WebGL, WebCL and Beyond!

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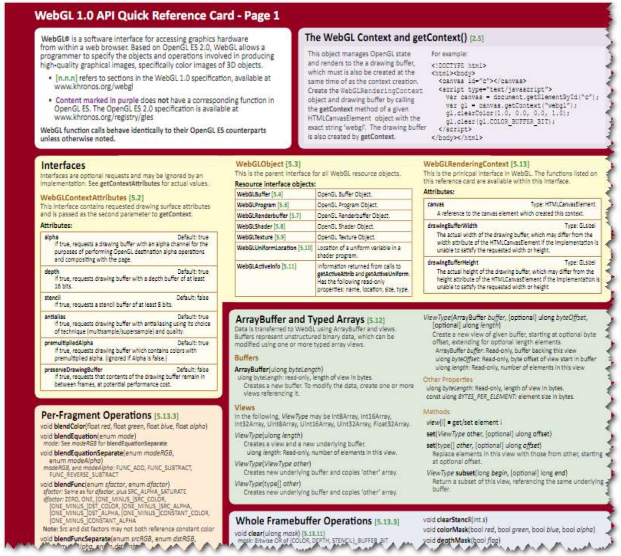
Two WebGL-focused Sessions Today

- **Industry ecosystem and standards for 3D and compute**
  - What is 3D anyway – jungle survival primer
  - Khronos and open standard acceleration APIs for native apps
  - The evolution of pervasive 3D on mobile platforms
  - WebGL and WebCL as part of HTML5
  - Web apps and use cases beyond games – augmented reality

- **Hands-On with WebGL**
  - Steve Baker - Intific

WebGL Reference Cards at end of session!


WebGL 1.0 API Quick Reference Card - Page 1

The WebGL Context and getContext()

Interfaces

WebGLObject

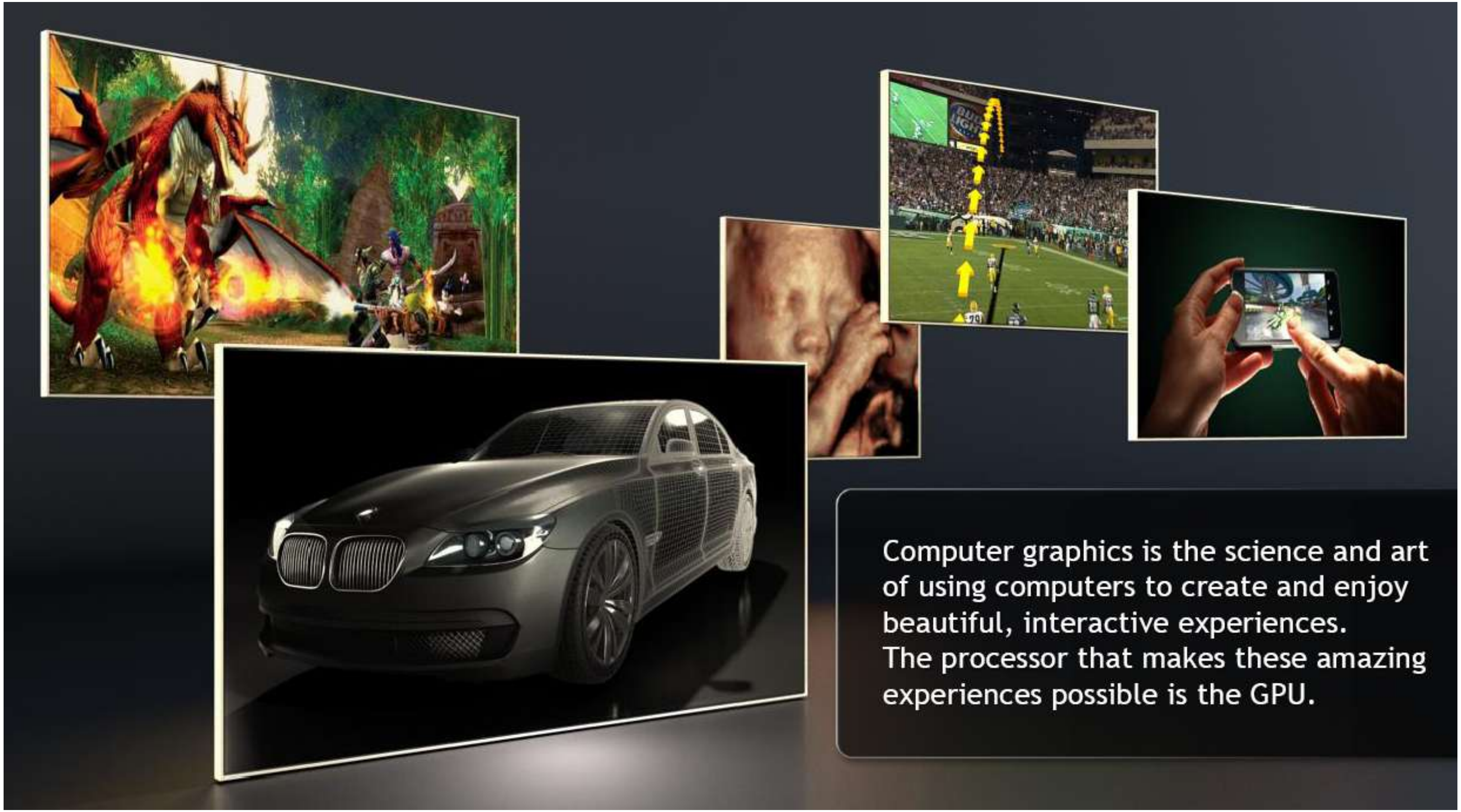
WebGLRenderingContext

ArrayBuffer and Typed Arrays

Per-Fragment Operations

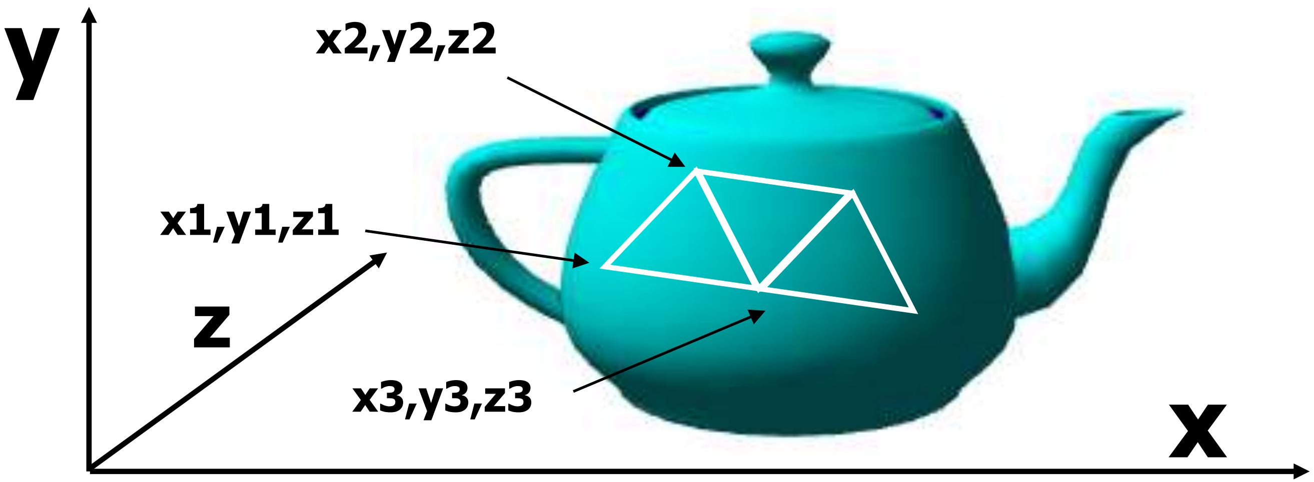
Whole Framebuffer Operations

What is Real-time 3D Graphics?



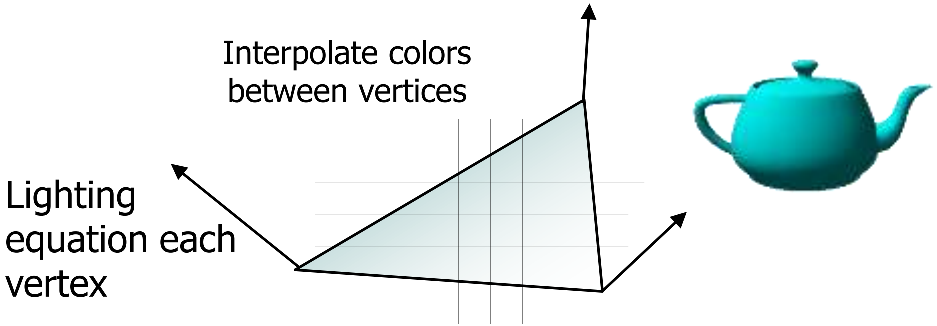
3D Pipeline Basics

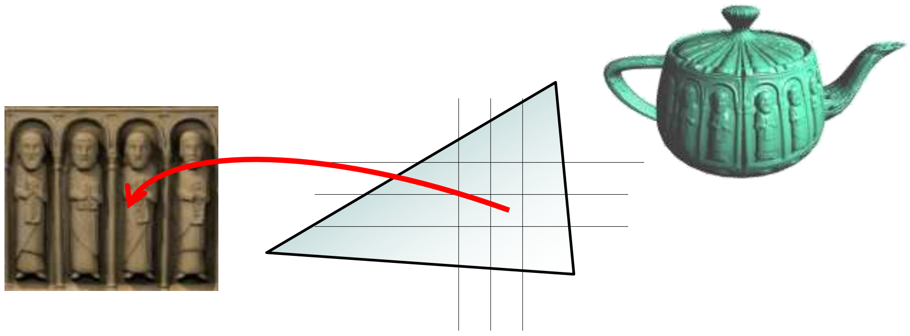
- The art of "faking" realistic looking scenes or objects using heuristic techniques learned over the years
- The objects making up a scene are held in a database
- Surfaces of objects are broken down into a grid of polygons
- The vertices of the polygons are located in 3D coordinate space - x,y,z
- Each vertex has a "material" – color and reflective properties
- Vertices are positioned in 3D space – matrix math zooms and rotates



3D Pipeline Basics – Pixel Shading

- **Project each polygon onto the screen**
  - Determine which pixels are affected
- **Smooth Shading**
  - Run lighting equation at each vertex
  - Compute vertex color depending on how lights interact with surface angles and properties
  - Interpolate colors between the vertices
- **Texture Mapping**
  - “Wallpaper” each polygon with an image
  - For each pixel compute image coordinates in image to paste
- **Environment Mapping**
  - Paste reflection of image of environment at each pixel





Fundamental 3D Processing Stages

Operations on Vertices

Traversal	What objects are in current scene?
Transforms	Where are the polygons?
Lighting	What color are the polygons?
Rasterize	What shape are they on the screen?

