1-1-1997

Graphics Performance Benchmarks: Summary Report

Kamal Elkhoury

Maruf Ahmed

Brian Goldiez

INSTITUTE FOR SIMULATION & TRAINING

Contract Number N61339-97-K-0009
STRICOM
June 18, 1997

Graphics Performance Benchmarks

Summary Report

Authors:
Kamal Elkhoury, Maruf Ahmed
Brian Goldiez

Institute for Simulation and Training
3280 Progress Drive
Orlando FL 32826

University of Central Florida
Office of Research & Graduate Studies

IST-CR-97-24

INSTITUTE FOR SIMULATION AND TRAINING

Graphics Performance Benchmarks
Summary Report

IST-CR-97-24
June 18, 1998

Prepared For:
STRICOM
Contract Number N61339-97-K-0009

Authors:
Kamal Elkhoury, Maruf Ahmed
& Brian Goldiez

Institute for Simulation and Training • 3280 Progress Drive • Orlando, Florida 32826
University of Central Florida • Division of Sponsored Research

TABLE OF CONTENTS

1. Introduction

We have studied seven different benchmarks for OpenGL and/or Direct3D. These included Picture-Level Benchmark, 3D WinBench 97, Gemini's Real World 3D, ViewPerf, Intellibench, D3DBenchMark, and WizMark. Among these, PLB, Viewperf and Wizmark are the three benchmarks that we think should be considered for further implementation and study, in order to understand the performance measurement technique of benchmarks.

No one test evaluates all of the parameters and configurations in today's graphics systems. In addition, many of the factors important to the Modeling and Simulation community are not evaluated by any of the graphics systems. Among these include, for example, dynamic paging, support for moving models, overload control, and dynamic scene effects. Performance tests should be developed which are relevant to the needs of the M&S community. Development of tests should seek to use many of the same measurement techniques embedded in the tests, above, but augmented with application across a broader range of products and inclusive of relevant M&S parameters. Both of these goals are achievable.

2. Picture-Level Benchmark (PLB)

2.1 Overview

The Picture-Level Benchmark (PLB) is a software package that provides an "apples-to apples" comparison of graphics display performance for different hardware platforms, and it is designed to measure the performance of CRT-based system.

It is developed by the GPC (Graphics performance characterization) group, which have members from various companies. Digital Equipment Corp., Hewlett-Packard, IBM, and Sun Microsystems. For more information refer to:
URL: http://www.specbench.org/gpc/plb.static/overview

2.2 PLB includes six major components

- The Benchmark Interchange Format (BIF), the file format for specifying the geometry and actions that will be performed in a test.
- The Benchmark Timing Methodology (BTM), which provides a standardized performance measurement.
- The Benchmark Reporting Format (BRF), for standardized reporting of test results.
- The Picture-Level Benchmark (PLB) program, which implements BIF file processing and runs the test.
- A suite of files for testing PLB implementation.
- A suite of BIF standard benchmark files that are used for graphics performance tests.

2.3 Operating Environment

Its availability under OpenGL will make the PLB accessible to a wider range of graphics users and vendors. The PLB program itself is platform-dependent. In order to run BIF files, someone (most likely the vendor) has to adapt the PLB code for a specific hardware configuration. The minimum system requirement are:

- 16MB of memory for windows 95
- 50MB hard disk
- IBM PCs compatible

2.4 Features

The most exacting method of performance measurement is for users to convert their applications into BIF files and run them directly on the vendors' ports to the PLB program. If the user doesn't have the time or technical expertise to do this, the PLB project group provides BIF eight separate files that are divided into three categories:
3-D wireframe (sys_chassis, race_car), 3-D surface (cyl_head, head, shuttle, studio) and "other(oceantopo). The user can run tests based on those kinds of applications.

2.5 Advantage

- The benchmark provides eight standard benchmark files for graphics performance.
- PLB software measure graphics performance in same way across different proprietary API.
- The benchmark and testing files are available via Internet.

