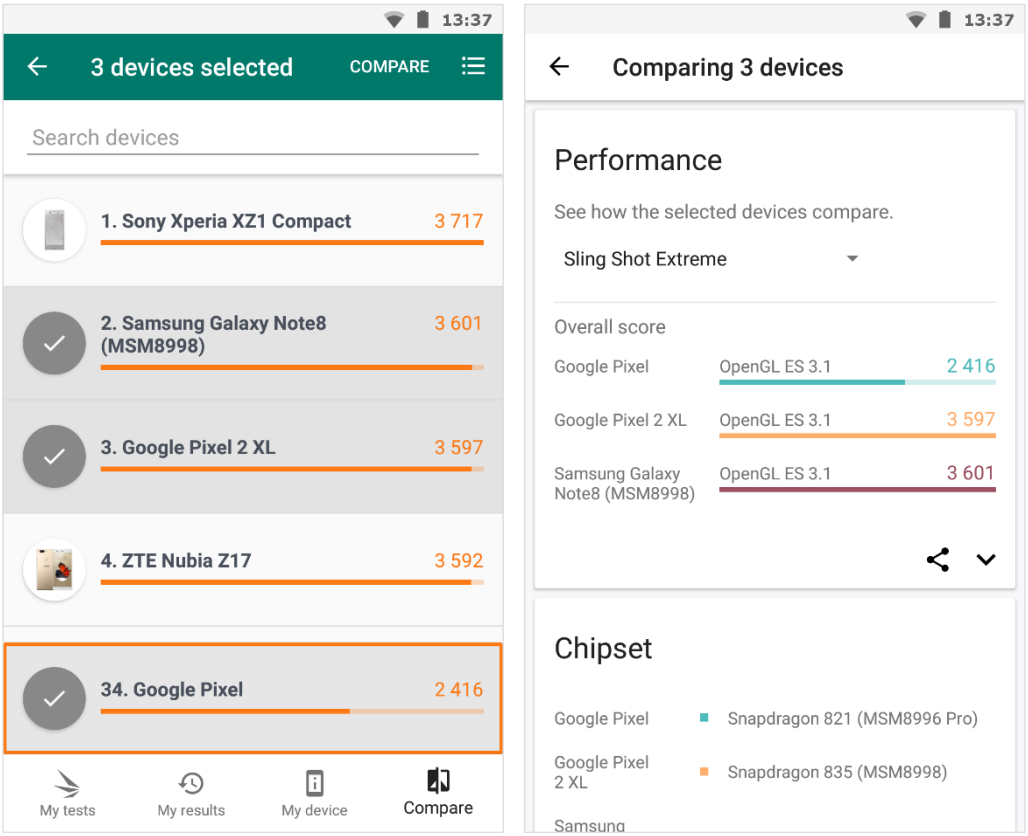


Tap on **OS version filter** to see additional options. You can choose to show or hide Android or iOS devices. For each platform, you can choose an API and select specific OS versions to include in the Compare list.

Use the **Device type** checkboxes to choose which types of device are included in the list. For example, to see a list of the best tablets, check **Tablet** and uncheck **Smartphone**. The **Others** category includes Android game consoles, smart TVs, and other Android-powered devices.

How to compare two or more devices

It's easy to compare devices with 3DMark. Tap on device images to select up to five devices and then click **compare** at the top of the screen.



In the comparison view, you can select different tests from drop-down menu. The chart shows how the devices' average scores compare.

You can expand the card with the drop-down arrow to see the charts for the Graphics and Physics scores.

You can also see the differences in hardware and specifications. Comparing models has never been this easy.

SETTINGS

Open the Settings screen from the menu icon in the top-right corner of the My Tests screen.

Application

Shows the version number of the app.

Benchmarks

Toggle the **Include demo** switch to turn the demo on or off for all tests. Benchmark demos are included for entertainment. They do not affect your score. The default setting is On.

