



AquaMark3™

The Reality Benchmark

Documentation

[www.aquamark3.com](http://www.aquamark3.com)

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## **Software and documentation**

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# 1 Introduction

The advent of programmable graphics hardware has introduced numerous possibilities for the creation of realistic gaming environments and immersive gaming experiences. While game engines grow in their overall complexity, performance considerations stay at high priority. The gamer community as well as game developers and hardware engineers need evaluation tools to measure the performance of both, the game engines and the 3D hardware.

AquaMark3 has been designed to benchmark current and next-generation PCs with a real world game engine, the *krass*<sup>TM</sup> Engine. Having been used in Massive Development's recent games *AquaNox* and *AquaNox 2: Revelation* as well as in *Spellforce* by *Phenomic Game Development*, the rendering component of the *krass*<sup>TM</sup> Engine delivers high-performance graphic effects with superior quality.

AquaMark3 utilizes recent hardware features of the DirectX 9 API, such as PixelShader 2.0, while staying fully backward compatible to DirectX 8 and 7 graphics hardware. Additionally users can configure the graphics features in fine detail in order to scale the performance appropriately for their target system.

Unlike synthetic benchmarks AquaMark3 allows benchmarking in a real-world scenario with an engine and art assets representing the complexity of current state-of-the-art games. Its art assets are based on those used in *AquaNox 2: Revelation*, but have been advanced to be slightly more complex regarding their average polygon and vertex count so as to represent games that will be released within the next 6-12 months.

AquaMark3 benchmark results do not only represent the performance of the tested system with games based on the *krass*<sup>TM</sup> Engine, the measured performance is generally transferable to other state-of-the-art game engines and rendering middleware as well. The vast majority of engines being used in recent game production cycles work in a similar and widely-accepted way of systems engineering.

## 2 General Information

The following documentation comprises the AquaMark3 application with its provided online and offline services. According to the overall design of AquaMark3 the documentation is split into two major parts: the first part includes the information related to the AquaMark3 executable, the second part refers to the AquaMark3 online result browser and the AquaMark3 forum.

### 2.1 Installing

First download the AquaMark3 file from one of the official mirror sites listed under the following link (<http://www.aquamark3.com/am3-mirrors.htm>). Before you start installing the AquaMark3 on your system please make sure that:

- all other running programs are closed.
- as AquaMark3 requires Microsoft® DirectX 9, DirectX 9 (or higher) is installed on your computer.

Then install the software by executing (double-clicking) the downloaded file and follow the subsequent steps of the installation wizard. When you have successfully finished the installation, we suggest you start AquaMark3 at least once from your start menu to create the application folder "My Documents\AquaMark3".

### 2.2 Uninstalling

To uninstall AquaMark3 select the *Uninstall AquaMark3* link in the program folder and start the uninstall process.

### 2.3 Registration

AquaMark3 is available under the following five product licenses, each intended to meet the needs of a specific customer group:

1. **AquaMark3 Basic** (standard version, available for free)
2. **AquaMark3 Professional** (default solution for private users)
3. **AquaMark3 Professional Plus** (comfortable solution for private users)
4. **AquaMark3 Commercial** (default solution for commercial users)
5. **AquaMark3 Commercial Plus** (identical to 4. but comprises licenses for 10 computers)

Depending on the license you purchased, the answering mail you receive will have attached the appropriate license file. This license file contains your license key in addition to some personal information. There are two possible ways to register and unlock your copy of AquaMark3.

1. *Automatic unlocking:*

- Open the directory "My Documents\AquaMark3"
- Copy the file `License.txt` (attached to the license e-mail) into this directory
- AquaMark3 is unlocked now

2. *Manual unlocking:*

- Start AquaMark3
- Click on the "Purchase AquaMark3" button
- Select the appropriate licensing category
- Enter the license key information (more detailed information is given in mail)
- Click on "Enter License"
- AquaMark3 is unlocked now

## 2.4 Licenses

### 2.4.1 AquaMark3 Basic (free, no license required)

The basic version of AquaMark3 is free and allows the customer to evaluate his system in the predefined standard way as well as to compare the outcoming results to others in the online data base. AquaMark3 Basic comprises the following essential program features:

- AquaMark3 TRISCORE™ measurement
- Selected special features
- Manual screenshot function
- Configurable demo mode
- Microsoft® Excel analysis support
- Submitting results to online database



## 2.4.2 AquaMark3 Professional

The AquaMark3 Professional is the default solution for private users, as its feature set examines your system very comprehensively. This license enables additional program features such as:

- Detailed feature-settings
- Advanced measurement for single run tests
- Additional special features for DX 9 card tests
- Pixel rate measurements
- Automated screenshot function
- Technical support for AquaMark3 as well as for ARC

## 2.4.3 AquaMark3 Professional Plus

AquaMark3 Professional is definitely the most comfortable way for private users to scrutinize their system closely. Compared to AquaMark3 Professional the Professional Plus license also offers automated multi-run and command-line measurements. You can test a whole range of possible settings without the need to redefine them manually again and again. Just choose the parameter range for the settings and AquaMark3 Professional Plus will do the rest for you. The license additionally includes the two features:

- Automated measurement functionality (multi-run)
- Command line measurement functionality (unlimited number of user specific settings)

## 2.4.4 AquaMark3 Commercial

AquaMark3 Commercial is the default solution for commercial users. Its range of functions is equal to AquaMark3 Professional Plus, but on top of that you're allowed to publish your results for commercial purposes. For you as a commercial user the features of the AquaMark3 Commercial present an excellent tool to offer your clients reliable and comparable benchmark results.

## 2.4.5 AquaMark3 Commercial Plus

AquaMark3 Commercial Plus supports the same functions as AquaMark3 Commercial, but comprises licenses for up to ten computers. As a licensee you are allowed to carry out your measurements on up to ten different systems *simultaneously* with only one license. AquaMark3 Commercial Plus is intended for the professional and commercial computer industry, i.e. hardware manufacturers, hardware testing labs, testing press etc.

## 2.4.6 AquaMark3 License Comparison Table

The table below outlines the AquaMark3 features subject to the different license models.

	AquaMark3 Basic	AquaMark3 Professional	AquaMark3 Professional Plus	AquaMark3 Commercial	AquaMark3 Commercial Plus
AquaMark3 Score Measurement	Yes	Yes	Yes	Yes	Yes
Detailed Feature Adjustment	No	Yes	Yes	Yes	Yes
Advanced Measurement (Single Run)	No	Yes	Yes	Yes	Yes
Advanced Measurement (Multi Run)	No	No	Yes	Yes	Yes
Automated Measurement (Command Line)	No	No	Yes	Yes	Yes
Special Features (Overdraw/OVIST)	Yes	Yes	Yes	Yes	Yes
Special Features (Shader/SVIST) (PS2.0 Required)	No	Yes	Yes	Yes	Yes
Special Features (Pixel rate/PIXPM)	No	Yes	Yes	Yes	Yes
Manual Screenshot Extraction	Yes	Yes	Yes	Yes	Yes
Automated Screenshot Extraction	No	Yes	Yes	Yes	Yes
Demo Mode (Configurable)	Yes	Yes	Yes	Yes	Yes
Excel Analysis	Yes	Yes	Yes	Yes	Yes
Submitting Results to Online Database	Yes	Yes	Yes	Yes	Yes
Full Fallback Support for Older Hardware (DX7-9)	Yes	Yes	Yes	Yes	Yes
Technical Support	No	Yes	Yes	Yes	Yes
Rights To Publish Results With Commercial Intention	No	No	No	Yes	Yes
Allowed Number Of Simultaneous Installations Per License	1	1	1	1	10

**Table 1:** Features of AquaMark3 subject to different licenses

## 3 General Functions

AquaMark3 offers the five different main functionalities listed here below. Their availability as well as their sub-features depend on your current graphics hardware, the installed driver version and the license of your AquaMark3 version.

- Score Measurement
- Advanced Measurement
- Custom Measurement
- Demo Mode
- Special Features

The following subchapters will explain these main functionalities in more detail.