2.6 Disadvantage

- The performance result is reported in one number.
- It doesn't tell how the number is calculated.
- It is platform dependent.

2.7 Method for reporting results

The result is reported into the two specific categories; PLBwire93 and PLBsurf93. These numbers represent the geometric mean of the PLBlit and PLBop for the standard benchmark files.

"PLBlit.": This is a literal number aimed at graphics users who want to measure performance for the same graphics entities from one platform to another and who are unable or unwilling to tune their applications to a particular hardware system or graphics interface. The PLBlit number reflects an application file that is run without optimizations.

"**PLBopt.**": This is an optimized number for those users who are willing to tune their applications to achieve better performance on specific hardware platforms with specialized graphics interfaces. The PLBopt number shows the best possible performance for a vendor's specialized hardware configuration and Application Programmer's Interface (API).

A typical performance number for a standard benchmark file, such as "sys_chassis," looks like this: PLBlit : PLBop
31.1 : 35.2
The "Sample report" shown below contains an explanation of how the result is reported and a description of the system used to achieve the graphics performance result reported.

"Normalizing Factor" is the scaling factor used to keep numbers from becoming too unwieldy, and the PLBlit and PLBopt columns give the reported PLBmark scores for each test.

Test files: Are the BIF files that provide by PLB project group for different categories.

2.8 Sample Report

Vendor and System Name Graphics Adapter	API
Composite PLBmarks	
PLBwire93	PLBwire93
PLBsurff937	PLBsurf93

Benchmark Name	Normalizing Factor	PLBmarks	
		PLBlit	PLBopt
Test files	3D Wireframe		
1. sys_chassis	N	lit	opt
2. race_car	N	lit	opt
3. seafloor	N	lit	opt
	3D Surface		
4. cyl_head	N	lit	opt
5. head	N	lit	opt
6. shuttle	N	lit	opt
7. studio	N	lit	opt
	Other		
8. oceantopo	N	lit	opt

This is a description of the system used to achieve the graphics performance results.

GRAPHICS HARDWARE CONFIGURATION		SYSTEM HARDWARE CONFIGURATION		SOFTWARE CONFIGURATION	
Graphics Accelerator	name	**Processor Type**	name	**Operating System**	O/S
Total Graphics Memory	## MB	**Number of CPUs**	#	**Window System**	name
Image Buffer	size	**Floating point**	type	**API**	name
Overlay/Underlay Bufferb	size	**Primary Cache(KB)**	## (KB)	**API Version**	id
Image Buffer	size	**Secondary Cache (KB)**	## (KB)	**API Vendor**	name
Image Buffer	size	**Memory (MB)**	## (MB)	**PLB Version**	id
Accumulation Buffer	size	**Disk (MB)**	## (MB)	**Driver Version**	id
Auxiliary Buffer	size				
Other Buffer	size				
Display List Memory	Description				
Texture Memory	Description				
Display Manufacturer/ Model*	Description				
Display Resolution	Width x height				
Display Size/Type	Description				
Display Refresh Rate	## Hz				
Swap on Vertical Retrace	yes/no				

3. 3D - WinBench 97

3.1 Overview

3D WinBench 97 measures the performance of a PC's 3D subsystem, which includes the Direct3D software, the monitor, the graphics adapter, the graphics driver, and the bus used to carry information from the graphics adapter to and from the processor subsystem.
3D WinBench 97 is developed by Ziff-Davis Benchmark Operation (ZDBOP).

ZDBOP is a division of Zaff-Davis dedicated to research and development of the core, publicly available benchmarks ZD publications worldwide use for performance testing.

3D WinBench 97 only runs on Windows 95 and Windows NT 4.0 with Service Pack3 WinBench 97 aims to measure both the current and future state of hardware 3D accelerator performance. For more information refer to:
http://www.fourthwave.com/wave/wave710.htm

3.2 Operating System

- 3D WinBench 97 runs on Windows 95 and Windows NT 4.0 with Service Pack3
- Window NT with Service Pack 3 support Direct3D through software emulation only. It does not support hardware acceleration of Direct3D.