Open the **Available tests** drop-down to see a list of all tests and their version numbers. You can also install and uninstall tests from this screen.

Support

You can repeat the **Tutorial** or tap **Report a problem** to get help from our support team.

SLING SHOT

Sling Shot is a cross-platform benchmark for modern mobile devices. Use it to compare mainstream Android devices with popular iPhone and iPad models.

Use Sling Shot Extreme to compare high-end Android phones and tablets with the latest Apple devices.

- Designed for the latest high-end smartphones and tablets.
- Mobile-optimized rendering engine using OpenGL ES 3.x, Vulkan & Metal.
- Benchmark the GPU with Graphics tests and the CPU with the Physics test.

Android devices must have Android 5.0 or later and support OpenGL ES 3.0 to run Sling Shot and Open GL ES 3.1 to run Sling Shot Extreme. An Android device must have Android 7.0 or later and Vulkan compatible hardware to run the Vulkan version of Sling Shot Extreme.

On iOS, Sling Shot and Sling Shot Extreme compatibility starts with iPhone 5s, iPad Air, iPad mini 2, and runs to the latest models.

SLING SHOT

Use 3DMark Sling Shot to compare mainstream Android smartphones and tablets with popular iPhone and iPad models.

Sling Shot is a demanding OpenGL ES 3.0 benchmark that tests the full range of API features including multiple render targets, instanced rendering, uniform buffers and transform feedback. It includes volumetric lighting and particle illumination, as well as depth of field and bloom post-processing effects.

The Graphics tests are rendered at 1920 × 1080 before being scaled to the device's display resolution. The Physics test is rendered at 1280 × 720 to ensure that GPU performance is not a limiting factor.

Use **Sling Shot Unlimited** to make chip-to-chip comparisons without vertical sync, display resolution scaling and other operating system factors affecting the result. Sling Shot Unlimited uses the same content and settings as Sling Shot but runs offscreen using a fixed time step between frames. It renders exactly the same frames in every run on every device. The display is updated with frame thumbnails every 100 frames to show progress.

SLING SHOT EXTREME

Run Sling Shot Extreme to compare high-end Android phones and tablets with the latest Apple devices.

Sling Shot Extreme uses Vulkan and OpenGL ES 3.1 on Android and the Metal API on Apple devices. It tests the full range of API features including multiple render targets, instanced rendering, and uniform buffers. It also includes volumetric lighting, depth of field and bloom post-processing effects using Compute Shaders.

The Graphics tests are rendered at 2560 × 1440 then scaled to the device's native display resolution. The Physics test is rendered at 1280 × 720 to ensure that GPU performance is not a limiting factor.

Use **Sling Shot Extreme Unlimited** to make chip-to-chip comparisons without vertical sync, display resolution scaling and other operating system factors affecting the result. Sling Shot Extreme Unlimited uses the same content and settings as Sling Shot Extreme but runs offscreen using a fixed time step between frames. It renders exactly the same frames in every run on every device. The display is updated with frame thumbnails every 100 frames to show progress.

CROSS-PLATFORM BENCHMARKING

The rows in the table below show valid cross-platform comparisons, i.e. you can compare Sling Slot scores across platforms, and you can compare Sling Shot Extreme scores across platforms. But you cannot compare Sling Shot scores with Sling Shot Extreme scores. Though they appear to be similar, they use different rendering resolutions and post-processing techniques.

When comparing scores across platforms, note that the test results reflect both hardware and software. APIs with low overhead, such as Metal and Vulkan, can deliver more performance than OpenGL ES even on devices with similar hardware.

BENCHMARK	RENDERING RESOLUTION	ANDROID API	IOS API
SLING SHOT	1920 × 1080	Open GL ES 3.0	Open GL ES 3.0
SLING SHOT EXTREME	2560 × 1440	Vulkan Open GL ES 3.1	Metal

DEVICE REQUIREMENTS

Android

	SLING SHOT	SLING SHOT EXTREME
OS	Android 5.0	Android 5.0
MEMORY	1 GB	1.5 GB
GRAPHICS	OpenGL ES 3.0	Vulkan OpenGL ES 3.1
STORAGE[2]	203 MB	203 MB

[2] With the Android app you can choose to install only the tests you need. This figure is the storage space required for installing the 3DMark app and the Sling Shot test. The total install size for 3DMark with all tests is 294 MB.