### 3.1 AquaMark3 TRISCORE™ (Score Measurement)

The score measurement runs the benchmark with default settings (high quality) and measures the AquaMark3 score. The AquaMark3 score comprises three independent values (→TRISCORE™): the overall system performance, the performance of the graphics subsystem, and the CPU performance.

Of those three values the overall system score is the most important measurement, as it is solely based on the number of frames rendered during a certain amount of time. The graphics and CPU scores are less precise as AquaMark3 is not a synthetic benchmark measuring raw processing power. It is necessary to take into account that the graphics score does not measure the performance of the graphics card only. The complete graphics score also comprises CPU and system memory, as the graphic card driver and the operating system also contribute to the result. Graphic card drivers, though running on the CPU, are seen as a part of setup of the graphical processing pipeline and therefore don't contribute to the CPU score. Nevertheless graphics and CPU performance are useful indicators to see whether the interaction of graphics card and CPU match the needs of action-based computer games.

See section 7.1 Final Score Computation for a discussion of the computation of the individual scores.

## 3.2 Advanced Measurement

The advanced measurement section allows configuring the benchmark settings with the most important parameters. You can set each of those settings either explicitly to one value, or select all possible values of a setting to be tested in one go. Note that choosing more than one setting to be tested with all their possible values will multiply all value settings for the necessary number of benchmark passes, e.g. if you test both all resolutions and all color depths, it will create  $5 \times 2 = 10$  benchmark passes.

Configurable settings are:

- Screen resolution. Only the most common resolutions are available: 640×480, 800×600, 1024×768, 1280×1024 and 1600×1200.
- Color depth: 16 or 32 bit.
- Full screen antialiasing: The antialiasing configuration in DirectX 9 is more complex than in previous DirectX versions. If a graphics card supports antialiasing, the “Full Screen Antialiasing Mode” setting allows to choose the antialiasing mode: “Off”, “Non-maskable” and perhaps “2×”, or higher values. For the “Non-maskable” mode DirectX 9 specifies, that all supported antialiasing variations of a graphics card are to be selectable as quality levels. So once you chose “Non-maskable”, the sub setting “FSAA Quality” gives you the choice between your graphics card’s different quality levels. Since each quality level is just a certain number between 1 and an unknown maximum number, the graphics card manufacturer has to provide further details as to which quality level corresponds to which type of antialiasing. In some cases though the quality levels of the “Non-maskable” mode might also be shown as “2×”, “4×” etc. modes in the “Full Screen Antialiasing Mode” setting above. For fully comparable measurements, we advise to either use the more specific antialiasing modes such as “2×”, etc or to ask hardware manufacturers for more information about the different “Non-maskable” quality levels.

The latest graphics cards might also offer a choice of different quality levels for antialiasing modes like “2×” or “4×”, but DirectX 9 drivers available at the time of the release of AquaMark3 did not yet offer this feature.

- Anisotropic filtering: Uses tri-linear filtering if anisotropy is off, otherwise it offers all anisotropy modes of the graphics card to choose from.
- Level of detail: Offers a choice between six levels of detail settings. These settings are identical to those found in the “custom options/load preset” dialog (cf. 3.7).

In addition to the settings mentioned above you can also enable or disable sound output during the benchmark.

### 3.3 Custom Measurement

The custom measurement allows benchmarking with your own specific graphics and sound settings that you can configure in great detail via Options in the main menu. See section 3.7 for the description of all available options.

If you want to compare a custom measurement to an advanced measurement, you first need to adapt the parameters of your custom measurement to the according values of the advanced one. Take the following steps to do this:

- Go to the video options menu.
- Load a video settings preset according to the “Level of detail” setting of the advanced measurement, e.g. “Very high”.
- Adjust the resolution, color depth, antialiasing and anisotropy according to the advanced measurement's settings you want to compare with. Note that the video options menu always sets the antialiasing mode to “Non-maskable”, so you can only choose between various quality levels. If you want to use a more precisely defined mode instead, consult you graphics card manufacturer as to which quality level corresponds to the desired antialiasing mode (cf. section 3.2).
- Go to the audio options menu.
- If you want to benchmark with sound, load the default audio values. Otherwise disable sound.

### 3.4 Demo Mode

In the demo mode you can watch the real-time benchmark animation with music. The demo runs with the current settings configured in the Options menu. See section 3.7 for a description of the available settings.

### 3.5 Special Features: Tests

The creation of AquaMark3's special features is based on a survey of previous, current and future uses of pixel shaders. This survey showed us some very interesting facts:

- It's *not* the number of implemented pixel shaders that determines the workload, **but** the number of pixels finally *rendered* in the output. When 100 pixel shaders written in 2.0 are responsible for only 10% of the rendered output, the actual number of shaders is not significant. However this obvious fact has often been unnoticed.
- This means we need to clearly determine the number of pixels which finally come through the pipeline and contribute to the frame buffer result. An exact determination is rather difficult, because in today's pixel pipelines many pixels are rejected by z- or alpha-test at different stages. But we have invented a new testing method which counts the exact number of pixels contributing to the frame buffer. The special thing about this method is: It does *not* change any pixel pipeline settings, so the counting pass delivers *exactly* the same number as the number of original rendering passes.
- Usually it is *unnecessary* to implement the pixel shader in the highest shading version available, as there are already many application possibilities for pixel shaders in the lower versions. For instance the rendering of alpha-blended particles does not require pixel shader version 2.0 - it is much more sensible to implement it through classical texture stages instead. That is why we implemented a test which counts the pixels rendered with a specific pixel shader version. All of today's game engines support DX7 and DX8, but there are only a few effects implemented manually in higher shader versions. So to get a representative overview about the shader versions used in AquaMark3 this pixel shader test is very important.

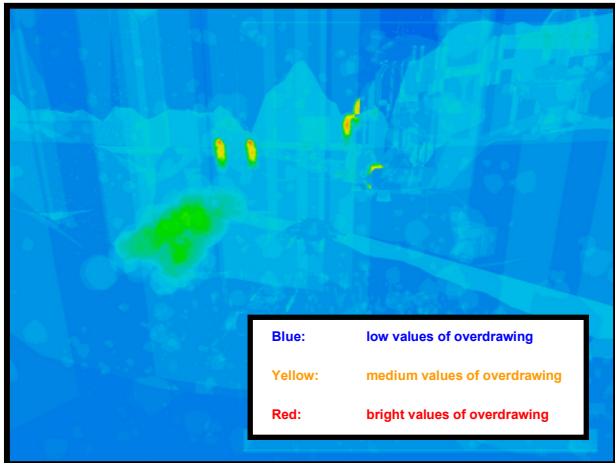
With this in mind AquaMark3 supports *three tests that have not been introduced into benchmark programs before*:

- Overdraw Visualization Technique (**AquaMark3 OVIST™**)
- Shader Visualization Technique (**AquaMark3 SVIST™**)
- Pixel Performance Measurement (**AquaMark3 PIXPM™**)

These tests use a different kind of drawing creating abnormal looking though very informative screen results. The following sections explain these three testing schemes in detail.

**Note:** The special features tests use exactly the same pixel shaders and vertex shaders as those used in the standard benchmark run. This means that all hardware tests like depth buffer checks, alpha channel checks etc. are executed in exactly the same way as in the original benchmark (except where noted otherwise). To generate their results the special feature tests use a novel concept: a processing step is applied subsequent to the pixel's color and depth calculation inside the hardware.

### 3.5.1 AquaMark3 OVIST™ (Overdraw Visualization Technique)



The overdraw visualization test fills the frame buffer with a brightness value according to the number of writing procedures per pixel. This procedure uses exactly the same shaders as those used for the standard test. Subsequent to the shading process a pseudo color for the respective pixels is calculated and rendered on screen. The final image then represents low overdraw in cold colors and high overdraw in hot colors, using the whole range from blue to red.