Hardware configuration:

- 16MB of memory for Windows 95.
- 32MB of memory for Windows NT.
- 40MB Hardisk
- IBM PCs Compatible computer.

3.3 Features

3D WinBench 97 is split into three different types of testing functionality: Quality test, WinMark and triangle tests.

3.3.1 Quality tests

Quality test help to accurately determine a 3D accelerator's rendering. This suite of tests shows how a scene should appear if an accelerator correctly implements the associated feature. You would then compare that image to the one the accelerator actually renders. The tester needs to subjectively determine the rendering quality because Direct3D currently provides no precise definition of how a pixel should appear.

3.3.2 WinMark

The 3D WinMark test suite runs a series of 10 scenes that vary in both complexity—the number of triangles they use to form their images—and the number of quality-enhancing options (such as fog and specular highlights) they employ. Each test flies through a scene using predefined paths and measures the rendering speed in frames per second. This suite returns an overall, unitless 3D-WinMark result summarizing the computer's 3D

performance. Individual 3D WinMark tests or additional scene tests not included in the suite can also be run to return a frames-per-second score.

3.3.3 Triangle Tests

The 3D Triangle Tests suite draws triangles of a fixed size and quality level at the fastest rate possible using Direct3D Immediate Mode. You can use the suite and its individual tests to verify a 3D accelerator manufacturer's performance claims for triangle setup and pixel fill rates. However, triangle test results are harder to relate to real-world application performance. The benchmark breaks down the results (in either triangles per second or pixels per second) according to the size of the triangles involved. You can also run individual triangle tests and user defined tests may be also run.

3.4 Advantage

- Hardware capability configuration. The benchmark has the ability to turn off features supported by hardware.
- Provides three types of testing; Quality tests, WinMark and Triangle tests.
- The Software program files are available via Internet and it is free.
- An easy user interface.

3.5 Disadvantage

- The quality test does not address quality issues outside of the score of the individual tests. That is each test asks the user to determine whether the specific quality being tested is working properly.
- The triangle size is fixed to 5 and 50, so it lacks flexibility it would be useful to run tests over ranges of triangle sizes.
- It is limited by 640x480 screen resolution.
- The 3D scenes are in ".sdl" format, so users cannot import their own databases from other formats, and are limited by the 10 databases included with the benchmark.

3.6 Method for reporting results

Results are displayed in the common ZD-BOP format, with both numeric results and colored bar charts, which can be displayed in either absolute (actual numeric score) or normalized (% fraction) mode: Result are report for:

3D Quality Tests - Results display a table listing the parameters tested, indicating whether or not each one was correctly implemented (as decided by the user).

3D Triangle Tests - Results are given in triangles/sec for both triangle sizes of size 5 and 50 as well as pixel fill rate for triangles of size 50 and 1000

3D WinMark - Results are given in frames/sec as well as a single "3D WinMark" score, although it is not clear what the intrinsic value of this number is or how it is derived results for RGB software emulation and the Orchid Righteous 3D for comparison purposes.

4. Gemini's Real World 3D

4.1 Overview

Gemini's Real World 3D developed by Gemini Technology. Gemini coined phrase "re2stone" to rate the relative performance of 3-D graphics system. An re2stone indicates the performance of each benchmark test on the following Onyx RE2 configuration (fairly typical for RE2 users):

- RealityEngine2 (RE2) graphics subsystem
- two raster managers (two RM4 boards)
- R4400 250 MHz CPUs (ip19 processors)

For example: A system which has a rating of 0.5 re2stones would be considered to be half as fast as an RE2 in that same particular test. An average re2stone rating for each benchmark (gvf, gvr, gvt) is computed and is available for each system tested.
For more information refer to: http://www.gemtech.com/rwb/details/intro.html

4.2 Operating Environment

- It runs on Windows 95 and Workstations.
- It supports Direct3D ,OpenGL and Glide.