DEFAULT SETTINGS

	SLING SHOT	SLING SHOT EXTREME
RESOLUTION	1920 × 1080	2560 × 1440
GPU MEMORY BUDGET	1 GB	1.5 GB
BLOOM/FFT	Using Pixel Shaders	Using Compute Shaders

GRAPHICS TEST 1

Sling Shot 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. In Sling Shot Extreme, the bloom effects use Compute Shaders. In Sling Shot, they use Pixel shaders.

- No volumetric illumination
- Particle effects
- Post-processing

Processing performed in an average frame

	RESOLUTION[3]	VERTICES	TRIANGLES	PIXELS[4]
SLING SHOT EXTREME	2560 × 1440	620,000	320,000	33.6 million
SLING SHOT	1920 × 1080	620,000	320,000	20.4 million

[3] This is the resolution used to render the Graphics tests. The Physics test is rendered at 1280 x 720 to ensure that GPU performance is not a limiting factor.

[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.

GRAPHICS TEST 2

Sling Shot 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.

- Volumetric illumination
- No particle effects
- Post-processing

Processing performed in an average frame

	RESOLUTION[5]	VERTICES	TRIANGLES	PIXELS[6]
SLING SHOT EXTREME	2560 × 1440	427,000	220,000	35.1 million
SLING SHOT	1920 × 1080	427,000	220,000	20.8 million

[5] This is the resolution used to render the Graphics tests. The Physics test is rendered at 1280 x 720 to ensure that GPU performance is not a limiting factor.

[6] 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 test has three levels with different workloads. The first level is the lightest and the last is the heaviest. The purpose of the three levels is to extend the performance range for which the test is relevant.

The physics test is run with a fixed timestep at 30 FPS. The physics test always begins with the first level and continues to the next level until either the test is finished or 90 seconds have passed. If a level did not finish completely, then it will contribute proportionally less to the final score. The final score is a weighted sum of all levels.

The first level of the test has 8 simulation worlds running in separate threads. Each world has one soft body with 107 vertices and 64 rigid bodies. The rigid bodies are invisible and are there to cause the blast effect to soft bodies. Additionally, there are 32 CPU simulated particle systems with about 500 particles in each.

The second level of the test adds 8 simulation worlds running in separate threads. Each new world has one soft body with 499 vertices and additionally 64 rigid bodies.

The third level of the test adds another 16 simulation worlds running in separate threads. Each new world has one soft body with 499 vertices and additionally 64 rigid bodies.

Each of the 32 worlds is simulated at 30 FPS and the whole test takes 16 seconds at 30 FPS. The first level starts at time 0, the second level starts at time 5 and the third level at time 10.

All physics are computed on CPU. Soft body vertex data is updated to GPU on each frame.

The Bullet Open Source Physics C++ Library version 2.83 alpha is used for physics computation.

SCORING

Sling Shot scores are rounded to the nearest integer. Higher is better.

Graphics Test scoring

Each of the Graphics Tests produces a raw performance result in frames per second (FPS). A harmonic mean of the raw results is evaluated and multiplied with a scaling constant to reach a Graphics score as follows:

$$S_{graphics} = 230 \frac{2}{\frac{1}{F_{g1}} + \frac{1}{F_{g2}}}$$

Where:

$S_{graphics}$	= Graphics score
F_{g1}	= Average frames per second in Graphics test 1
F_{g2}	= Average frames per second in Graphics test 2

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

Physics Test scoring

The levels of the physics test produce a raw performance result in frames per second (FPS). The score is defined as a sum of raw results from levels that can be completed before a given time limit of 90 seconds. A scaling constant is used to reach the final physics score.