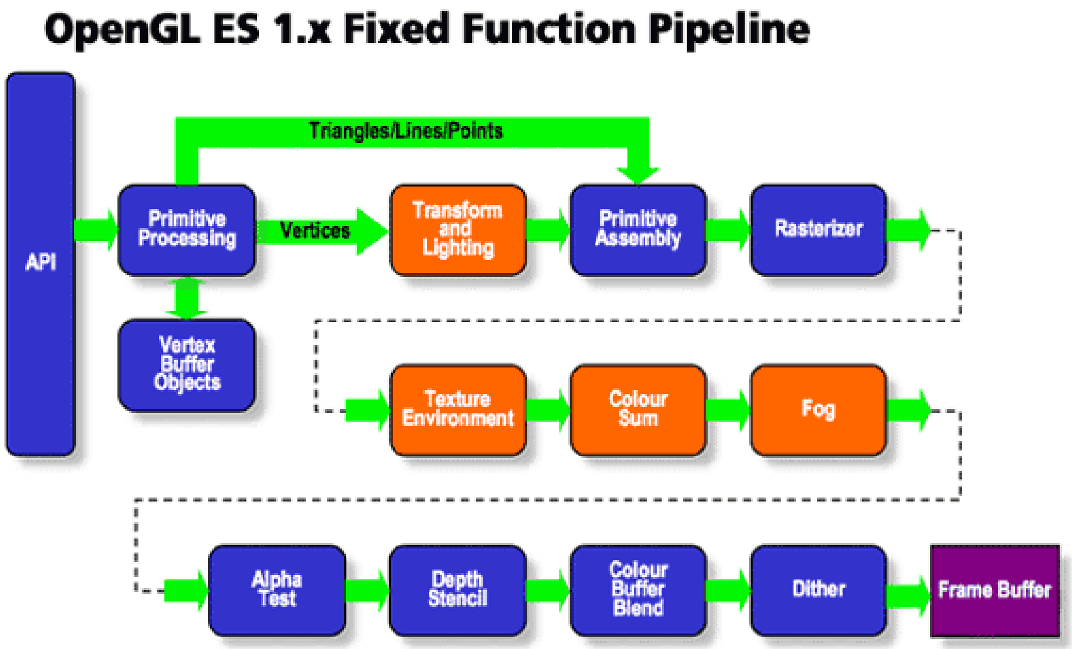
Geometry ↑

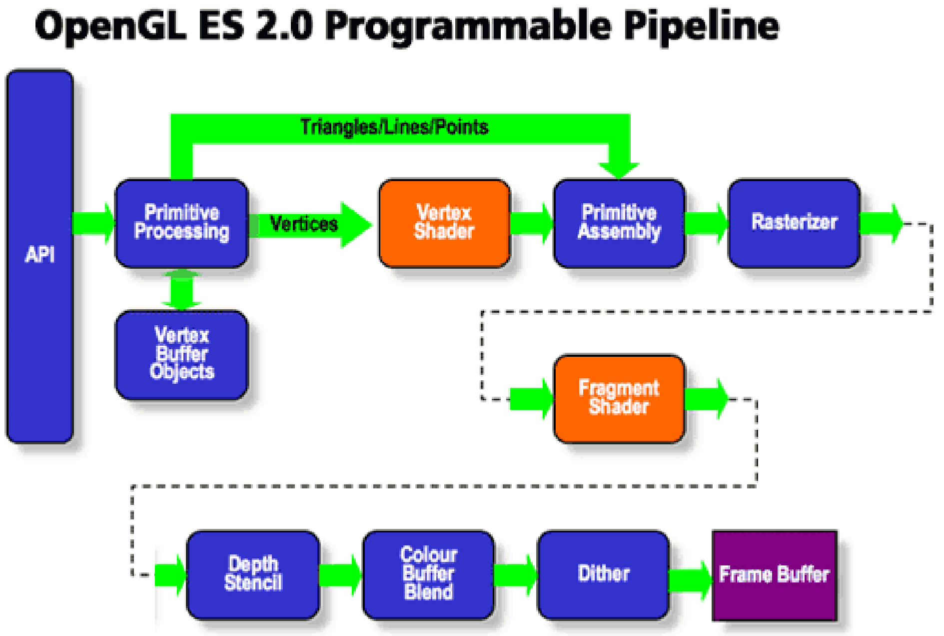
Rasterization ↓

Operations on Pixels

Color	What color is each pixel?
Clip	Which pixels are visible?
Write	Write the pixels to the framebuffer

Actual 3D Pipelines





3D has evolved over more than 30 years

'Doom' on a PC – 1993
id Software

'Samaritan' Real-time Demo on a PC – 2011
Epic Unreal Engine

http://www.youtube.com/watch?v=RSXyztq_0uM

Khronos and Hardware APIs

- **Khronos defines open, royalty-free standards to access graphics, media, compute and input hardware**
- **Khronos APIs are low-level – just above raw silicon – to create the "foundation" functionality needed on every platform**
- **Safe forum for industry cooperation 'By the industry for the industry'**
  - Open to any company to join
  - IP framework to protect members and industry

APIs enable software developers to turn silicon functionality into rich end user experiences

KHRONOS GROUP

Over 100 members – any company worldwide is welcome to join

Board of Promoters

Khronos Family of Standards

Authoring and accessibility

COLLADA	WebGL	WebCL	StreamInput
3D Digital Asset Exchange format	Plugin-free 3D Web Content	Web Compute	Unified Sensor and Input Processing

Application Acceleration

OpenGL	OpenCL	OpenGL ES	OpenVG
Cross platform desktop 3D	Parallel Computing	Embedded and Mobile 3D	Vector 2D

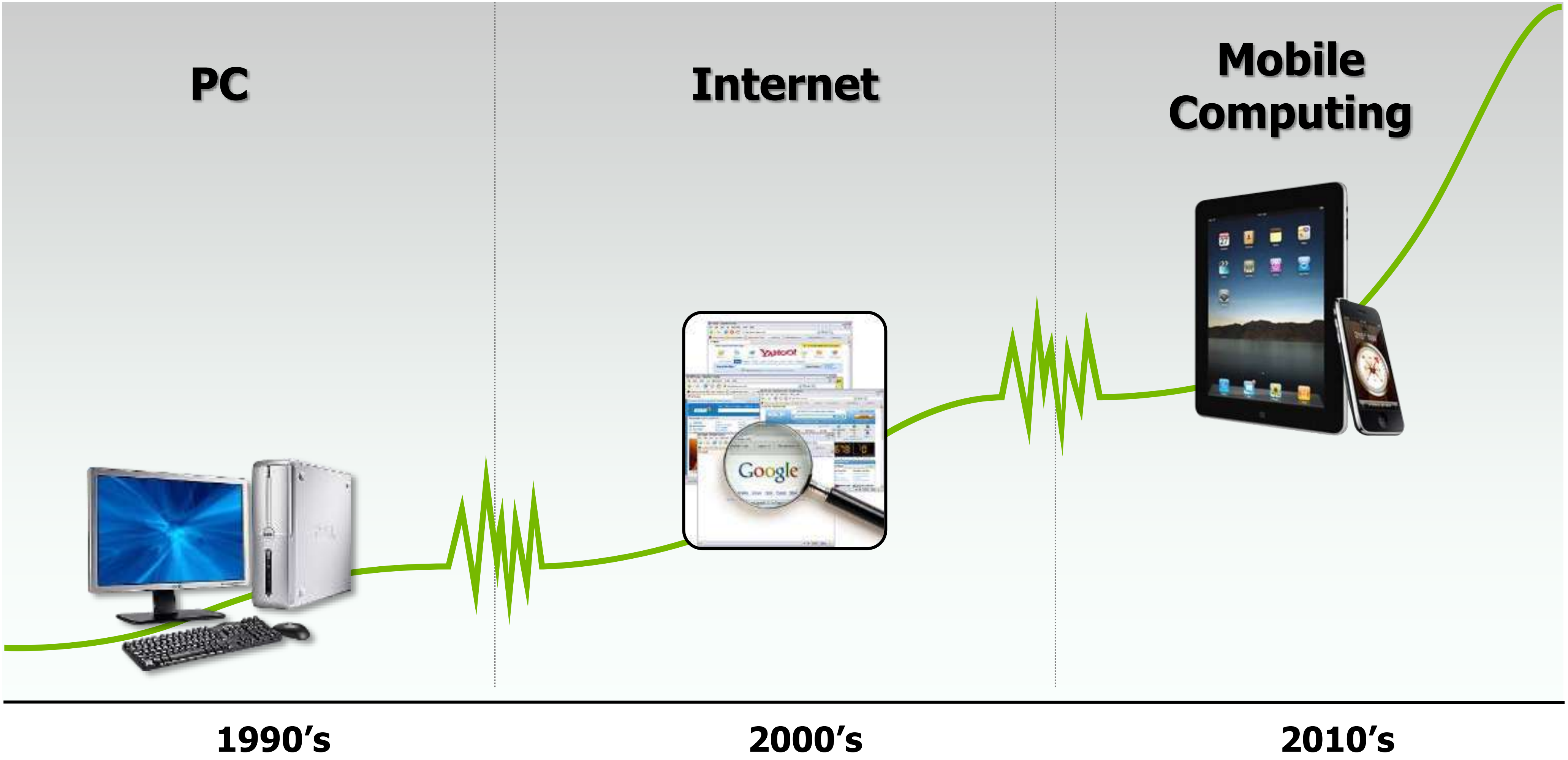
OpenMAX	OpenSL ES	EGL
Streaming Media	Advanced Audio	Surface Management