System requirement for PC

- 16MB of memory for Windows 95.
- 32MB of memory for Windows NT.
- 40MB Hardisk
- IBM PCs Compatible computer.

4.3 Features

Gemini Real World measure performance for the following entities:

- total number of polygons in entire scene
- total number of objects (and subobjects) in the entire scene .
- total number and sizes of all texture maps.
- texture mip-mapping methods used if any.
- hardware anti-aliasing methods used if any.

4.4 Advantage

- It test different system architecture (OpenGL, Direct3D, Glide).
- It is run on workstation and PCs.

4.5 Disadvantage

- The benchmark is optimized for OpenGVS and it is not required to run the test on GVS. OpenGVS runs on the top of (OpenGL or Direct3D) and developed by Gemini Technology.
- The Metric re2stone is dependent on hardware configuration.
- System test performance is compared to RE2 configuration.

4.6 Method for reporting result

For each test, a report header is generated. It identifies the specific hardware system configuration under review including significant and relevant rendering factors used during the test such as:

- total number of polygons in entire scene
- total number of objects (and subobjects) in the entire scene
- total number of CPUs used by the application test,
- total number and sizes of all texture maps loaded with the test scene,
- texture mip-mapping methods used if any,
- hardware anti-aliasing methods used if any

Many workstation and PC class computer image generation devices cannot produce steady state update rates as the update rate can change from frame to frame depending on pixel fill load, transformation load, and even CPU load. As such, each benchmark test measures and stores the following information each frame during the run.

- update rate this frame (Hz)
- exact number of polygons in the active scene this frame (after scene management calculations by OpenGVS)
- exact number of active objects (and subobjects) in active scene this frame (takes into account the object hierarchy information such as the terrain database)
- CPU percent utilization this frame (how busy the CPU is where 100% means completely busy)

At the end of each benchmark test, this information with the results of thousands of measured frames are automatically summarized (written) to a text file along with a statistical overview of the results.

5. Viewperf

5.1 Overview

Viewperf is a portable OpenGL performance benchmark program written in C, developed by IBM. Later updates and significant contribution were made by SGI, Digital and other OPC project group members. For more information refer to:
http://www.specbench.org/gpc/opc.static/vp50.html

Viewperf parses command lines and data files, sets the rendering state, and converts data sets to a format that can be traversed using OpenGL rendering calls. It renders the data set for a pre-specified amount of time or number of frames with animation between frames. Finally, it outputs the results.

Viewperf reports performance in frames per second. Other information about the system under test--all the rendering states, the time to build display lists (if applicable), and the data set use--are also output in a standardized report.

Viewperf measures performance for the following entities:

- 3D primitives, including points, lines, line_strip, line_loop, triangles, triangle_strip, triangle_fan, quads and polygons;
- attributes per vertex, per primitive and per frame;
- lighting;
- texture mapping;
- alpha blending;
- fogging;
- anti-aliasing; and
- depth buffering.

5.2 Operating Environment

- It runs on multiple operating systems, including OS/2, UNIX and Windows NT.
- It runs across different processors, including Alpha, Intel, MIPS, PowerPC.
- It runs on multiple windowing environments, including Presentation Manager, X and Windows.

5.3 Features

- It provides a single-source code for apples-to-apples comparison and performance tuning across different hardware platforms.
- It encompasses a wide variety of OpenGL features and rendering techniques.
- It is easily accessible through the OPC project subcommittee, ftp and through OpenGL sample disk distribution.

5.4 Advantage

- It uses databases that are designed for and used by real applications.
- It uses rendering parameters and models selected by independent software vendors (ISVs) and graphic users.
- It produces numbers based on frames per second, a measurement with which users can readily identify.
- It provides one number for each rendering path using one data set.