**Picture 1:** Sample Screenshot from run with activated OVIST™ feature.

### 3.5.2 AquaMark3 SVIST™ (Shader Visualization Technique)

The shader visualization test fills the frame buffer with a color and a brightness value which depend on the kind of pixel shader resp. the number of times it has been used per pixel. Just like in the overdraw test the respective pixels will afterwards be rendered in pseudo colors. In the final picture the color of a pixel indicates the predominantly used shader version responsible for the pixel's creation, while its brightness indicates the number of overdraws. Cold colors are used for pixels with no pixel shader influence, pixel shader 1.x creates yellow, and hot colors up to red are used for pixels only influenced by pixel shader 2.0. Note that unlike the overdraw visualization (cf. section 3.5.1) this visualization here aborts the rendering pipeline before the alpha test but after depth test and pixel shader execution. This is necessary because we want to count pixel shader executions, which also happen for pixels that fail the alpha test.



pixel shader 1.x creates yellow, and hot colors up to red are used for pixels only influenced by pixel shader 2.0. Note that unlike the overdraw visualization (cf. section 3.5.1) this visualization here aborts the rendering pipeline before the alpha test but after depth test and pixel shader execution. This is necessary because we want to count pixel shader executions, which also happen for pixels that fail the alpha test.

**Picture 2:** Sample screenshot from run with activated SVIST™ feature.

### 3.5.3 AquaMark3 PIXPM™ (Pixel Performance Measurement)

The result of this test is the average number of pixels drawn per second. PIXPM™ is a kind of “real life fill rate test” which additionally contains complex pixel shaders as well as different texture and blending modes. The test consists of two individual runs:

- The first run creates the overdraw of each frame. It measures each frame and creates a sum of how many overall pixels have been drawn in this frame. Since this measurement is transferring data from the graphics card back to the CPU (similar to taking a screenshot at every frame), this run is usually rather slow.
- The second run is a normal benchmark run which takes the results of the first run to calculate the drawn pixel per second.

## 3.6 Special Features: Usability Improvements

In addition to the special feature tests described above (cf. section 3.5) we implemented the following two features mainly to make AquaMark3 more comfortable and increase its usability:

- Automated Screenshot Grabber (**AquaMark3 ASGRA™**)
- Automated Testing Technique (**AquaMark3 AUTT™**)

The following sections explain these two support features in more detail.

### 3.6.1 AquaMark3 ASGRA™ (Automated Screenshot Grabber)

AquaMark3 provides an automatic extraction of an adjustable number of screenshots for the running application with its current settings. The shots are taken at regular frame intervals, so in a post processing step different settings and different hardware can easily be compared. The customer can use his favorite software package to view the different screenshots and compare them to each other. Using this feature makes it easy to compare different aliasing modes and texture sampling settings thoroughly.

To activate this feature select the Special Features menu from the main screen and determine the number of screenshots you would like to grab within one benchmark run. A slider in the menu allows adjusting the number of frames between the separate screenshots.

You can also take screenshots interactively any time you want: Just press the “Print Screen” (Prt Scr/Sys Rq) key on your keyboard.



Alternatively, when you start AquaMark3, you can specify the number of a certain frame you want to use for a screenshot on the command line. To start AquaMark3 and create screenshots of frames 100, 200 and 300, type at a command prompt:

```
cd <path where AquaMark3 is installed>
AquaMark3.exe -grabframe 100,200,300
```

Note that there must *not* be a space between the frame numbers. Each benchmark pass started this way, will make screenshots from frames 100, 200, and 300.

All resulting screenshot(s) will be stored as **32-bit uncompressed TGA** images in the same folder as the text output files of the benchmark, i.e. in a subfolder of “My Documents/AquaMark3”.

**Note:** If you take screenshots, any of the time based measurements (esp. frame rates) as well as the AquaMark3 score will be very inaccurate.

### 3.6.2 AquaMark3 AUTT™ (Automated Testing Technique)

This feature helps you to run AquaMark3 measurements with different settings without starting each measurement individually. It saves a lot of setup time and allows transparent and concise evaluation of huge sets of different system parameters later on. The result files generated by AUTT™ are located in the same folder as all other result files (My Documents/AquaMark3/...).

There are two ways to use this feature: Either you use the graphical user interface in the “Advanced Measurement” menu (cf. section 3.2) or you start the benchmark from a command line with specific options. This is sensible for measuring equal benchmark settings on a variety of test systems.

After performing at least one “Advanced Measurement”, there will be a file called “BenchConfig.txt” in the “My Documents/AquaMark3” folder. This file can be edited and/or copied to a different location in order to start AquaMark3 again with the same settings.

To start AquaMark3 with a certain BenchConfig file, type at a command prompt:

```
cd <path where AquaMark3 is installed>
AquaMark3.exe -bench <path to benchconfig>\BenchConfig.txt
```

You can also start multiple AquaMark3 measurements from one batch file (\*.bat).

The basic syntax of the BenchConfig file is fairly simple. Each row has a name and is separated by an equals sign. As an alternative to a precise value, an asterisk marks all possible values to be tested. Look at the generated BenchConfig file to see which values correspond to the graphical user interface setting.

## 3.7 Custom Option Configuration

The “Options” button in the main menu allows configuring the settings being used for a “Custom Measurement” and during “Demo Mode”.

### 3.7.1 Video (General)

Clicking the "Video" button at the top of the screen will open the Video → General menu. Two further sub-menus appear: Light and Detail.

All video menus offer loading one of five default settings by pressing the “Choose Preset” button. These presets are identical to the ones used in the “Advanced Measurement” for the level of detail setting.

If the graphics card does not support a particular feature in the video menu, it might not be available, i.e. appear as turned off.

The Video → General menu is used to define various image display parameters: Color depth, Resolution, Gamma correction, Full Screen Antialiasing, Texture filtering, VSync, Triple buffering, and Intel® Hyper-Threading Support.

The antialiasing options are simplified compared to the complex “Advanced Measurement” settings, i.e. the antialiasing mode is always set to “Non-maskable”, so only the quality level needs to be adjusted (cf. section 3.2).

### 3.7.2 Video (Light)

This menu activates or deactivates a variety of dynamic and static light effects for terrain and objects.

### 3.7.3 Video (Detail)

A range of game display parameters can be selected from the Video → Detail menu: Landscape detail, Additional terrain texture, Terrain detail texture, Objects detail texture, Plants, Plankton, Texture cache size, Particle detail, and Halos.

### 3.7.4 Audio

This menu allows adjusting the sound settings. The buttons at the bottom of the screen allow canceling the changes to the audio settings, resetting them to the defaults or accepting the changes. When you leave the Audio screen, changes are automatically accepted. The following Audio settings are available: Enable Sound, Sound quality, Use hardware for 3D sound, Number of channels, FX volume, and Music volume.

Note that the “Default settings” of this screen are the same as the ones used in an “Advanced Measurement” with enabled sound.

## 4 Benchmarking Method

The AquaMark3 measurements are technically a long cut scene running on an appropriately designed map inside the *krass*<sup>TM</sup> Engine. The actions of most objects are simulated in real-time using the artificial intelligence and physics system of the engine.

The simulation runs at a frequency of 25 Hz and after each simulation step one frame is drawn on screen by the rendering engine. On test systems that are incapable of doing one simulation and one rendering step within 1/25th second the benchmark will run slower than real-time. Typically, during a user-interaction phase of a game, you would reduce the frame rate in order to stay in real-time. During a benchmark however the results would not be reproducible if a certain number of frames wasn't rendered or the simulation frequency wasn't reduced. Especially on low-end systems the benchmark would become a CPU-centric synthetic benchmark if fewer frames were rendered than simulated and might result in no frames to be rendered at all. Alternatively, reducing the simulation frequency would impact the decisions of the artificial intelligence and might thus result in fewer or different visual effects; altering the benchmark results significantly.

The benchmark test shows different visual environment scenes, so called chapters, highlighting certain visual or game play specific features. In contrast to synthetic benchmarks however, these effects never stand alone, as they are always embedded in the complex context of a real-life game engine.