KHRONOS GROUP

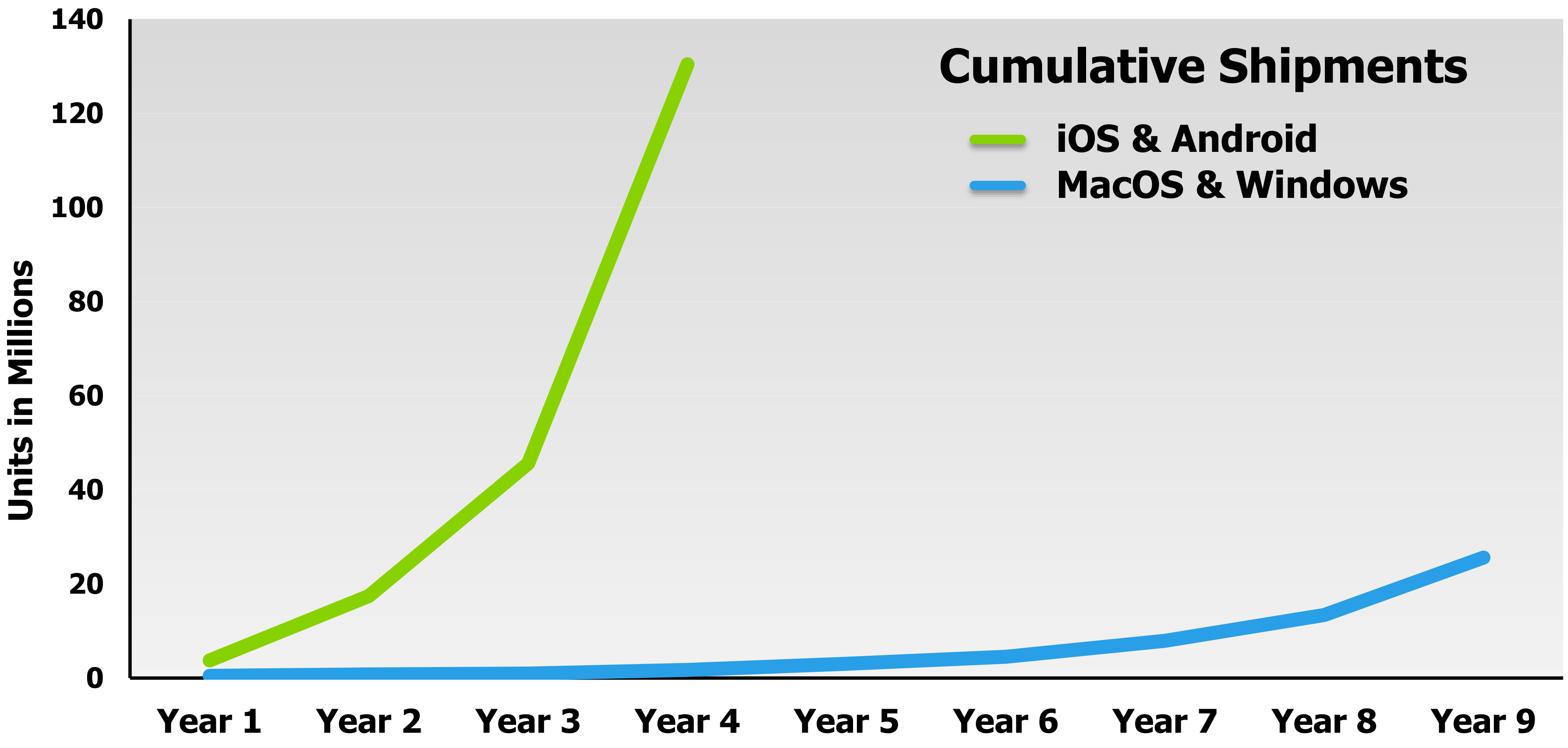
A coordinated ecosystem of compute, graphics and media standards and APIs

Khronos creates royalty-free specifications to meet real market needs and helps drive industry adoption across multiple platforms