5.5 Disadvantages

Although Viewperf is a good tool for measuring OpenGL performance as it relates to applications, like all benchmarks it has limitations. Most important of these is that it cannot be used to compare performance across different application programming interfaces (APIs). Also, it does not run itself; users must participate in the benchmarking process. When testing and reporting results, Viewperf does not account for the following key factors:

- effects caused by switching primitives,
- input effects on the event loop,
- user interface rendering and management,
- complex motion of multiple models,
- effects of CPU load on the graphics subsystem,
- color index visual performance, and
- multi-context, multi-window effects.

5.6 Viewset

A Viewset is a group of individual runs of Viewperf that attempt to characterize the graphics rendering portion of an ISV's (Independent Software Vendor) application. Viewsets are not developed by the OPC project group; they come from ISVs (Independent Software Vendor) themselves. Currently there are five standard OPC Viewsets:

- Parametric technology's CDRS
- IBM's Data Explorer (DX)
- Intergraph's Design Review (DRV)
- Alias/Wavefront's Advanced Visualizer
- Lightscape Technology's Lightscape Visualization system

5.7 Method for reporting result

The report contains a description of the system used to achieve the graphics performance results reported, and a results table. The table columns indicate, respectively:

- The test number within the viewset
- The percentage weight defined by the ISV (Independent Software Vendor) to indicate the relative importance of that test within the overall application Performance for the test, measured in frames per second.

- The time in seconds it takes to build a display list, which includes opening a display list with an ID, inserting elements (state, vertices, normals, primitive type, color, etc.), and closing the display list; readers should look at this number closely to get a more complete performance picture for a particular test.
- The visual ID used by Viewperf for this test given the command line options; note that the visual ID tends to be system dependent and might be irrelevant to some window systems.
- The portion of the frame buffer into which the image is rendered.
- Whether the visual is double-buffered.
- Whether the frame buffer is divided to do stereo imaging.
- The number of bits allocated per buffer (last 10 columns).

This is a description of the system used to achieve the graphics performance results.

GRAPHICS HARDWARE CONFIGURATION		SYSTEM HARDWARE CONFIGURATION		SOFTWARE CONFIGURATION	
Graphics Accelerator	name	**Processor Type**	name	**Operating System**	O/S
Total Graphics Memory	## MB	**Number of CPUs**	#	**Window System**	name
Image Buffer	size	**Floating point**	type	**API**	name
Overlay/Underlay Buffert	size	**Primary Cache(KB)**	## (KB)	**API Version**	id
Image Buffer	size	**Secondary Cache (KB)**	## (KB)	**API Vendor**	name
Image Buffer	size	**Memory (MB)**	## (MB)	**PLB Version**	id
Accumulation Buffer	size	**Disk (MB)**	## (MB)	**Driver Version**	id
Auxiliary Buffer	size				
Other Buffer	size				
Display List Memory	Description				
Texture Memory	Description				
Display Manufacturer/ Model*	Description				
Display Resolution	Width x height				
Display Size/Type	Description				
Display Refresh Rate	## Hz				
Swap on Vertical Retrace	yes/no				

6. Intellibench

6.1 Overview

Intellibench is a user configurable "shell" driver which installs between the graphics engine and the display driver. It "hooks out" the display driver and allows manipulation or output of calls into the display driver. It is a sophisticated, flexible performance analysis, debugging and profiling tool.
For more information refer to: http://www.intelligraphics.com/intlbnc2.html.

6.2 Operating Environment

Pentium processor on target system, Microsoft Windows95 or Windows NT 4.0.