### 4.1 Chapter Details

#### 4.1.1 Dynamic occlusion culling

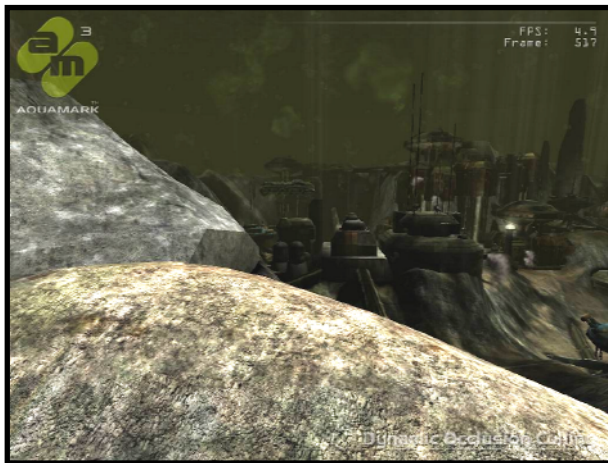
One of the serious problems in handling huge outdoor scenes in real-time 3D games is the detection of the potential visibility set of objects to be rendered (referred to as PVS). To extract the PVS it is necessary to test if an object is being occluded by other objects. For indoor scenarios with a well-defined geometry and short view ranges, this problem has been partly solved by algorithms like BSP rendering or portal techniques. Unfortunately, these solutions don't apply well to outdoor scenarios (especially dynamic ones). The *krass*<sup>TM</sup> engine solves this problem for the occlusion between objects and terrain, which is the most important portion of the problem. Think of an entire city consisting of hundreds of individual buildings for instance: If that city is occluded by a hill, no object needs to be rendered. AquaMark3 solves this problem by implementing a software rasterization process of the terrain geometry into a depth buffer. Before an object is rendered a conservative estimation of its bounding shape is transformed and tested for full occlusion. Because this task is purely CPU driven and no data is shared with relevant simulation data, it fits well to a *multi-threading* concept.

Before the rendering starts, every object is checked for its visibility with respect to the terrain. This query decreases the total amount of objects to be rendered significantly (~20% - 90%) and so leads to less load on the graphics hardware.



As shown above, AquaMark3 occlusion culling becomes important in cases, where a huge amount of individual objects is covered by terrain. This is the case in the first chapter, where the player's ship navigates close to the seafloor through a canyon. As it moves along, a large number of objects come into the range of sight, but the canyon walls obstruct the view for most of the time (see left picture).

**Picture 3a:** Dynamic occlusion culling active



Once the ship moves upwards, these formerly occluded objects become visible. Note the performance decrease (compare FPS display in screen-shots a & b), when this happens.

**Picture 3b:** Dynamic occlusion culling fails

#### 4.1.2 Many particles



In games particles are a common technique for volumetric effects with high visual quality yet efficient algorithmic computation. This chapter demonstrates a high number of particles being used for simulating dust and smoke. Other applications include explosions and weapon effects. In AquaMark3 each particle is approximated by a mass point with one degree of freedom for its rotation.

**Picture 4:** Large number of particles

### 4.1.3 Masked environment mapping

This chapter deals with the use of partial environment mapping on objects with highly specular materials. The environment map is modulated with a transparency map to determine the relationship of the incoming light contribution with the diffuse material computation.

### 4.1.4 Large scale vegetation system

To enrich the lifeless atmosphere of the sea bed the terrain system can be combined with a highly efficient animated plant rendering system that can generate a large number of similar, but colored and dynamically lit plants. Systems of this type become more and more popular, because they can be seen as a Level of Detail concept for simulated artifacts e.g. the plants in our case. In AquaMark3 this system is designed to fill the gap between rigid and animated objects. Each plant is animated individually and the animation supports the recognition of huge waves rolling over the sea floor.

AquaMark3 nearly puts the total computational load onto the graphics hardware by utilizing a concept



which we call “Hardware Driven Geometry Instancing”. Therefore the only task of the CPU is to deliver a plant’s size, position, rotation and color. This concept enables processing a huge amount of geometry on the graphics hardware. In this chapter, the number of polygons per second goes up to 25 million depending on the graphics hardware and the CPU, and so reaches the highest polygon throughput in the entire benchmark.

**Picture 5:** Large Scale Vegetation System (Hardware Driven Geometry Instancing).

### 4.1.5 Large scale terrain rendering

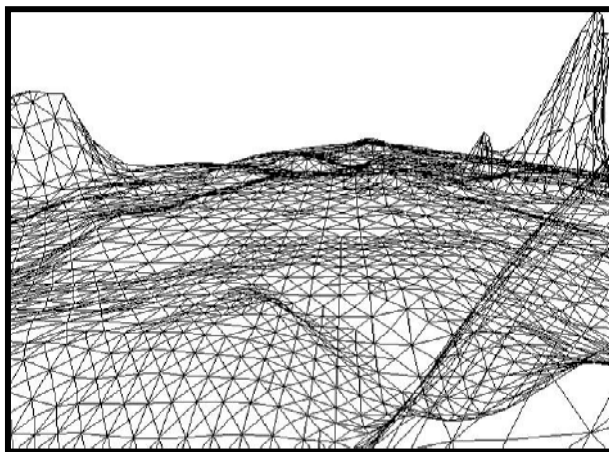
The AquaMark3 terrain system enables scenes with large viewing distances while still having complex surface materials with several detail and light textures. The AquaMark3 terrain database is represented by a discrete height map defined on a rectangular grid that covers the entire game world.



**Picture 6a:** Large viewing distances

The height data taken from satellite surface scans has been adapted manually to fulfil our requirements: it can be used to build the level structure and its tile can be repeated unlimited times in each direction without cracks.

On top of this data a continuous level of detail system (cLOD) is implemented, allowing the extraction of a view-dependent terrain geometry which is rendered later on. Depending on the “Landscape Detail” setting in the video options menu the cLOD system extracts a very simple (for low end hardware) or a very complex rendering geometry (for high end hardware).



**Picture 6b:** Quad tree based cLOD System

Because that data extraction is independent from other tasks, it can easily be executed in a **second thread**. In addition to the extracted geometry the terrain uses two base materials (sand and rock) combined with a base color map and a different detail map for each material. The material maps are combined with several light maps in a pixel shader.

#### 4.1.6 Vertex and pixel lighting



**Picture 7:** Different Lighting Models

The objects in this scene show a broad range of different material and lighting effects used in modern game engines. AM3 tests two things: It applies many vertex and pixel shader changes straining the graphics hardware and its many texture lookups (determining the lighting contribution and material reflectivity) also strain the texturing and rasterization components.

#### 4.1.7 3D Volumetric fog system



**Picture 8:** 3D volumetric fog on terrain and objects

AquaMark3 supports a 3D volumetric fog system providing a 2D texture for every object in the scene to be rendered. This texture should also be software-based to deal with visibility queries coming from ray casting systems which determine if an object can be “seen” through the fog from arbitrary viewpoints.

#### 4.1.8 Complex multimaterial shader

This section demonstrates different material shaders within single objects, different shaders representing different materials individually. Materials are determined by the following parameters:

- Number of simultaneous caustic maps
- Mask application of environmental maps
- Number of simultaneous light sources
- Number of simultaneous detail maps
- Fog map

### 4.1.9 Massive Overdraw



This scene demonstrates the application of the particle system for large explosions. For each particle a textured rectangle is drawn that gets blended over the previous frame buffer contents. The test stresses the graphics hardware by the high overdraw of textured areas as many particles overlap each other. To ensure correct screen results, the entire particle set is sorted in back to front order for each frame with respect to the viewer's position.

**Picture 9:** Massive overdraw caused by alpha blended particles



## 5 Rendering Techniques

The *krass*<sup>TM</sup> Engine uses a broad variety of rendering techniques and offers fine control of their application to both the content creators and the users. This chapter describes the basic algorithms behind the main techniques.

### 5.1 Vertex Shaders and Pixel Shaders

The following section gives a short overview of the shaders used in AquaMark3. It includes information about their number, their version, their destination, and their internal accuracy.

#### 5.1.1 Overall Number of Shaders

The effects and their variations are currently implemented by approx. 190 different vertex shaders and >35 pixel shaders. This large number of shaders together with the various non-pixel shader rendering techniques for DirectX 7 class hardware allow testing the rendering hardware and their resource management to its limits. This table shows an AquaMark3 shader overview.