A New Era in Personal Computing

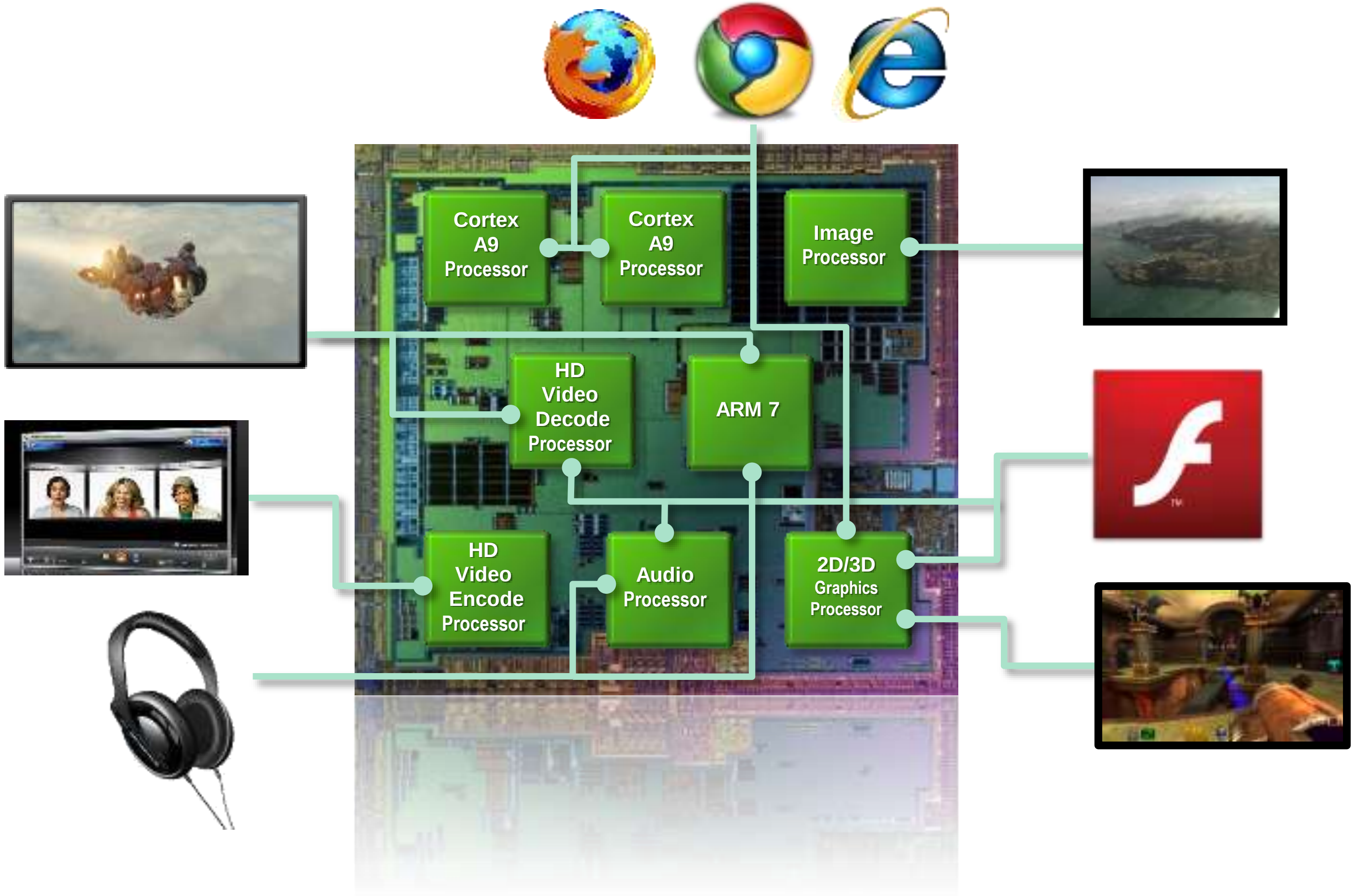


20 Years Faster to 100M Per Year

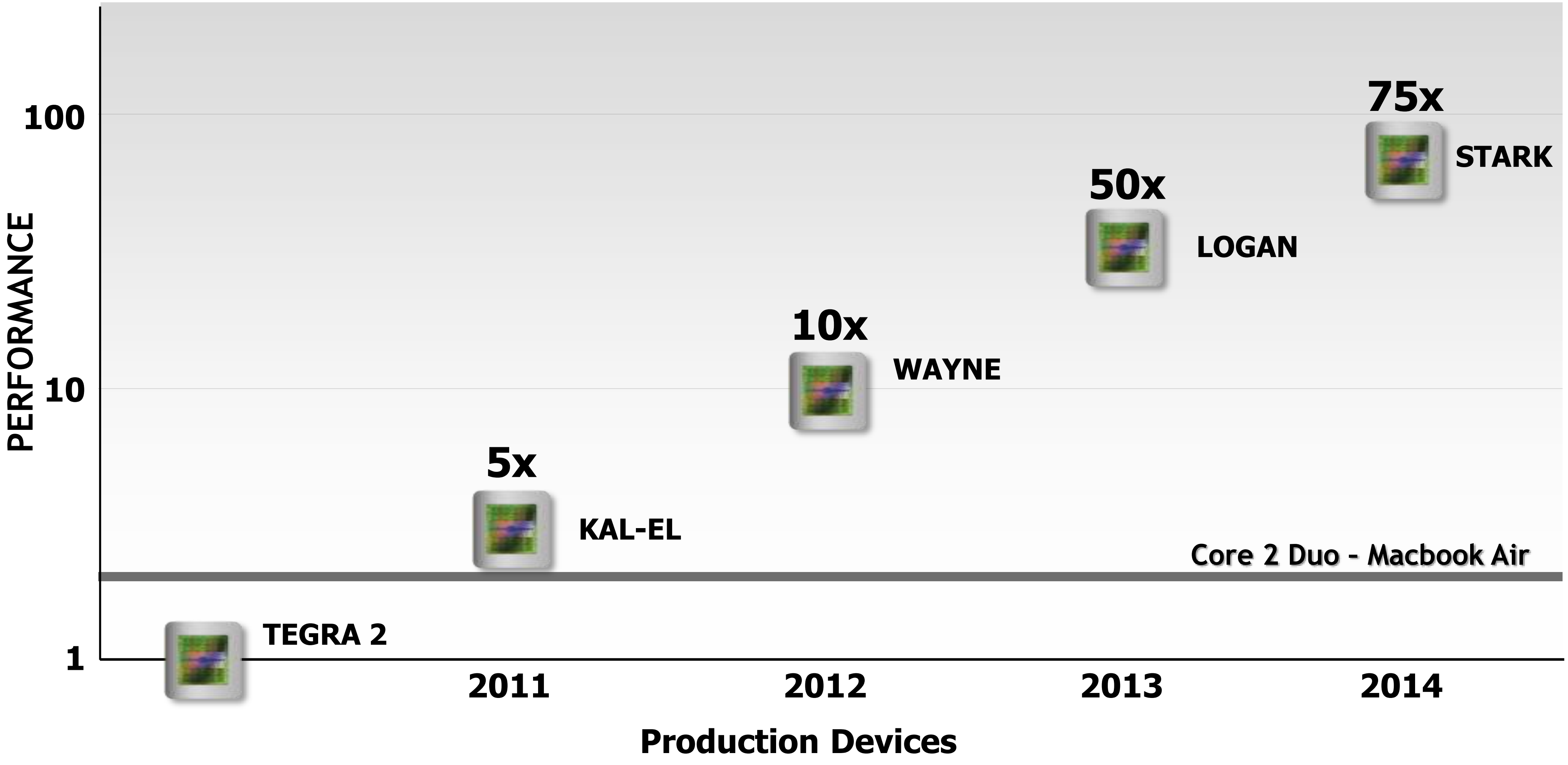


Source: Gartner, Apple, NVIDIA

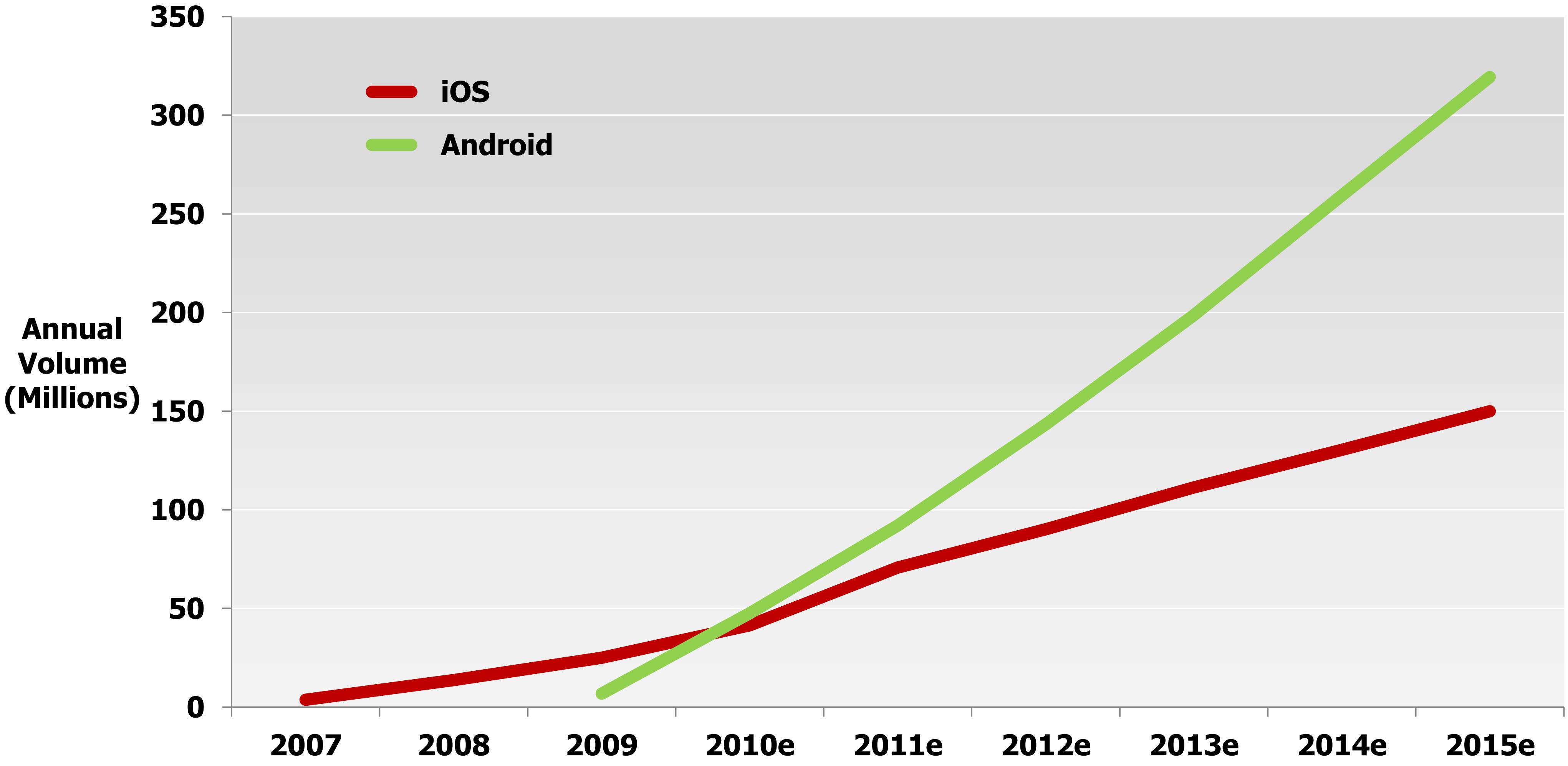
Mobile Silicon Experiential Processing



Mobile Roadmap Acceleration



Mobile - Android Becoming Dominant OS



Source: Gartner, NVIDIA

OpenGL Ecosystem – 3D Everywhere

Leading-edge functionality developed first on desktop

OpenGL ES 2.0 on desktop as subset of OpenGL 4.2 for mobile content flexibility – including native support for WebGL

WebGL driving new-generation security features into OpenGL family

Mobile functionality subset that is deployed on billions of devices

Pervasive OpenGL ES 2.0 availability enables Browser vendors to build 3D directly into HTML5

OpenGL ES Pervasiveness

- **OpenGL ES 1.1 – fixed-function pipeline**
  - Based on OpenGL 1.5
  - Vertex Arrays / Buffer Objects
  - Transform & Lighting
  - Multi-texturing (min 2 units)
  - Fixed-point & Floating-point profiles

- **OpenGL ES 2.0 – programmable pipeline**
  - Based on OpenGL 2.0
  - Adds vertex and fragment shader programming
  - Removes fixed function pipeline
  - Super-compact, efficient API
  - High level language (GLSL ES)
  - On-line or off-line compilation

WebGL – 3D on the Web – No Plug-in!

- **Historic opportunity to bring accelerated 3D graphics to the Web**
  - WebGL defines JavaScript binding to OpenGL ES 2.0
- **Leveraging HTML5 and uses <canvas> element**
  - Enables a 3D context for the canvas
- **JavaScript is easily fast enough now for visual computing**
  - Plus OpenGL ES 2.0 enables local geometry caching and GPGPU computation

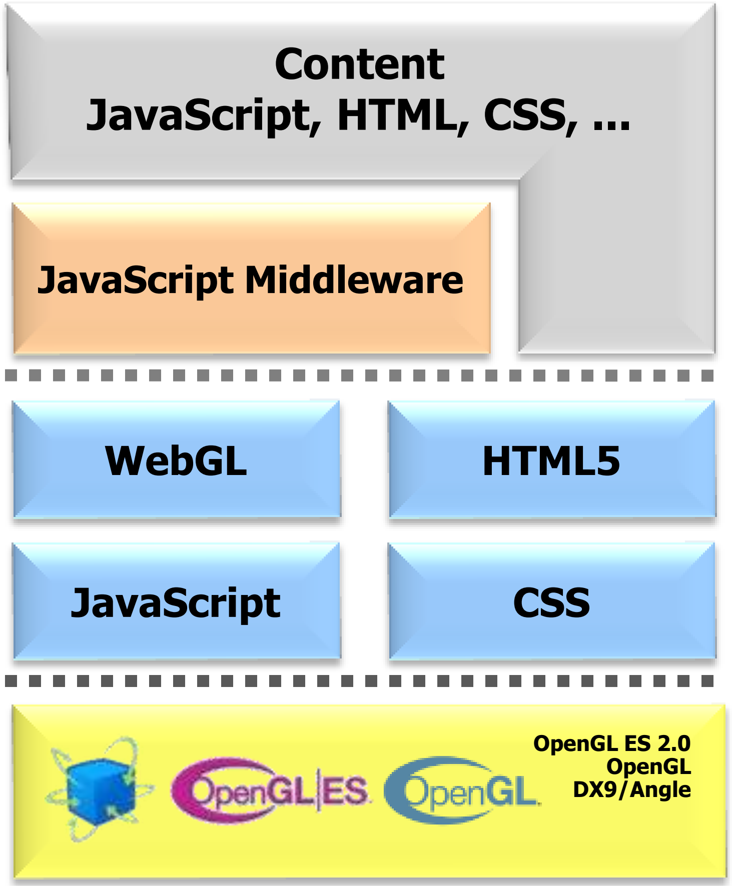
Being defined by major browsers and GPU vendors working together