The score is defined as follows:

$$S_{physics} = 9\ (N_{p1}W_{p1} + N_{p2}W_{p2} + N_{p3}W_{p3})$$

Where:

$S_{physics}$	= Physics score
$C_{physics}$	= A scaling constant, set to 9
N_{pn}	= a frame rate normalization factor for level N

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

W_{pn} is defined as follows for the default version of the test:

$$W_{pn} = \max(0, \min(Lhigh, F_n))$$

Where:

$Lhigh$ = A maximum frame rate limit set to 60
F_n = Average frames per second for the current level

And as follows for the Unlimited version of the test:

$$W_{pn} = \max(0, F_n)$$

Where:

F_n = Average frames per second for the current level

The frame rate normalization factors N_{p1} , N_{p2} , and N_{p3} are used to normalize the frame rates of the different levels before using them in score calculation. A set of reference CPUs is used to define the factors.

- N_{p1} is always set to 1.
- N_{p2} is the average relative frame rate difference of levels 1 and 2 on the reference CPUs.
- N_{p3} is the average relative frame rate difference of levels 2 and 3 on the reference CPUs multiplied by N_{p2}.

The following table lists the CPUs that are used as reference.

REFERENCE CPUS FOR NP2	LEVEL 1 FRAME RATE	LEVEL 2 FRAME RATE	RELATIVE DIFFERENCE
Apple A7 (iPhone 5s)	36.69	6.35	5.78
Qualcomm Snapdragon 800 (LG Nexus 5)	40.19	8.59	4.68

REFERENCE CPUS FOR NP2	LEVEL 1 FRAME RATE	LEVEL 2 FRAME RATE	RELATIVE DIFFERENCE
Qualcomm Snapdragon 805 (Motorola Nexus 6)	46.67	9.89	4.71
Tegra K1 (NVIDIA SHIELD)	59.05	20.59	2.87
AMD A4-5150M	112.36	13.57	8.28

Reference CPUs for Np3	Level 2 frame rate	Level 3 frame rate	Relative difference
AMD A10-4600M	70.79	6.15	11.51
Intel Core i5-3317U	79.50	18.17	4.38
Intel Core i7 920	226.89	145.83	1.56

The following table defines values for the frame rate normalization factors.

N_{p1}	1.00
N_{p2}	3.26
N_{p3}	10.60

3DMark Sling Shot score

The 3DMark Sling Shot and Sling Shot Extreme score is formed from the Graphics score and Physics score using a weighted harmonic mean as follows:

$$S_{3DMark} = \frac{W_{graphics} + W_{physics}}{\frac{W_{graphics}}{S_{graphics}} + \frac{W_{physics}}{S_{physics}}}$$

Where:

$W_{graphics}$ = the weight for the Graphics score, set to 7/9
$W_{physics}$ = the weight for the Physics score, set to 2/9

⚠ Even though the tests appear to be similar, Sling Shot scores should not be compared with scores from Sling Shot Extreme. The two tests use different rendering resolutions and post-processing techniques making their scores incomparable.

SLING SHOT ENGINE

Rendering

Multithreading

The engine utilizes one thread per available CPU core. One of the threads is considered as the main thread, which makes the graphics API calls. The other threads are worker threads, which do not make API calls.

The 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 and computation of shader parameters (constants buffer contents and dynamic vertex data). When the main thread is finished with the tasks associated to its own items, it executes API calls for items assigned to the worker threads.

Lighting

Lighting is done in deferred style. Geometry attributes are first rendered to a set of render targets. Finally illumination is rendered based on those attributes.

Surface illumination

The g-buffer is composed from two 32 bits per pixel textures and a depth texture. Surface illumination model the basic Blinn Phong reflectance model.

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 4x4 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 simple 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 4x4 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 utilizing transform feedback. Particles are simply self-illuminated.