API supported	Shader version support	Number of instructions per shader	Number of shaders
DX9	VS1.1 (DX8)	VS1.1 (DX8) : up to 70	VS1.1 (DX8) : 190
	VS2.0 (DX9)	VS2.0 (DX9) : up to 50	VS2.0 (DX9) : 3
	PS1.0 (DX8)	PS1.1 (DX8) : up to 13	PS1.1 (DX8) : 30
	PS1.4 (DX8)	PS1.4 (DX8) : up to 13	PS1.4 (DX8) : 5
	PS2.0 (DX9)	PS2.0 (DX9) : up to 40	PS2.0 (DX9) : 4

**Table 2:** Shaders in AquaMark3

#### 5.1.2 Floating Point Numbers in Shaders

AquaMark3 applies the whole range from FP16 to FP32 floating point accuracy. We think it's still the developer's decision which accuracy to apply for a certain effect to optimize the rendering efficiency. In general all effects created with floating point numbers that either cover a wide numerical range or that need to be represented by an exponent (as world space coordinates per pixel) benefit from a high internal precision (FP32). Especially effects using geometric information inside the pixel shader need high precision (e.g. high dynamic range illuminated normal mapping with a self shadowing term). AquaMark3 does not necessarily require this functionality, but we still use high internal precision for the texture coordinate iterators allowing effects which calculate texture coordinates based on world space positions (caustics, fog, detail maps etc.).

### 5.1.3 Partial Precision

The majority of AquaMark3 effects use partial precision hints, which are an official feature of DX9 shaders. Graphics hardware that supports multiple pixel-precision modes, will not run at the highest precision when it is determined that a lower precision mode will not affect image quality but increases performance. Graphics hardware that only supports one precision mode (DX9 requires at least FP24) is fixed at high precision and can not take advantage of partial precision hints to gain performance.

## 5.2 Chapter Techniques

### 5.2.1 Terrain

The terrain is stored in memory as a two dimensional height field which is converted into a view-dependent polygon mesh by a continuous level-of-detail algorithm.

For each terrain position a two dimensional texture contains material information that consists of a basic color and an identifier for a structure texture. An additional detail texture improves the appearance of close distance views.

The incoming light is calculated with up to four textures: one static light/shadow map, one dynamic light/shadow map, and two caustic maps. The static light/shadow map is precomputed with the level editing tool. The dynamic light/shadow map is a render target continuously updated with the results of rendering light sources and shadow silhouettes. The two caustic maps are animated textures simulating the light reflection and refraction of the sea surface.

The results of material and light calculation are multiplied and then processed by the fog computation. The fog system determines the visibility of objects by a precomputed integral that is stored in a texture (cf. section 5.2.2). This texture is mapped onto the terrain as a final texture layer to generate a volumetric fog effect.

### 5.2.2 3D Volumetric Fog system

Currently the majority of hardware that customers have installed does not support hardware accelerated volume textures. To meet this challenge we designed a small workaround: we put the texture data set into the CPU main memory and extract one fog texture slice for each rendered frame. This slice is uploaded to the hardware and used as a standard 2D texture. To access this fog texture we apply the following parameters which give us the texture parameterization.

- observer's vertical position (origin of camera in world space)
- difference between vertical positions of vertex and observer
- distance between camera and vertex (linear norm is sufficient)

Knowing the maximum distance (far plane) and the maximum height and depth of the covered game world makes it possible to map the three values to the 3D texture coordinates (u, v, w). Because the observer's vertical position remains constant for one frame, this parameter is used as the fixed

coordinate (w) to extract one texture slice (constant z) from the 3D data by linear interpolation. This fog texture is applied to the rendering of every object and must be the final pass of each object's rendering sequence. So depending on the hardware and the number of supported texture layers this pass has to be modeled as an additional multi-texture layer or as an additional rendering pass.

### 5.2.3 Objects

Objects in the scene can have two basic types, static or dynamic. Static objects include buildings, rock formations and other fixed geometric landscape details. All those objects can be equipped with a precomputed static light map in the level editing tool for basic light and shadow information. Dynamic objects like ships, vehicles, and movable defense turrets do not have a static light map.

All objects can have dynamic vertex based lighting. Additionally lighting information is based on an environment map, whose contribution to the overall lighting is based on a grayscale map. Finally up to two caustic maps are added to the lighting.

The material color is computed from a basic color texture, a detail texture, and optionally an emissive component. The material calculation combined with the result of the lighting computation and fog textures make up the final result.

### 5.2.4 Particle Effects

The main problem when rendering particles is that they are usually rendered with alpha blending. This blending operation is a very simple approximation of two terms called emission and transmission. Where the color defines the intensity of light (and its color) emitted by the individual particle, the alpha component represents the absorption of the light which goes through the particle (density). Unfortunately, the alpha blending operation of many individual particles depends on the order of rendering. Strictly speaking to obtain a correct result, all particles have to be sorted in terms of their distance to the viewer. This process is independent from the main simulation tasks (collision, physics, artificial intelligence etc.) and so has been transferred to a **second thread**.

The particle system is designed to render a large number of physically accurately simulated particles as efficiently as possible. The physical simulation allows particles to be emitted from a moving position, with a randomly selected velocity, trajectory, orientation, and rotation velocity. Additionally the life time of each particle is randomly computed. Based on the age of a particle the color, opacity and, if present, a texture animation key frame are selected. The artists can confine all random values to a certain interval.

For each particle two triangles need to be rendered with the parameters based on the physical simulation. To avoid having a large number of rendering calls to the graphics driver, the particles are not drawn separately, but in as large batches as possible. If you are interested in the details of the batching concept, then refer to the plant system render technique below, as it applies the same method. In order to apply this concept to the particle system the varying data of each particle is encoded into two vertex shader constants per particle, and the vertex shader decodes this data and places correctly lit and transformed particles into the scene.

## 5.2.5 Plant System

The plant system is designed to render as many plants as possible without affecting the CPU significantly. The plant renderer is able to render up to 32 plants within a single draw primitive call. To achieve this, the rendered mesh does not include one plant model only. Instead it includes 32 instances of the same model. All instances are located at the same origin in model space and are rotated randomly around the vertical axis to introduce some visual variation without affecting the runtime performance. For each vertex the index of the current plant instance to which the vertex belongs is stored together with its position, normal, color and texture coordinate.

The data layout for the corresponding vertex shader is simple. Together with the standard data like matrices, light sources etc. the constant registers are used to store the world position, the color and the scale of each individual plant. Each plant requires two constant registers, so the number of plants rendered within one batch is only limited by the number of vertex shader constants supported by the hardware.

Large plants are additionally animated to simulate their movement in flowing water. To achieve this, the head of each plant is shifted both horizontally and vertically with a large-scale wave movement. The whole animation is computed inside the vertex shader allowing smooth deformations of the plant body.

## 6 Additional Techniques

### 6.1 Hyper-Threading Technology (Intel® Pentium® 4 processor)

AquaMark3 demonstrates a sensible use of multi-threading techniques in current and future 3D high-end games. To obtain the maximum benefit of the multi-threading techniques the current *Intel® Pentium® 4 processor with Hyper-Threading Technology* is a very powerful yet simple concept which will be widespread very soon. AquaMark3 offers several different approaches where multi-threading makes sense in the games context. If you consider the current state-of-the-art, these approaches might easily lead the way for future game development.

There are three different chapters where AquaMark3 uses *Intel® Pentium® 4 Hyper-Threading Technology* in different techniques. All of these techniques do not affect the functional progressing of the benchmark simulation itself. They are used to execute visualization related pre-processing tasks. This approach increases the overall performance of the application to provide the player with a higher visualization refresh rate. The following benchmark chapters support the *Intel® Pentium® 4 Hyper-Threading Technology*:

1. Dynamic Occlusion Culling System for Outdoor Scenarios
2. Real-time Terrain Tessellation from Quad-Tree based cLOD Data
3. Culling and Sorting of Alpha-Blended Particles

In the according chapter the different implementations using the *Intel® Pentium® 4 Hyper-Threading Technology* are discussed in more detail. Apart from a short description of the problem and its solution, we motivate the use of the multi-threading approach.