WebGL Implementation Anatomy

Content downloaded from the Web.
Middleware can make WebGL accessible to non-expert 3D programmers

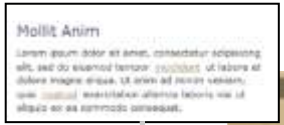
Browser provides WebGL functionality alongside other HTML5 specs - no plug-in required

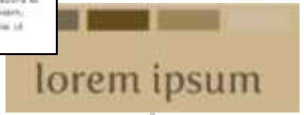
OS Provided Drivers. WebGL on Windows can use Google Angle to create conformant OpenGL ES 2.0 over DX9



HTML5 Content Architecture

HTML content generated by layout engine ‘on page’





All content passes through CSS layout

<video> tag

<canvas> tag

JavaScript drives interactivity for 2D and 3D graphics

Composition of off-screen buffers

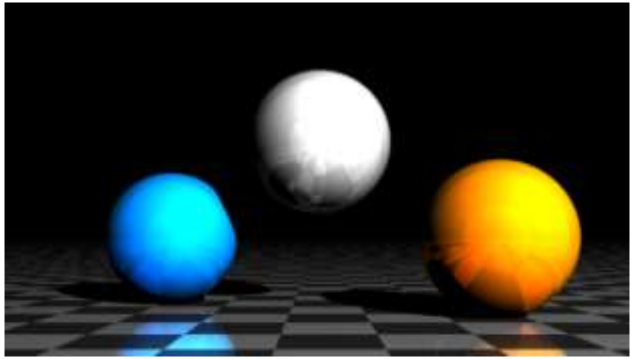
CSS Layout and Transforms

Composition needs to be GPU accelerated

Video, Vector Graphics and 3D created off-screen buffers

WebGL and HTML Interaction

- **3D is not trapped in a rectangular window**
  - 3D can overlay and underlay HTML content
  - Easy to make HUDs or user interfaces
- **Strong ties with other advanced HTML5**
  - WebGL can use HTML5 <video>
    or canvas as a texture
- **Can use 3D for core Web UI – as well as content**
  - Advanced transforms and special effects
- **Render HTML DOM sub-tree as texture**
  - Support user interaction when in 3D
  - Mozilla and Google prototyping as extension
- **WebGL is democratization of 3D**
  - Accessible, pervasive, enabling
  - Spawning amazing innovation



WebGL Deployment

- **WebGL 1.0 Released at GDC March 2011**
  - Mozilla, Apple, Google and Opera working closely with GPU vendors
- **Typed array 1.0 spec ratified by Khronos in May**
  - Supporting bulk data transfer between threads (workers)
  - Many use cases - background mesh loading, generation, deformation, physics ...
- **1.0.1 release of WebGL spec and conformance suite imminent**
  - 100% robust stance on security
  - Fixing bugs in 1.0.0 conformance suite
  - Implementations will report getContext("webgl") (not experimental)

Show all versions	IE	Firefox	Safari	Chrome	Opera
3 versions back	6.0	3.6	3.2	10.0	10.6
2 versions back	7.0	4.0	4.0	11.0	11.0
Previous version	8.0	5.0	5.0	12.0	11.1
Current	9.0	6.0	5.1	13.0	11.5
Near future		7.0		14.0	12.0
Farther future	10.0	8.0	6.0	15.0	12.1

WebGL is not enabled by default in Safari

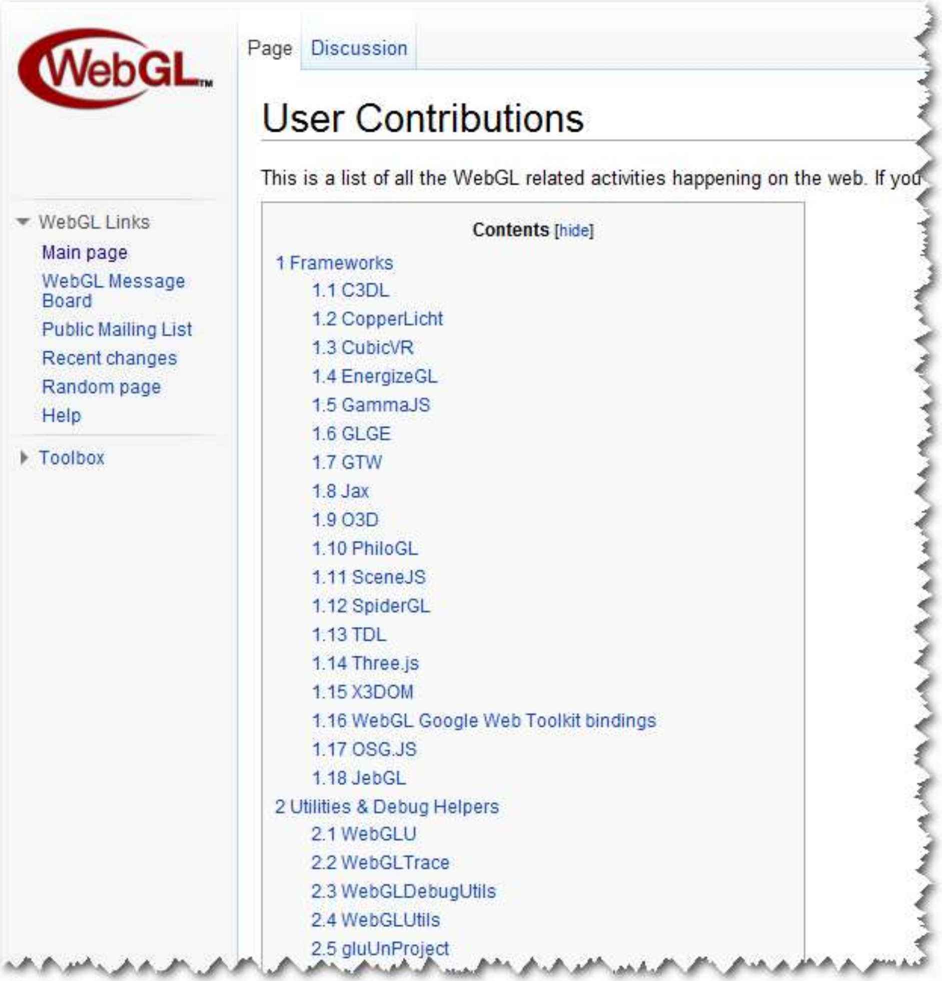
http://caniuse.com/#search=webgl

Aquarium Demo

- On PC and Android
- http://webglsamples.googlecode.com/hg/aquarium/aquarium.html

Frameworks and Tools

- WebGL is deliberately low level to enable the full power and flexibility of OpenGL ES 2.0
- If you are not an expert 3D programmer – don't panic!
- WebGL is perfect foundational layer for JavaScript middleware frameworks
- Lots of utilities and tools already appearing



Declarative 3D for the Web

- **Need to enable 'non-expert' web programmers with layers over WebGL**
  - 10,000s of 3D programmers worldwide versus millions of web developers
  - Middleware and layered architectures play a vital role
- **W3C Incubator for Declarative 3D**
  - *"easy way to add interactive high-level declarative 3D objects to the HTML-DOM"*
  - X3DOM (www.x3dom.org/) and XML3D (www.xml3d.org/)
- **Bind 3D even closer into the browser stack**
  - Use as much HTML5 machinery as possible – DOM, JavaScript, CSS
  - Focus on driving optimized WebGL/OpenGL ES 2.0 back-end
  - Use Typed Arrays and drive for optimal performance

W3C Incubator Activity

Scope
Deliverables
Dependencies and Liaisons
Participation
Communication
Additional Information

Please note this is a draft for discussion purposes, prior to review by the W3C Advisory Committee

Declarative 3D for the Web Architecture Community Group Charter

The **mission** of the Declarative 3D for the Web Architecture Community Group is to determine the requirements, options, and use cases for an integration of interactive 3D graphics capabilities into the W3C technology stack. This group is aimed to extract core features out of the requirements as foundation to propose feasible technical solutions. These should cover the majority of 3D use cases for the Web – but not necessarily all of them.

There are upcoming open (e.g. WebGL) and proprietary (e.g. Adobe) proposals for imperative graphics APIs in the Web context but we are missing an easy way to add interactive high-level declarative 3D objects to the HTML-DOM to allow anyone to easily create, share, and experience interactive 3D graphics – with possibly wide ranging effects similar to those caused by the broad availability of video on the Web.

The Community Group aims at creating the necessary technical and organizational prerequisites to eventually start a Working Group.

WebGL Security

- **Any new functionality in the browser increases exposure to attack**
  - True since the beginning of the web – the new functionality becomes hardened
- **ANY graphics in the browser need the GPU drivers to be hardened**
  - HTML, Canvas, WebGL, Adobe Molehill, Silverlight 5 …
- **WebGL is designed with security as the highest priority**
  - Hardening is being strongly promoted and enabled
- **Short term – browser vendors will maintain white and black lists**
  - Compromised system can have WebGL disabled until mitigation developed
- **Longer term – GPUs provide increasingly robust security and multi-tasking**
  - GPU becoming a first-class computing platform alongside CPU