Post-processing

Depth of field

The effect is computed by filtering rendered illumination in half resolution with three separable skewed box filters that form hexagonal bokeh pattern when combined.

The filtering is performed in two passes that exploit similarities in the three filters to avoid duplicate work.

The first pass renders to two render targets and the second pass the one target combining results of the three filters. Before filtering, a circle of confusion radius is evaluated for each pixel and the illumination is premultiplied with the radius.

After filtering, illumination is reconstructed by dividing the result with the radius. This makes the filter gather out of focus illumination and prevents it from bleeding in focus illumination to neighbor pixels.

Bloom

The effect is computed by transforming the computed illumination to frequency domain using Fast Fourier Transform (FFT) and applying a 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 using the fragment shader. The FFT is performed with Cooley-Tukey algorithm as a series of render passes.

The effect is computed in 256 × 256 resolution in both Sling Shot and Sling Shot Extreme. In Sling Shot, the FFTs are computed using 16-bit floating point textures. In Sling Shot Extreme, the FFTs are computed using 32-bit 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.

With Sling Shot Extreme, Compute Shaders are used for the FFT and bloom. A total of 256 invocations within a work group is required.

SLING SHOT VERSION HISTORY

Sling Shot using OpenGL ES 3.0 and OpenGL ES 3.1

VERSION				NOTES
2.4	×	●	×	Improved compatibility with Arm Mali-G72 and Mali-G76 GPUs. Sling Shot Extreme benchmark scores for those GPUs will be lower with this version.
2.3	×	●	×	Added Vulkan version of Sling Shot Extreme.
2.2	×	×	●	Fixed a Physics test bug introduced in 3DMark Sling Shot iOS app version 1.0.745. Scores from 2.2 are again comparable across platforms and devices.
2.0	×	●	●	Improved compatibility with ARM Mali GPUs. Scores from v2.0 are not comparable with v1.0 results.
1.0	×	●	×	Launch version

Sling Shot Extreme using Vulkan

VERSION				NOTES
3.1	×	●	×	Improved compatibility with Arm Mali-G72 and Mali-G76 GPUs. Sling Shot Extreme benchmark scores for those GPUs will be lower with this version.
3.0	×	●	×	Enabled depth buffer to the lighting pass. Scores from v3.0 are not comparable with v2.3 results.

VERSION				NOTES
2.3	✕	●	✕	Added Vulkan version of Sling Shot Extreme.

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.

			
DIRECTX 12	●	×	×
DIRECTX 11	●	×	×
VULKAN	●	●	×
OPENGL ES 3.0	×	●	●
METAL	×	×	●

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.

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 devices. For instance, we would advise against comparing the Vulkan score from an Android device with the Metal score from Apple device. Likewise, it could be misleading to credit a device's GPU for any difference in OpenGL ES 3.0 performance between different vendors' GPUs.

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

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

	OPENGL ES 3.0	VULKAN
OS	Android 5.0 or later	Android 7.0
MEMORY	1 GB	1 GB
GRAPHICS	OpenGL ES 3.0 compatible	Vulkan compatible
STORAGE	113 MB	113 MB

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 Android, the first part runs until 24,576 draw calls per frame. The second part starts from the beginning on all platforms.

DRAW CALLS PER FRAME	DRAW CALLS PER FRAME INCREMENT PER STEP	ACCUMULATED DURATION IN FRAMES
192 – 384	12	320
384 – 768	24	640
768 – 1536	48	960
1536 – 3072	96	1280
3072 – 6144	192	1600
6144 – 12288	384	1920
12288 – 24576	768	2240
24576 – 49152	1536	2560

DRAW CALLS PER FRAME	DRAW CALLS PER FRAME INCREMENT PER STEP	ACCUMULATED DURATION IN FRAMES
49152 – 98304	3072	2880
98304 – 196608	6144	3200
196608 – 393216	12288	3520

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.

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.