### 6.2 Licensed Technologies

AquaMark3 utilizes the following third-party technologies:

- Entech™ technology [<http://www.entechtaiwan.com>] to detect the clock speed of the graphics hardware.
- FMOD™ sound system [<http://www.fmod.org>]

## 7 Measured Data

The most important measurement in game-based benchmarks like AquaMark3 is the average number of frames per second (*AvgFPS*) easily calculated by dividing the total number of frames in the benchmark by the duration the benchmark needs to complete. The benchmark does not include the first 20 frames in the measurement to avoid counting uneven frame rates that occur during the first frames of each benchmark, when several subsystems are still initializing.

To get deeper insight refer to the text output files of the benchmark, below the “My Documents /AquaMark3” folder. These files are the basis for further evaluation and can be read with any text editor.

In addition to the *AvgFPS* value, the textual output files contain the minimum and maximum frames per second value (*MinFPS*, *MaxFPS*). These are based on one second averages of the frames per second value.

Two other *AvgFPS* values can be found in the output files: The *AvgFPS CPU* and the *AvgFPS GFX* that are both based on single frame measurements. Each frame takes a certain amount of time to complete. The first part of each frame calculation is spent on simulating the game physics and artificial intelligence on the CPU, the second part is spent on rendering the graphics. Both parts are measured independently. Based on these values the two theoretical *AvgFPS* values are computed, as if each of these frame parts would have been processed individually. Note that the absolute value of these two measurements is of theoretical nature, but considering these values in relation to values of other test systems allow a performance judgment of the two mainly stressed components.

The *AvgFPS CPU* is a fairly precise indicator of the CPU performance in combination with the motherboard and system memory. However the *AvgFPS GFX* does not only judge the performance of the graphic card. It also depends on the CPU and system memory, since graphic card drivers and the operating system contribute to the measurement.

Other measurement values include the triangle throughput (*Avg/Min/Max-TrianglesPerSecond*) that measures the number of triangles sent to the graphics card during a certain amount of time. Note that some objects are rendered several times during multi-pass algorithms, and so are counted several times. Graphics cards that support only few simultaneous textures or cards that do not support advanced pixel shaders will have to render more, but simpler triangles. Therefore the triangles per second measurement has to be judged with caution.

In the detailed frame based measurement reports there is also the number of triangles and vertices that has been processed within each frame. Four numbers describe the visual complexity of each frame: The number of rendered objects (*NumOfRenderedObjects*), the number of culled objects (*NumOfCulledObjects*), the number of visible particles (*NumOfVisibleParticles*) and the number of visible plants (*NumOfVisiblePlants*). Objects are rendered when they are within the field of view of the camera and not culled by the occlusion culling system. The objects that are within the field of view, but are culled contribute to the number of culled objects. The number of visible particles and plants depends on the field of view, but not the occlusion culling, as particles and plants are never culled.

## 7.1 Final Score Computation

The AquaMark3 Score, as computed during a Score Measurement (cf. section 3.1), is based on three measurement values described in the previous chapter.

The total score is based on the average frames per second which is the total number of frames divided by the time the benchmark needs to complete. The AvgFPS value is multiplied by 1000 and the result is the AquaMark3 total score. The value of 1000 has been explicitly chosen to scale the result on high-end desktop PC at the time of release to a value of approximately 50 000.

The CPU and graphics scores are based on the AvgFPS CPU and AvgFPS GFX described in the previous chapter. These values are scaled by 50 and 100 in order to be both between 6 000 and 8 000 on a high-end desktop PC.

A high-end desktop PC at the time of release has a fully DirectX 9-compatible graphics card and a CPU of 3 GHz nominal value.

Note that the scaling of CPU and GFX score are based on the assumption that the above mentioned high-end system has a matching performance of both subsystems for action-based computer games. Other genres of games or the gamers' preference might be better represented by different weighting factors. All useful basic measurements are provided in the associated text files and can be analyzed with different score computation formulas according to the user's preference.

## 7.2 Benchmark Results

After the benchmark is finished, the most important results are displayed on screen. For each benchmark pass an average triangles per second value and an average frames per second value is displayed. By pressing the "More" button you can also see the performance for each of the nine chapters of AquaMark3.

Much more data than displayed on-screen is in text files created by the benchmark. These files are also stored in a folder called "AquaMark3" below the Windows "My Documents" folder. Each benchmark creates a subfolder with the date and time of the start of the measurement. There are at least two files in each of these folders: One is called "Summary.txt" and contains the most important results of all benchmark passes, the other file is called "Details Pass 01.txt" and contains detailed information up to per-frame measurements of the first benchmark pass. There are detail data files for each pass result of the automated testing technique AUTT™.

All text files contain plain text, measurement data is separated by tab-stop characters and numbers are written in Standard English decimal style. For further analysis this format can be easily imported into most spreadsheet software, e.g. Microsoft® Excel.

## 8 Evaluation

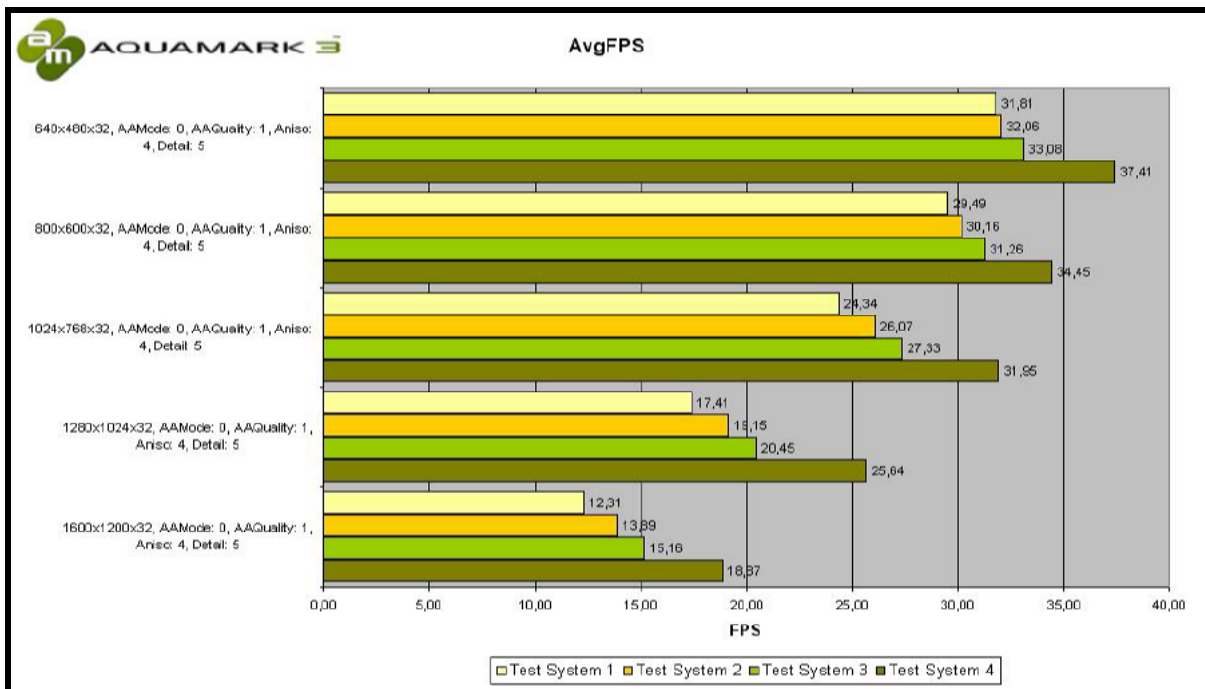
AquaMark3 supports multiple methods to evaluate your recorded data. You can either evaluate your data on-site supported by a Microsoft® Excel spreadsheet or evaluate your results online. Online evaluation is very powerful, but on-site evaluation might make more sense if you want to benchmark your own system configurations and don't want them to be distributed or published.