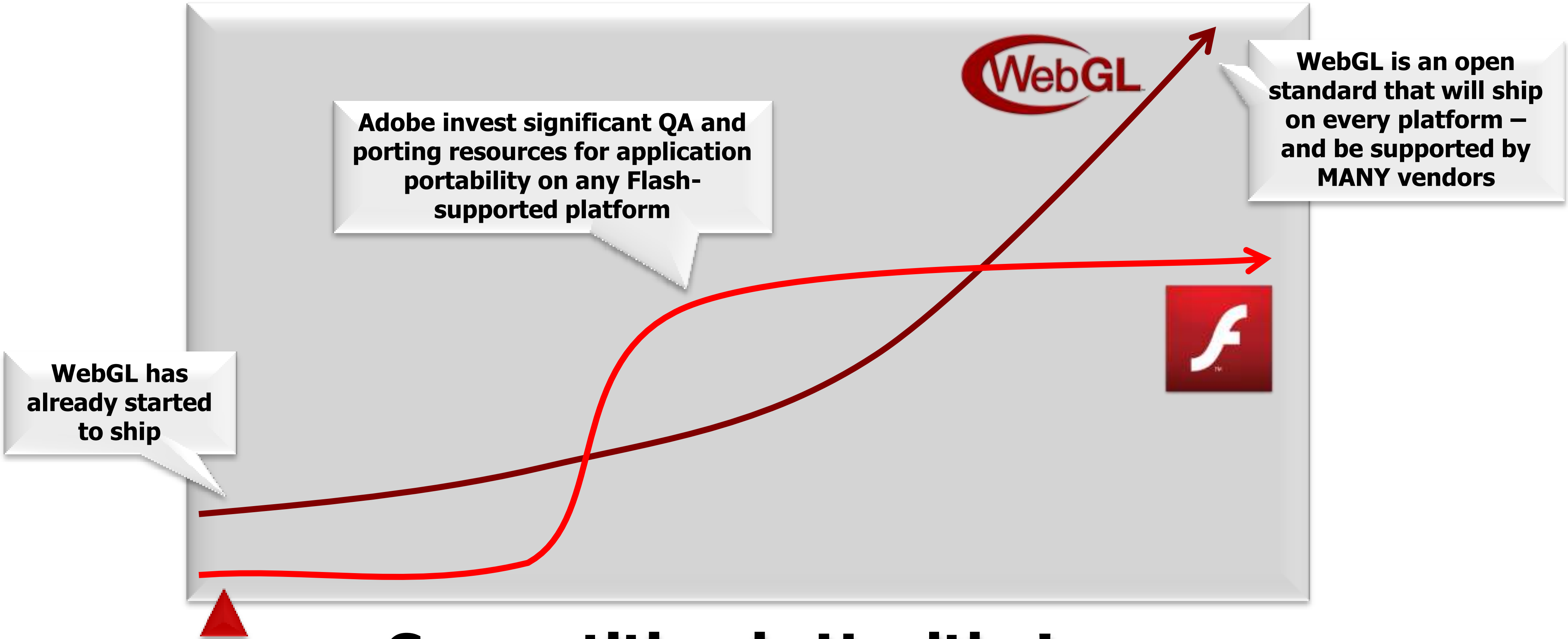
WebGL Security in the Press!

- **Confusion in the industry as we start this hardening process**
  - Shader programs *cannot* access general system resources or perform out of range memory access!
- **Issues in the Press**
  - Cross domain image access – timed loop attack – SOLVED!
    - WebGL *and HTML* spec updates - mandating CORS for video, images and audio
    - Servers have to grant cross-domain access to media resources
  - DOS Attacks and general hardening
    - ARB_robustness extensions that provide additional protection being mandated
    - New robustness spec limits the side-effects of a GPU reset after a DOS attack
    - ANGLE shader validator improved; more improvements coming

Flash Stage 3D aka ‘Molehill’

- **GPU-friendly 3D ‘stage’ behind classic Flash graphics**
  - No interaction with classic Flash except classic 2D overlays the new 3D
- **Different design approach to WebGL**
  - Defines an OpenGL ES 2.0 assembler
- **Portability at the cost of functionality**
  - No loops
  - Lowest common denominator
- **Competition will ensure WebGL keeps it’s eyes on the ball for *security* and *portability***

Possible Flash Stage3D vs WebGL Adoption



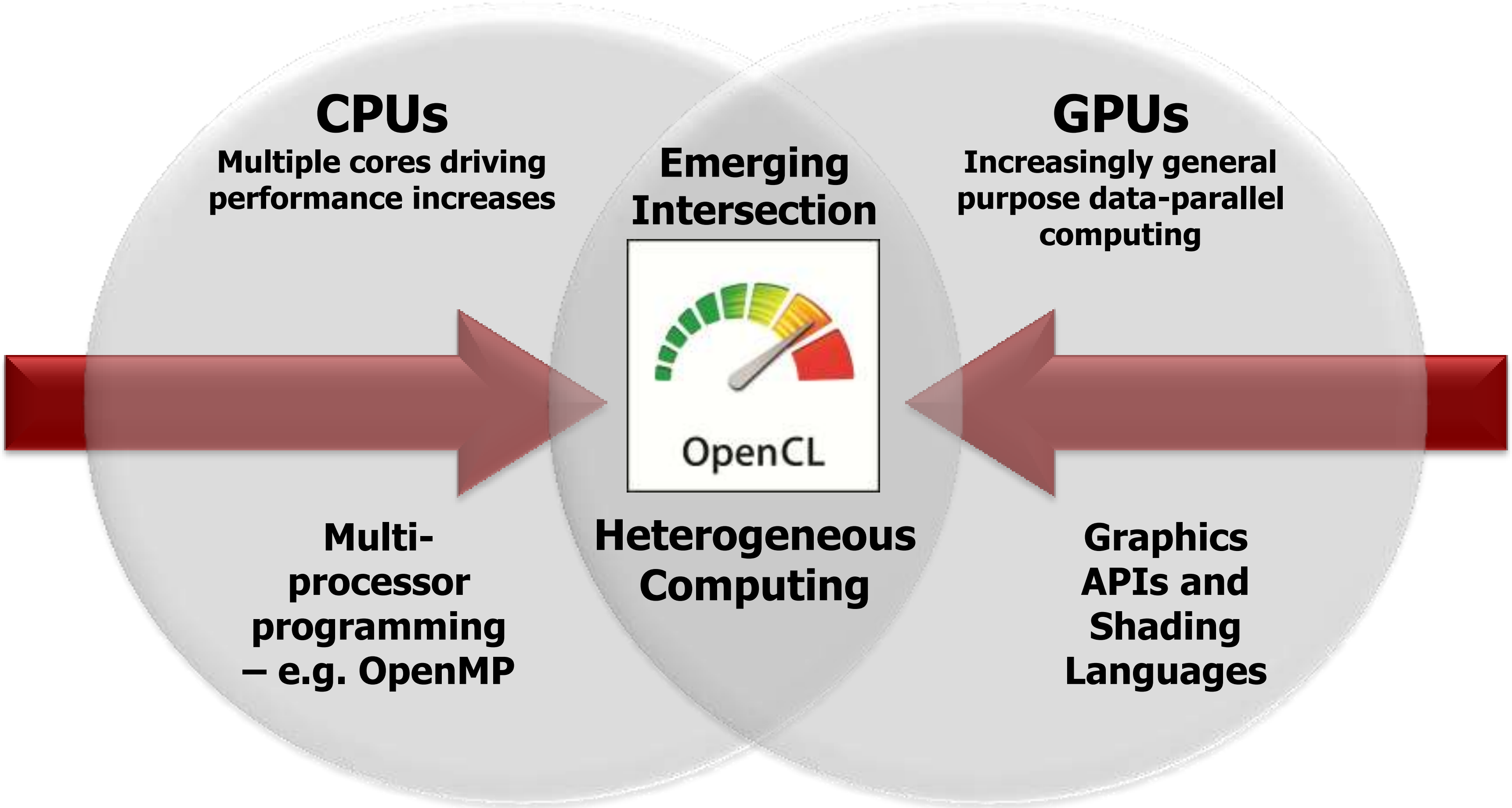
Today

Competition is Healthy!

Mobile Web versus Apps

- **Mobile Apps have functional and aesthetic appeal**
  - Beautiful, responsive, focused
- **HTML5 with WebGL can provide the same level of "App Appeal"**
  - Highly interactive, rich visual design
- **Using HTML5 to create 'Web Apps' has many advantages**
  - Portable to any browser enabled system
  - Same code can run as app or as web page
  - Web page is discoverable through the web – not a closed app store
- **Need to evolve tools to package a web page as an app - with no chrome**
  - As Adobe has done with Air for Flash applications
  - E.g. Blackberry WebWorks: http://us.blackberry.com/developers/browserdev/opensource.jsp

Processor Parallelism



OpenCL is a programming framework for heterogeneous compute resources

The BIG Idea behind OpenCL

- **OpenCL execution model …**
  - Define N-dimensional computation domain
  - Execute a kernel at each point in computation domain
- **C Derivative to write kernels – based on ISO C99**
  - APIs to discover devices in a system and distribute work to them
- **Targeting many types of device**
  - GPUs, CPUs, DSPs, embedded systems, mobile phones.. Even FPGAs

Traditional loops

```
void
trad_mul(int n,
         const float *a,
         const float *b,
         float *c)
{
  int i;
  for (i=0; i<n; i++)
    c[i] = a[i] * b[i];      }
```