6.3 Features

- Simple user interface
- Provides a simple, systematic method for analyzing and tuning driver performance
- Enables rapid analysis of competition's performance
- Automates the driver testing process, freeing valuable development resources
- Provides for quick and easy Development debugging, even by non technical personnel
- Works in conjunction with existing benchmark applications
- Enables individual functions to be separately timed, manipulated and tuned
- Outputs performance data to COM port, file, or exports to Microsoft Access
- Profiles driver functions
- Multiple platform support for either Windows 95 or Windows NT 4.0

6.4 Advantage

- Quick and easy install and uninstall using InstallShield
- Configurable through Windows 95 or Windows NT application interface.
- Works with any graphics controller and associated Windows95 or Windows NT display driver
- Print function information may be output to COM port, file, or to Access database
- DIB Engine-evaluate performance of graphics bitmaps

6.5 Disadvantage

- The lack of support for multiple API's and composite factor for system performance.

6.6 Method for reporting result

N/A

7. D3Dbench

7.1 Overview

D3Dbench mark is a rasterization performance benchmark. It uses Microsoft's Direct3D Immediate Mode rendering API for abstracting hardware access and Microsoft's Foundation Class (MFC) for Windows-specific issues.

D3Dbench measure only raw rasterization speed. While this isn't a perfect benchmark, it does provide a basis for comparing hardware rendering performance.

This bench mark targets game developers who want to know what kind of performance a given accelerator can offer. For more information refer to:
http://www.newmedia.com/NewMedia/96/11/td/PC_3D_Accelerator.html.

7.2 System Environment

- a PC with Intel motherboard
- a Pentium 166MHz CPU
- Triniton Chipset
- 64MB RAM
- Windows 95 with ServicePak 1 installed

7.3 Advantage

- Flexible array of low-level pipeline testing options.
- Useful in triangle meshes of definable sizes, to see the effects of meshing on performance

7.4 Disadvantages

- It is not yet available to the public, and as such does not provide any documentation.
- D3Dbench does not take into account issues that will affect overall game speed, including overlap between CPU and hardware, CPU loads.

7.5 Method for reporting result

D3DBench provides results in both polygon rate and fill rate without providing adequate visual feedback for visual performance analysis..

8. WizMark

8.1 Overview

WizMark is a 3D performance benchmark created by 3Dfx Interactive. It measures the performance of Microsoft's Direct 3D accelerated by hardware. For more information refer to: http://www.3dfx.com/tech/bench.html

8.2 Features:

Some features, that WizMark utilizes:

- gouraud shading
- perspective correct texture-mapping
- gouraud modulated texture mapping
- texture bilinear filtering
- texture LOD MIP-mapping
- alpha-blending
- z-buffering

8.3 System Environment

The minimum system, software and 3D graphics board component requirements for WizMark V2.0 are:

- 2MB system memory
- 2MB texture memory
- Z-buffer
- 2MB memory for display
- Windows® 95 and
- DirectX™ 3.0A
- Direct3D™.

8.4 Advantage

- Good application-level test using single database; visual quality can also be evaluated.

8.5 Disadvantage

- Tests only D3D; no customization possible.
- Does not have any user-selectable parameters.
- Wizmark is based on the single 3D database ("Wizard's Tower") designed by 3Dfx.

8.6 Method for reporting result

N/A

9. Summary

The table below show a brief description of seven benchmarks.

Benchmark name	Source	Direct3D	OpenGL	Glide	Description	Frame rate	Polygon rate	Fill rate	Others	Options	Adv.	Disadv.	Av
PLB	:http://www.specbench.org/gpc/plb.static/overview	X	X	X	An apple to apple comparison	X				Can run directly on vendor port	Measure graphics performance across different API	It's platform dependent	Yes
3Dwinbench	.http://www.fourthwave.com/wave/wave710.htm	X			Measure the performance of PCs 3D-subsystem	X	X			Quality tests, WinMark , and Triangle tests	Hardware capability configuration	Triangle size is fixed, resolution is limited	Yes
Gemini Real - World	http://www.gemtech.com/rwb/index.html	X	X	X	test suites based on Gemini's OpenGVS platform				re2stone	Textured and non-textured versions available	Good overall system and 3D subsystem testing	Results provided on relative scale, not widely recognized	Yes
Viewperf	http://www.specbench.org/dist/gpc/opc.static/vp50.html		X		Renders data sets provided by independent vendors	X					Widely recognized in industry as standardized test	Although tests allow customizatio n, tests outside of SPEC's no recognized in industry	Yes
Intellibench	http://www.intelligraphics.com/intlbnc.html				Is a shell driver between the graphics engine and display driver							DIB Engine-evaluate performance of graphics bitmaps	No