OPENGL ES 3.0 PATH

All lighting draw calls use the same primitive topology, shader program, and other graphics rendering state. The following OpenGL ES 3.0 API calls are made for each lighting draw call:

```
glActiveTexture()
glBindTexture()
glBindSampler()
glBindBufferRange()
glBindVertexArray()
glDrawElements()
```

All shadow map draw calls use the same primitive topology, shader program, and other graphics rendering state. On each shadow map draw call, the following OpenGL ES 3.0 API calls are made:

```
glBindBufferRange()
glBindVertexArray()
glDrawElements()
```

OpenGL ES 3.0 is only used in single-threaded mode, where the draw calls for all geometries are made first for the shadow map pass and then for the lighting pass.

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

VERSION				NOTES
1.1	×	●	●	Improved compatibility with the latest Android models.
1.0	●	●	●	Launch version

HOW TO REPORT SCORES

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

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

✓ "Smartphone scores 2,000 in the Sling Shot Extreme benchmark."
× "The smartphone scores 2,000 3DMarks."

Always include details of the device used to obtain the score. Be sure to include the Android OS version and the exact device model.

Delisted Devices

We have rules for manufacturers and developers that specify how a platform can interact with our benchmark software. When a device is suspected of breaking those rules it is delisted. Scores from delisted devices are not shown in the Hardware Channel and should not be used to compare devices.

Using 3DMark scores in reviews

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

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RELEASE NOTES

3DMark Android 2.0.4661 – March 16, 2020

Compatibility

- Updated CPUID module to improve compatibility with upcoming devices.
- Benchmark results are now submitted using HTTPS.

3DMark Android 2.0.4652 – January 14, 2020

This update marks the end of support for 3DMark Ice Storm benchmarks. These tests no longer provide useful results with modern devices. Ice Storm tests are now hidden in the app by default. If needed, you can use them by going to the Settings screen and using the option to "Show unsupported tests."

3DMark Android 2.0.4646 – November 21, 2019

Fixed

- Fixed a UI crash in My Device and Compare screens.

3DMark Android 2.0.4645 – November 20, 2019

Fixed

- Corrected an issue in application manifest that prevented Android TV devices from seeing 3DMark in Play Store.

3DMark Android 2.0.4643 – November 18, 2019

Compatibility

- Now compatible with Android TV devices.

Improved

- The app now uses https to send and receive data.

Fixed

- Fixed a crash that could occur when running the API Overhead feature test on the fastest Android devices.
- Ice Storm Demo now has music and audio again.
- Fixed test automation in the Professional Edition app.

3DMark Android 2.0.4608 – June 28, 2019

A change in this update means that Sling Shot Extreme benchmark scores will be lower on devices with an Arm Mali-G72 or Mali-G76 GPU. Other benchmarks and devices are not affected.

Improved

- Now available as a 64-bit app.
- 3DMark can now detect when Huawei performance mode is enabled.
- Result files now include the workload version number.

Fixed

- Fixed a few cosmetic rendering bugs in Sling Shot and Sling Shot Extreme.
- Improved compatibility with Arm Mali-G72 and Mail-G76 GPUs. Sling Shot Extreme benchmark scores for those GPUs will be lower with this version.

3DMark Android 2.0.4589 – January 16, 2019

A change in this update means that Sling Shot Extreme Vulkan benchmark scores will improve on some devices. Other benchmark scores are not affected.

Compatibility

- The Vulkan version of the Sling Shot Extreme test has been modified to improve the comparability of scores with the OpenGL ES 3.1 version. Vulkan scores will improve on many devices. Vulkan scores from this version (Sling Shot Extreme - Vulkan v3.0) should not be compared with results from earlier versions.

Fixed

- Fixed an issue that could cause the API Overhead feature test to fail on newer devices.

3DMark Android 2.0.4580 – May 23, 2018

New

- Added user privacy settings for app analytics and crash reporting.
- Added a link to our Privacy Policy.