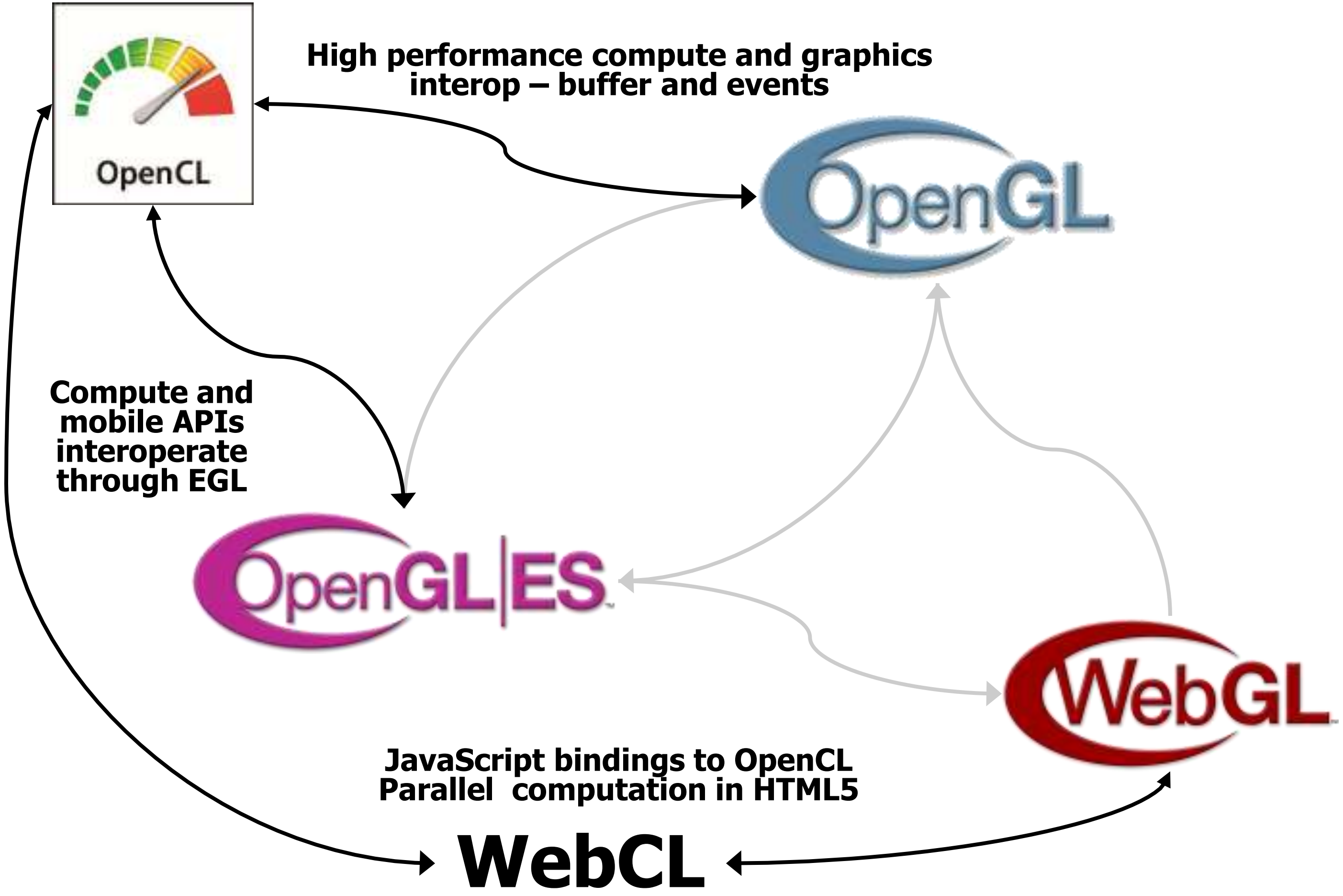
Data Parallel OpenCL

```
kernel void
dp_mul(global const float *a,
       global const float *b,
       global float *c)
{
  int id = get_global_id(0);

  c[id] = a[id] * b[id];

} // execute over "n" work-items
```

WebCL – Parallel Computing for the Web

- **Khronos launching new WebCL initiative**
  - First announced in March 2011
  - API definition already underway
- **JavaScript binding to OpenCL**
  - Security is top priority
- **Many use cases**
  - Physics engines to complement WebGL
  - Image and video editing in browser
- **Stay close to the OpenCL standard**
  - Maximum flexibility
  - Foundation for higher-level middleware

Visual Computing Ecosystem



WebCL Open Process and Resources

- **Khronos open process to engage Web community**
  - Public specification drafts, mailing lists, forums
  - http://www.khronos.org/webcl/
  - webcl_public@khronos.org
- **Khronos welcomes new members to define and drive WebCL**
  - info@khronos.org
- **Nokia open sourced prototype for Firefox in May 2011 (LGPL)**
  - http://webcl.nokiaresearch.com
- **Samsung open sourced prototype for WebKit in July 2011 (BSD)**
  - http://code.google.com/p/webcl/

- **Deformation Demo:**
- Calculates and renders transparent and reflective deformed spheres on top of photo background
- Performance comparison on Mac
  - JS: ~1 FPS
  - WebCL: 87-116 FPS
- http://www.youtube.com/user/SamsungSISA#p/a/u/1/9Ttux1A-Nuc

Expanding HTML5 Capability

- **HTML5 evolving into cross-platform programming platform**
  - Gradually exposing complete system capabilities
- **WebGL will enable visually rich, dynamic HTML5 'apps'**
  - Portable to any Web-capable system, Web discoverable
  - Run in browser or with no 'Chrome' – like Flash/Air, Rim WebWorks
- **Opportunity to synergize Web and native APIs to expand HTML5**
  - Leverage APIs investments, reduce developer learning cycles

Visual-based Augmented Reality

Camera video stream sent to the compositor

Camera images used to track the camera's location and orientation

3D augmentations composited with video stream

Camera Tracking

Camera-to-scene transform locks the 3D rendering to the real world

3D Augmentation Rendering

Compute Power Driving Sensor Innovation

Diverse Devices and Platforms
Need Application Portability
Touch screens, controllers, microphones etc.
Mobile phones, tablets, desktop systems

No cross-platform API for accessing and enabling these innovative input devices

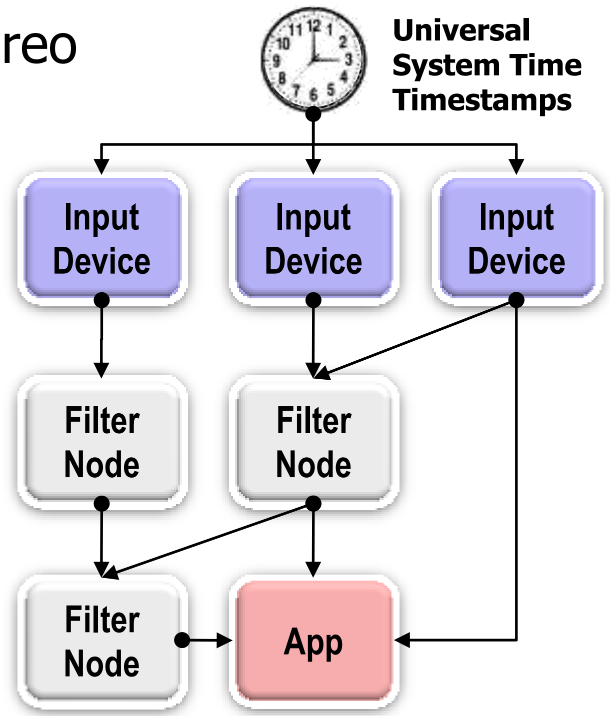
Positional Sensor Fusion
Combined Sensor Processing
Gyro, accelerometer, compass
Application control and
situational awareness

StreamInput Cross-platform Sensor API

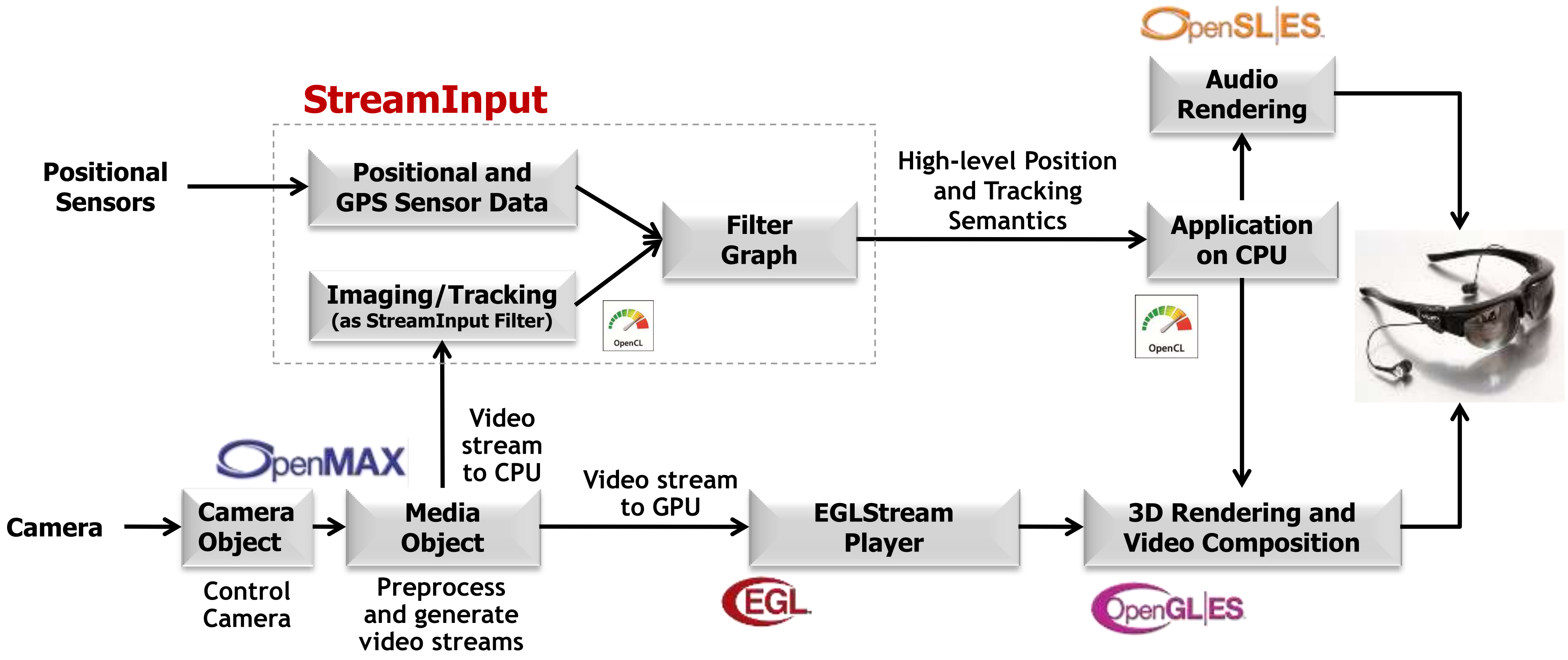
Cameras as Sensors
Gesture and Motion Detection
Depth cameras – a la Kinect
Standard cameras inc. stereo