D3Dbench-mark	http://www.newmedia.com/NewMedia/96/11/td/PC_3D_Accelerator.html.	X			Primitive-level D3D benchmark for measuring rasterization performance and triangle throughput		X				Flexible arrary of low-level pipeline testing options	Unfinished product;	No
WizMark	http://www.3dfx.com/tech/bench.html	X			measures performance of Microsoft's Direct 3D accelerated by hardware	X					Good application-level test using single database;	Tests only D3D; no customizatio n possible	No

10. Conclusion

Benchmarks are used by particular segments of a community to compare products or by product developers for competitive analysis. There are many benchmark tests for graphics systems and more are being developed. This report has captured a small subset based on a search of World Wide Web. This report should be updated periodically to remain current and relevant to those interested in benchmarking graphics systems.

We have studied seven different benchmarks for both OpenGL and Direct3D. Among these, PLB, Viewperf and Wizmark are the three benchmarks that we think should be considered for further implementation and study, in order to understand the performance measurement technique of benchmarks.

We considered PLB because it provides an apples to apples comparison of graphics display performance for different hardware platform. It also provides 8- standard files based on popular application, if the user can not have the technique to convert their application to BIF files. One of the important issue of PLB is that the performance result is reported using one number.

For Viewperf we have several standard viewsets in the market. These viewsets are developed by ISV (Independent Software Vendor) under sponsorship of OPC and these viewsets have their own different test cases.

For WizMark we have a 3Dfx board on which we can carry on the test.

We chose these three benchmarks for our initial work and, if it is necessary, we may choose some other benchmarks that will suit our needs in the future.

It should be noted from Section 8 that no one test evaluates all of the parameters and configurations in today's graphics systems. In addition, many of the factors important to the Modeling and Simulation community are not evaluated by any of the graphics systems. Among these include, for example, dynamic paging, support for moving models, overload control, and dynamic scene effects. Performance tests should be developed which are relevant to the needs of the M&S community. Development of tests should seek to use many of the same measurement techniques embedded in the tests, above, but augmented with application across a broader range of products and inclusive of relevant M&S parameters. Both of these goals are achievable.

Appendix A

This appendix contains some other benchmarks that we might consider in the future. It contains a brief description and explanation about the feature of these benchmarks.

[excerpt from 4th Wave's 3D Accelerator Performance Characterization [April 25, 1997]]

Glaze

Evans & Sutherland

Glaze is a relatively new benchmarking program from E & S, primarily designed to compare tested accelerators with their REALimage accelerator platform. It works by calculating the frame rate of one of five provided 3D objects, but unfortunately the results are output to the application window in real-time without the capability of saving the results or calculating an average frame rate. It does have several rendering options, including:

- Primitive type: triangles, triangle fans, polygons, points, lines
- Motion control: rotate or freeze-frame
- Zoom: in or out
- Translate model: up, down, left, right
- State: transparency, anti-aliased lines, back-faced culling, fill mode, display list
- Shading: flat or smooth
- Fog: black (depth cue) or white
- Lights: shaded or colored, number of lights
- Textures: On/off, reflection, mode, filter

It is designed with 10 pre-set conditions of these options that are used to demonstrate particular 3D functionality, such as anti-aliased models, models with multiple light sources, etc. However, due to its limited functionality of this program, (particularly its lack of ability to
tabulate results) we did not use it in our tests.