3DMark Android 2.0.4573 – December 18, 2017

New

- Completely redesigned app is now faster and more useful than ever.
- New charts, lists, and cards help you learn more about your device.
- See how your scores and device compare with the latest models.
- New Sling Shot Extreme benchmark test using the Vulkan API.
- New Material Design UI is fast, responsive, and easy to use.

3DMark Android 1.7.3516 – August 17, 2017

New

- New API Overhead feature test lets you compare the performance of Vulkan and OpenGL ES 3.0 APIs on your Android device. The Vulkan part of the test requires Android 7.0 or later and Vulkan compatible hardware. The OpenGL ES 3.0 part of the test requires Android 5.0 or later and OpenGL ES 3.0 compatible hardware. Please note that devices which shipped with early Vulkan drivers may have performance and stability issues in this test.

Fixed

- Fixed an issue with updating the device list that could cause crashes on some devices.

Compatibility

- Fixed a Sling Shot benchmark compatibility issue on devices with the Mali-G71 GPU.

3DMark Android 1.6.3439 – January 13, 2017

Compatibility

- This update fixes an issue in the previous version (1.6.3428) that could affect performance on some Qualcomm-powered devices. Benchmark scores on those devices will return to the correct level with this update.

3DMark Android 1.6.3428 – December 7, 2016

This minor update renames some tests to make it easier to compare scores across platforms. The test names in the Android app now match the test names used in the iOS app. Benchmark scores are not affected.

Improved

- "Sling Shot using ES 3.0" test is now simply called "Sling Shot."
- "Sling Shot using ES 3.1" test is now called "Sling Shot Extreme."

- Improved benchmark compatibility information.

3DMark Android 1.5.3285 – August 31, 2015

Compatibility

- Sling Shot fix for devices that support OpenGL ES 3.2.
- Sling Shot compatibility warning is now specific about requiring Android 5.0 or later.

3DMark Android 1.5.3263 – July 27, 2015

This update completely replaces the standalone Sling Shot app released for limited testing in April 2015. That app is no longer available from Google Play and should not be used for further testing since its scores are not comparable with this update.

New

- New Sling Shot benchmark for testing OpenGL ES 3.1 and OpenGL ES 3.0 performance on compatible devices running Android 5.0 or later.
- New hardware monitoring chart shows how CPU clock frequency, CPU usage, temperature and battery charge changed while the benchmark was running.

Improved

- 3DMark now recommends the best test for your device.
- New layout makes choosing benchmarks easier.
- Save storage space by installing only the benchmark tests you need.
- Added Russian localization.

Compatibility

- Added support for Android TV.
- Sling Shot now runs on ARM Mali GPUs.

3DMark Android 1.4.2925 - December 15, 2014

Fixed

- Fixed a bug that caused the UI to hang with a black screen if the benchmark run ended unexpectedly.
- Minor UI improvements and bug fixes.

3DMark Android 1.4.2717 - December 5, 2014

New

- 3DMark now recommends the best benchmark test for your device.

- New Benchmarks page shows which tests are currently installed.
- New Test Details pages explain what each benchmark measures.

Improved

- Downloading and installing tests is now faster and uses less memory.
- Optimized app startup time and update check.
- Device Channel is now called Best Devices.

Compatibility

- 3DMark is compatible with Android 5.0 (Lollipop).

Fixed

- Fixed a problem where 3DMark could not install tests even though there was enough space on the storage or SD card.
- Fixed sorting by screen size on Best Devices list.

3DMark Android 1.3.1439 - March 24, 2014

Improved

- Added the ability to selectively delist devices based on Android version.

Compatibility

- Delisted Samsung devices that comply with Futuremark benchmark rules after being updated* have been relisted in the 3DMark Device Channel.
- Samsung Galaxy S IV: scores are valid when using Android 4.2.2 and 4.4.x or later.
- Samsung Galaxy Note III: scores are valid when using Android 4.4.2 or later.

*Provided that the device is running the official update provided by Samsung.

Fixed

- Fixed a bug that prevented downloads on devices set to use Turkish language.