### 8.1 On-site Evaluation

AquaMark3 comes with a handy Microsoft® Excel spreadsheet (*AquaMark3\_Analysis.xls*) which allows you to compare up to 4 measurements to each other. The spreadsheet can be selected and started from the installed program folder. To use the sheet it's necessary to activate macro execution in your Excel application. Once the spreadsheet is loaded, you can select one of the 4 data sheets (Name: Data Sheet 1-4) and load a specific measurement ("summary.txt") into the selected sheet by clicking the "Load Data" button. Note that when you use different "summary.txt" files in the 4 data sheets, only benchmark runs with *identical settings across all sheets* will be shown. Alternatively, you can also open the "summary.txt" file manually and copy and paste the individual lines of multiple summary files into one data sheet.

Use the predefined table named "Chart Options" to select the parameter for comparison. You can only compare result parameters available in ALL of the loaded data sheets. For instance, if the polygons/second number lacks in one of three measurements you will not be able to compare the other two to each other unless you delete the third "incomplete" measurement.

Apply every change to the application by pressing the "Apply Changes" button. After a short computing time, you can select the table called "Chart" and see the result of your comparison:



**Picture 10:** Charts from Microsoft® Excel sheet to compare measurements on-site.



## 9 AquaMark3 – Online services (<http://www.aquamark3.com>)

### 9.1 The AquaMark3 Forum

We set up a forum for AquaMark3 together with [www.aquamark3.com](http://www.aquamark3.com). It works just like any other professional hardware forum: create a nick, define a password, enter your valid e-mail address and off you go.

To bring the forum and our AquaMark3 Result Comparator ARC™ together you can easily swap from one to the other. Your login for the forum is valid for ARC – and vice versa, so one login fits both!

### 9.2 AquaMark3 Result Comparator ARC™

AquaMark3 comes with its own AquaMark3 result comparator called ARC™ you'll find on the <http://www.aquamark3.com> website. The ARC™ is designed to be the meeting place for every AquaMark3 user in order to:

- easily administrate his test results even of multiple test runs
- share his results with others
- compare results to other results in the ARC database
- get exact information about the best upgrade for his system
- get all necessary information without confusing data overflow
- communicate with other AquaMark3 users in the AquaMark3 forum

We hope the AquaMark3 ARC™ will become the public scoreboard needed to encourage discussions. After uploading your test results, be it a single run or an automated test series, you can either overview or administrate your results (1<sup>st</sup> step), search for other results and sort them (2<sup>nd</sup> step) and in the last step (3<sup>rd</sup> step) thoroughly compare one of your results to another one. A plain hierarchy of web pages realizes this three step concept. The following picture gives you a short impression of the 3 step concept and its related web pages.



**Picture 11:** Overview on the 3 steps concept to manage the AquaMark3 measurements.

## 9.2.1 AquaMark3 ARC™ – Overview

The AquaMark3 application can directly submit each measurement thus creating a new entry in the ARC database. Use the ARC overview page to manage your uploaded AquaMark3 measurements and just delete measurements you have accidentally submitted more than once.

## DATE: is the submit date and time

## Delete: click here to delete the measurement and all its runs, you will get a confirmation message on top of this page

## CPU: Central Processing Unit / Processor

## HT: Intel Hyper Threading, only displayed on capable CPUs. On = Enabled for Measurement, Off = Disabled

## CR: CPU clockrate frequency in MHz (MegaHertz)

## SRAM: System MainMemory in MB (MegaByte)

## OS: OperationSystem

## GFX: Graphics Adapter Card

## CM: the GFX's Core and Memory clockrate in MHz (MegaHertz)

## VRAM: the GFX's

#	AquaMark Score	RES	AA	AF	FPS	TPS	DETAILS
# 1	AquaMark Score: 3014 (CPU: 3498, GFX: 315)	1024x768 x 32bit	AA: Off	AF: 4x	FPS: 3.01	TPS: 530 K	<a href="#">Compare</a>
<b>Public Measurement:</b> Benchmark test namens änderung (2003-05-07 10-26-33) <a href="#">Change Name</a>							
DATE: 2003-05-13 12:57:27 <a href="#">Set this Measurement to be private.</a> <a href="#">Delete this measurement</a> CPU: AMD Athlon(tm) XP 2100+ CR: 1698 MHz SRAM: 512 MB OS: Microsoft Windows XP GFX: NVIDIA GeForce4 TI 4600 CM: 300 / 648 MHz VRAM: 128 MB DRIVER: 6.14.1.4345							
# 1	AquaMark Score: n/a (CPU: n/a, GFX: n/a)	1024x768 x 32bit	AA: Off	AF: Off	FPS: 28.59	TPS: 3906 K	<a href="#">Compare</a>
# 2	AquaMark Score: n/a (CPU: n/a, GFX: n/a)	1024x768 x 32bit	AA: Non-mask Q1	AF: Off	FPS: 25.44	TPS: 3196 K	<a href="#">Compare</a>
# 3	AquaMark Score: n/a (CPU: n/a, GFX: n/a)	1024x768 x 32bit	AA: Non-mask Q2	AF: Off	FPS: 25.42	TPS: 3193 K	<a href="#">Compare</a>
# 4	AquaMark Score: n/a (CPU: n/a, GFX: n/a)	1024x768 x 32bit	AA: Non-mask Q3	AF: Off	FPS: 14.47	TPS: 1816 K	<a href="#">Compare</a>
# 5	AquaMark Score: n/a (CPU: n/a, GFX: n/a)	1024x768 x 32bit	AA: Non-mask Q4	AF: Off	FPS: 19.41	TPS: 2440 K	<a href="#">Compare</a>
<b>Public Measurement:</b> Benchmark 2003-05-07 10-37-44 <a href="#">Change Name</a>							
DATE: 2003-05-13 12:57:29 <a href="#">Set this Measurement to be private.</a> <a href="#">Delete this measurement</a> CPU: AMD Athlon(tm) Processor CR: 991 MHz SRAM: 512 MB OS: Microsoft Windows XP							

**Picture 12:** Overview page.

The following actions can be performed on the overview page:

- **Navigate through Measurements**

Up to 5 measurements are displayed at a time. To navigate through all measurements, click on the "Next Page >>" or "<< Previous Page" links.

- **Name & Rename Measurement**

To name or rename your measurements enter the name in the text field and save it by clicking on the "Change Name" button.

- **Delete Measurement**

To delete a measurement with all its included runs click on the "Delete this measurement" link. For final deletion you have to confirm this action in the following request message.

- **Publicize for comparison**

To make the measurement with all its included runs available to the public, click the "Set this Measurement to be public" link. If a measurement is marked as public, other users will have read access to your data for searching and comparison purposes. To reverse this action, please click on the "Set this Measurement to be private" link.

- **Select to Compare**

To start a comparison between one of your measurements and all public measurements available in the database, simply click on the "Compare" link behind one of your measurement's runs.

## 9.2.2 AquaMark3 ARC™ – Search

On this page you can search our database for comparative measurements. All measurements set to be public can be accessed and selected for a comparison with your measurement.

**Picture 13:** Upper part of the search page.

You can select the following criteria to specify your search.

- **Basic Search Criteria**

You can set the basic search criteria in the upper part of the page. If you click on the "Use My Measurement" link, the corresponding value of your currently selected measurement is copied into the input field. If you click on the "Search for Any" link, all available values for a certain search criterion are taken into account, thus extending your search. You have to specify a minimum-maximum range to search for numerical values such as frequencies, as these values show a marginal variation on different systems. If you search for measurements which contain roughly the same values as yours, use the "Approximately" button. This will cover roughly a +/- 5% searching range based on your measurement's value.

- **Extended Search Criteria**

In the middle part of the page you can set the extended search criteria which include detailed settings for graphics card features or internal quality settings of AquaMark3.

- **Reset Search Criteria**

If you're unsure about the current settings, made a mistake or just want to reset all selections, click on the "Reset all criteria fields" link.