GLPerf

Standard Performance Characterization Group

GLPerf, a forthcoming OpenGL benchmark from the widely-recognized SPEC organization, GLperf allows testing based on the exact same objects and attributes, making it a reliable tool for measuring performance across different OpenGL-based systems. A simple input file format within GLperf allows users to specify the OpenGL primitives they want to time. The benchmark is flexible, thus it allows testing for a variety of objects (line strips, polygons, triangles) with different attributes (line width, number of lights, texture functions, etc.). The performance testing flexibility of GLperf is matched by the reporting options made available to the user. A user can specify, for example, whether timing is to be reported as objects per second, pixels per second, or microseconds per object.

For the purposes of our testing, we constructed a series of four tests, each of which runs over an increasing polygon size of 5 pixels up to 400 pixels, and over the four main modes of texturing: untextured, point sampled, bilinear filtered and trilinear filtered. The results are given in polygon rate and are used to show the performance penalties resulting from both polygon size and texturing mode. In addition, since OpenGL is now supported on both Windows NT and Windows 95, GLPerf was used to run the same tests under both operating systems for a cross-OS comparison.

GLQuake

id Software/3Dfx Interactive

Based on the popular game "Quake", from id Software, GLQuake is actually a small executable "fix" for the game that allows it to utilize OpenGL acceleration. Designed by both id and 3Dfx, GLQuake has been optimized to run on 3Dfx hardware, although currently it does reportedly run on some other accelerators (it didn't on any of the other boards in this report). Using the Quake built-in command "timedemo," the frame rate is computed for one of three pre-designed animations within the Quake world.

Although its usefulness was limited to the 3Dfx cards in our tests, it was included due to its status of being the most recognized 3D-based game on the Windows platform today. In addition, it may be used on boards other than those in our tests.

MonaLisa

Ziff-Davis Benchmarking

The MonaLisa benchmark is an important program from the Ziff-Davis Benchmarking Operations (ZD-BOP) group, with which they are attempting to correlate the performance of a 3D accelerator to the visual quality through a multi-faceted benchmarking application. It is currently not complete, and in addition has many performance limitations, and as such has not been included in our test suite at this point.

PCPlayer

PC Player Magazine (Germany)

PCPlayer is a relatively simple Direct3D benchmarking application from PC Player Magazine in Germany. It appears to repeatedly fly over a small 3D terrain model and compute the resulting average frame rate, but since all of the documentation and output are in German, we did not use this test in our suite.

Realibench

Datapath Ltd. (England)

Realibench is based on Datapath's 3D/VR authoring system, Realimation , which allows database traversal of in the Realimation format RBS. Databases can also be imported from the Open Flight format and converted to the RBS format. Realibench traverses an RBS database over a pre-defined flight path and calculates the average frame rate, which it reports at the conclusion of the benchmark.

This benchmark stands as potentially the most important in our suite of tests for several reasons. Most importantly, it is the only benchmark that allows the user to dynamically change the rendering API on the fly, which allows a cross-API comparison to be directly made on cards supporting multiple APIs. OpenGL (16 bpp), Direct3D, Glide, and RenderWare (16 bpp) are supported. It is also supported on both the Windows NT and Windows 95 platforms, allowing for cross-OS comparisons to be made.

Even more importantly, Realibench provides us with the critical ability to evaluate the visual quality of a 3D scene in real-time as it moves through the animation. The 3D database used can come from any source, as long as it is exported to the RBS format. For our current testing efforts we used three different databases Real3D, Bayou_clean, Helisim2_Embed.

WorldToolKit Direct

Sense8

Based on Sense8's popular 3D/VR authoring application, WorldToolKit, WTK Direct is a fairly customizable benchmark with four different types of tests that provide results in polygon rate, fill rate and frame rate.

For the purpose of our tests, we concentrated on two of the tests, triangle grid and overwriting, in order to calculate the polygon rate and fill rate of the accelerators.

WTK Direct is a useful benchmark for easily testing the polygon rate and fill rate, and allows the user to specify several rendering options, such as texturing mode, but it does not provide any advantage over the other benchmarks used in our tests, and is in many respects much more limited.