3DMark Android 1.3.1375 - March 7, 2014

Improved

- Optimizations to improve the speed at which tests are downloaded and installed.

Fixed

- Fixed a bug that prevented the Device Channel from updating with the latest devices.

3DMark Android 1.3.1309 – February 21, 2014

New

- Do you love your phone? Let other 3DMark users know with the new Recommend My Device feature.
- 3DMark Android benchmark is now available in Simplified Chinese.

Improved

- 3DMark now supports the ability to install and uninstall benchmark tests from within the app. Look out for new tests coming soon.
- Improved UI rendering performance.

Compatibility

- Now requires Android 4.0.0 or higher. Android 3.2 support has been retired.
- Fixed a compatibility issue affecting Sony Xperia SP and Samsung Galaxy S III models with the Qualcomm Snapdragon MSM8960 chip.
- Improved reliability on devices with less than the recommended 1 GB of memory.
- Support for installing 3DMark on AOSP devices that cannot access Google Play store.
- Sideloading support for networkless installation.

3DMark Android v1.2.0.1232 – November 25, 2013

New

- Device models that do not comply with our benchmark rules have been delisted from the Device Channel.
- You should not use scores from delisted devices to compare devices.

Improved

- Compare your score with Windows 8 tablets in the Device Channel.
- Devices are colour-coded by OS in the Device Channel.
- You can filter scores by OS in the Device Channel.

Compatibility

- Improved compatibility with the latest NVIDIA hardware.
- Improved compatibility with some Samsung Galaxy S3 models.

3DMark Android Edition v1.1.0.1179 – Sept 9, 2013

New

- New Ice Storm Unlimited test.
- Compare 3DMark scores with Apple iOS devices in the Device Channel.

Improved

- Forced vertical sync on Android devices limits apps to displaying a maximum of 60 frames per second. Your score will be shown as "Maxed out" if your device hits the vertical sync limit during a test.
- 3DMark will recommend the best test for your device to avoid vertical sync limits.

Compatibility

- Nexus 7 (2013) is correctly identified.

Tests

- Ice Storm updated to version 1.2.0

3DMark Android Edition v1.0.3-1138 - August 20, 2013

Compatibility

- Added a workaround for a driver bug on Nexus 7 devices running Android 4.3.

3DMark Android Edition v1.0.2-1109 - May 2, 2013

New

- Added chipset model to device detail pages.

Improved

- Ice Storm Extreme Physics test for measuring CPU performance now runs at 720p to ensure the result is not influenced by the GPU. Ice Storm Extreme scores may improve slightly on devices with low-end GPUs.

Optimized

- Faster image loading in the Device Channel.
- Better score bar scaling in search result lists.
- Reduced app size to 149 MB.

Compatibility

- Automatically skip demo on devices with TI OMAP 44xx chipset to avoid a memory-related crash. There will be some visual corruption during the Physics test however this does not affect the score and you will now be able to complete all the tests on these devices.
- Automatically skip demo if the device runs out of memory during the demo, typically on devices with 512 MB of memory. The recommended minimum device memory for 3DMark is 1 GB (1024 MB).

Fixed

- Fixed a bug that prevented your best score being shown as your Highest Score.
- My Device now shows the Android OS version installed on the current device. Device Channel detail pages show the Android OS version shipped with the model.

Tests

- Ice Storm version 1.1.1

3DMark Android Edition v1.0.1-949 – April 11, 2013

New

- You can now search the Device Channel.
- You can now report unknown and incorrectly identified devices.

Fixed

- Fixed a bug that caused crashes for some users.
- Fixed the "no score" bug that could cause the test to exit after the demo.
- The Device Channel list loads faster and uses less memory.

3DMark Android Edition v1.0.0 – April 2, 2013

- Launch version.
- Added Ice Storm Extreme test for the latest smartphones and tablets.

Tests

- Ice Storm version 1.1.0

ABOUT UL

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

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

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

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

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

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