- **Compare Criteria**

The AquaMark3 measurements contain multiple scores which can be used to sort the results

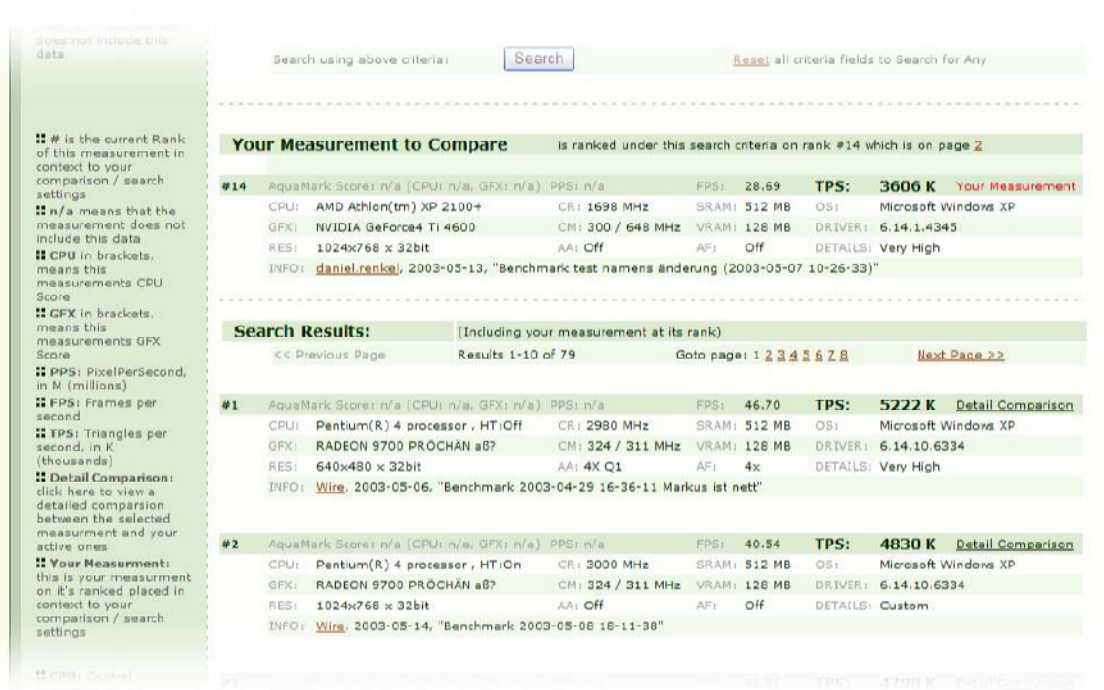
of the search query. Scores marked with gray color or a not/available (n/a) tag aren't part of a selected measurement.

- **Search & Search Results**

Click on the "Search" link, to obtain all measurements compatible with your basic and extended search criteria. Up to 10 measurements are displayed at a time. To navigate through all measurements, click on the "Next Page >>" or "<< Previous Page" links or choose a specific page by page number. Your currently selected measurement run will be shown in the search results, with its rank determined by the compare criteria. Your own measurement is marked by a red "Your Measurement" tag on the right, making it easily identifiable.

- **Detail Comparison**

Click on the "Detail Comparison" link in the upper right corner of the specific search result you want to compare you measurement to.



The screenshot shows a search results page with a search bar at the top. Below the search bar, there is a section titled "Your Measurement to Compare" which is ranked #14. This section lists various hardware and software specifications for the measurement. Below this, there is a "Search Results:" section showing a list of search results. The first result is ranked #1 and the second is ranked #2. Each result includes a table of specifications such as CPU, GPU, RAM, and OS. The page also includes navigation links like "Previous Page", "Next Page", and "Goto page: 1 2 3 4 5 6 7 8".

**Your Measurement to Compare** is ranked under this search criteria on rank #14 which is on page 2

#14	AquaMark Score: n/a (CPU: n/a, GFX: n/a)	PPS: n/a	FPS: 28.69	TPS: 3006 K	Your Measurement
CPU:	AMD Athlon(tm) XP 2100+	CR: 1698 MHz	SRAM: 512 MB	OS: Microsoft Windows XP	
GFX:	NVIDIA GeForce4 TI 4600	CM: 300 / 648 MHz	VRAM: 128 MB	DRIVER: 6.14.1.4345	
RES:	1024x768 x 32bit	AA: Off	AF: Off	DETAILS: Very High	
INFO:	daniel.renke), 2003-05-13, "Benchmark test namens änderung (2003-05-07 10-26-33)"				

**Search Results:** (Including your measurement at its rank)

<< Previous Page Results 1-10 of 79 Goto page: 1 2 3 4 5 6 7 8 Next Page >>

#1	AquaMark Score: n/a (CPU: n/a, GFX: n/a)	PPS: n/a	FPS: 46.70	TPS: 5222 K	Detail Comparison
CPU:	Pentium(R) 4 processor , HT:Off	CR: 2980 MHz	SRAM: 512 MB	OS: Microsoft Windows XP	
GFX:	RADEON 9700 PROCHÄN a8?	CM: 324 / 311 MHz	VRAM: 128 MB	DRIVER: 6.14.10.6334	
RES:	640x480 x 32bit	AA: 4X Q1	AF: 4x	DETAILS: Very High	
INFO:	Wing, 2003-05-06, "Benchmark 2003-04-29 16-36-11 Markus ist nett"				

#2	AquaMark Score: n/a (CPU: n/a, GFX: n/a)	PPS: n/a	FPS: 40.54	TPS: 4830 K	Detail Comparison
CPU:	Pentium(R) 4 processor , HT:On	CR: 3000 MHz	SRAM: 512 MB	OS: Microsoft Windows XP	
GFX:	RADEON 9700 PROCHÄN a8?	CM: 324 / 311 MHz	VRAM: 128 MB	DRIVER: 6.14.10.6334	
RES:	1024x768 x 32bit	AA: Off	AF: Off	DETAILS: Custom	
INFO:	Wing, 2003-05-14, "Benchmark 2003-05-06 16-11-36"				

**Picture 14:** Lower part of the search page (detailed comparisons).

### 9.2.3 AquaMark3 ARC™ – Detailed Comparison

This page shows a detailed comparison between your measurement and the comparative measurement you selected on the previous page. It visualizes your measurement's scores and lists detailed information about both systems underlying the measurements.

- **Measurements to Compare**

The upper measurement tables show the selected measurements compared to each other and include general information for each measurement.

- **Bar Charts**

The middle part of the page contains different bar charts, giving a quick overview about the performance relation between your measurement and the comparative measurement selected from the search results on the previous page. The graphical bars show the different TRISCORES™ and multiple Per-Second numbers (if available in measurement data set) in relation to the comparative measurement. For each bar the number taken from your measurement defines the 100% value (green bar). The other measurement's bar is displayed in relation to this basis, e.g. percentage values greater than 100% can occur. Bars marked with gray color or a not/available (n/a) tag refer to scores that aren't part of one of the two measurements.

- **Detailed System Information**

On the lower part of the page, you find detailed information on both systems - your measurement's system on the left side, the comparative measurement's system on the right side.



**Picture 15:** Detailed comparison page.

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## 9.3 AquaMark3 ARC™ – Security

### 9.3.1 How do we get the data?

We only take the data we need, and what is even more important: **we don't** publish anything. If you don't want people to know about your system, you don't have to make any of your results public. All measurements are listed as private per default on your overview page.

We don't take any data unnecessary for result comparison and all the information we take will be displayed in your test results.

### 9.3.2 What is this information good for?

Of course you can keep the test results to yourself, but to be honest: that's not what benchmark results are for. We think it's a good idea to compare them with other people also willing to share their results. Now if you're a hardware specialist, you know what to do with your system after running the benchmark and checking in the ARC, but you probably have a killer machine anyway.

So how about joining our forum and helping other people to determine the weak spots in their systems? They have the data, you have the knowledge. But if you don't... finding someone there who does, is very simple.

## 10 Credits

Managing Director **Alexander Jorias**

Technical Director **Ingo Frick**

Lead Programmer **Lutz Latta**

Lead Webdesign **Daniel Renkel**

Text & Communication **Wolfgang Walk**

Lead Artist **André Weiss**

Graphics **Tobias Reis**

Editor **Sieggi Fleder**

Level Design **Björn Braun**

**Philipp Schreiber**

Programming **Mark Novozhilov**

**Christoph Lürig**

**Markus Wiekenberg**

Office Management **Reni Schmidt**

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