Core StreamInput Concepts

- **Application discovers what sensors can provide required semantic input**
  - "Am I in an elevator, in a moving car, or being carried in a pocket"
  - "Need full body tracking and gestures"
- **Handles almost any sensor**
  - Multi-axis motion/position sensors, capacitive multi-touch surfaces
  - RGB and Depth sensing cameras – including mono and stereo
  - Microphone arrays for speech recognition etc.
  - Haptic devices, Biometric sensors etc. etc
- **Graph-based API**
  - Application sets up a graph of input device nodes
  - Graph generates high or low level data for app
- **Multi-sensor synchronization**
  - Timestamp EVERYTHING in a system

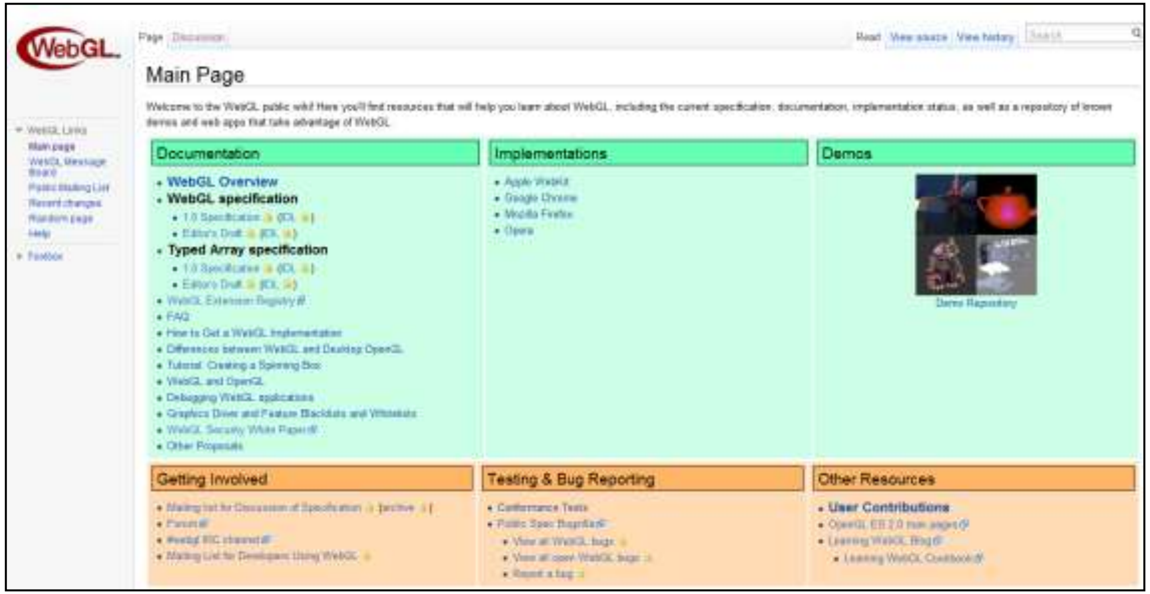


Khronos APIs in Example AR Flow



Get Involved!

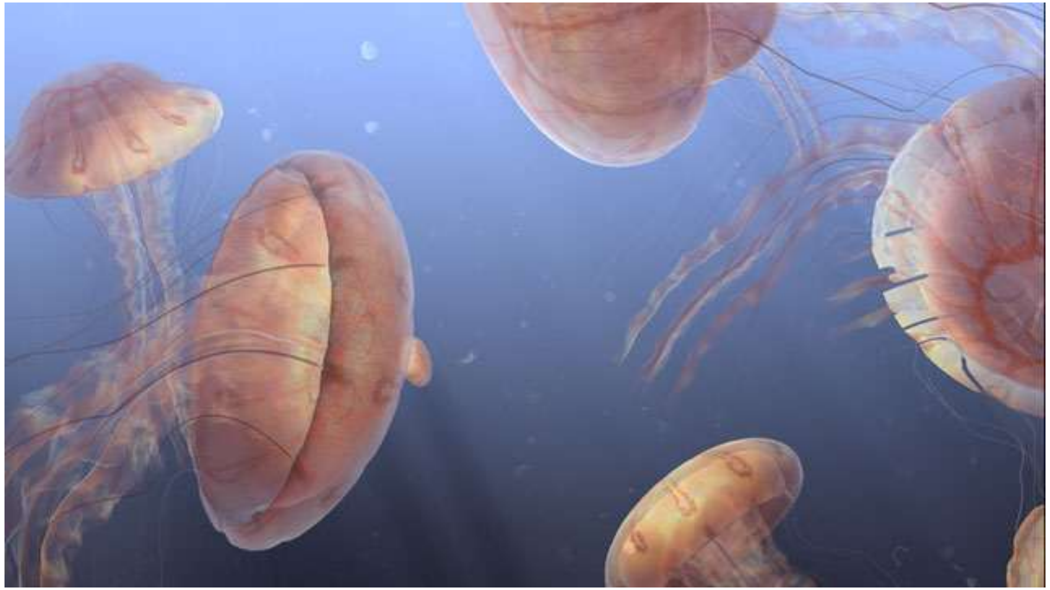
- **Engage with the WebGL working group on Khronos forums and mailing lists**
- **Let us know if you have news or links that Khronos can help highlight**
  - info@khronos.org or edit the Wiki
- **Join Khronos to have a voice in how the specs evolve!**
  - Any company is very welcome



http://www.khronos.org/webgl/wiki/Main_Page

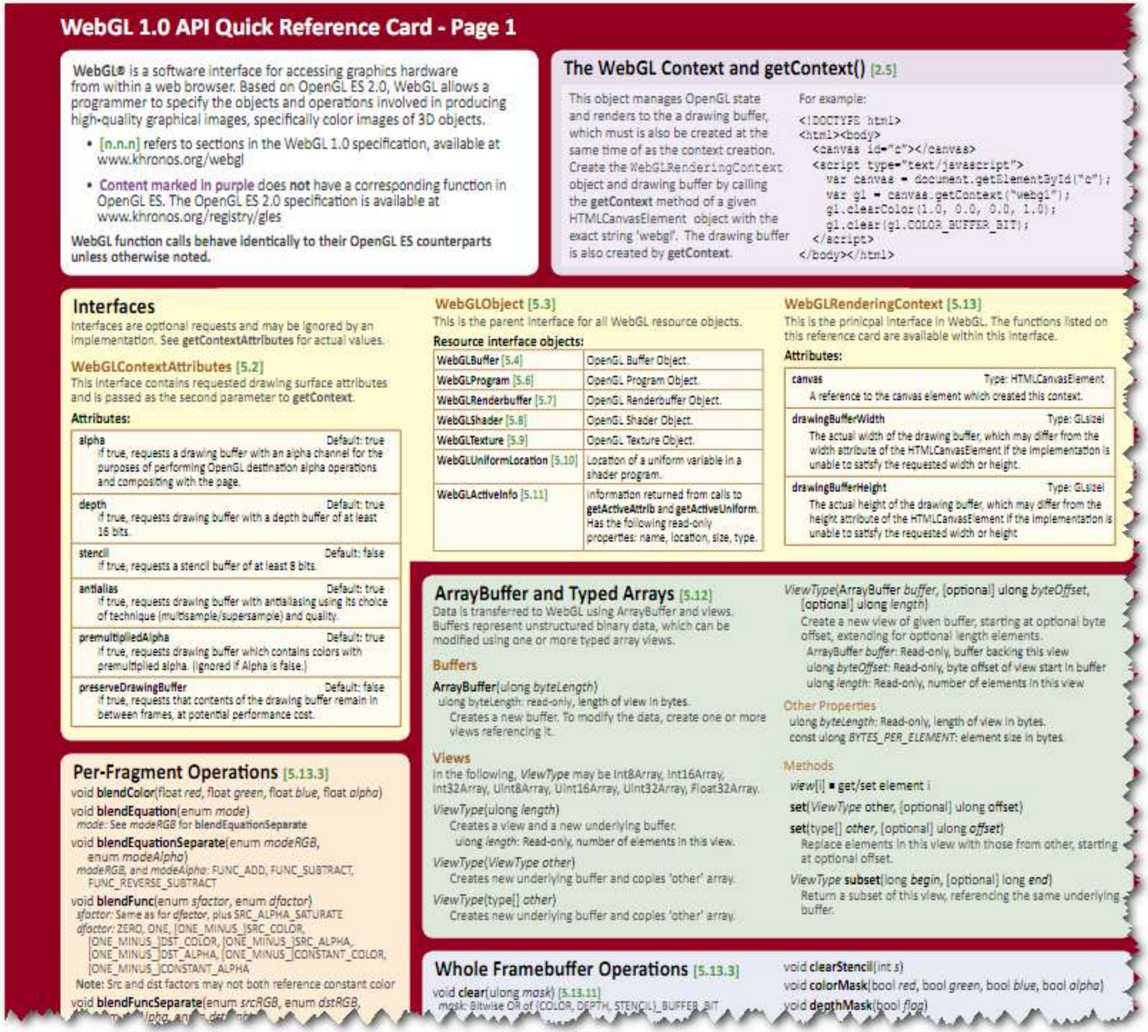
In Summary

- WebGL brings another vital piece of system capability into the HTML5 browser for web apps – 3D graphics
- WebGL is being deployed right now on PC – soon on mobile – and is being strongly supported by browser and GPU vendors
- WebGL is a low-level, secure technology – that can be used directly and will support a rich ecosystem of tools and frameworks
- WebGL and WebCL show how to take well proven native APIs and bring them to the web – with more to come!



Questions?

Come get a Reference Card!


WebGL 1.0 API Quick Reference Card - Page 1

WebGL® is a software interface for accessing graphics hardware from within a web browser. Based on OpenGL ES 2.0, WebGL allows a programmer to specify the objects and operations involved in producing high-quality graphical images, specifically color images of 3D objects.

- [n.n.n] refers to sections in the WebGL 1.0 specification, available at www.khronos.org/webgl
- Content marked in purple does not have a corresponding function in OpenGL ES. The OpenGL ES 2.0 specification is available at www.khronos.org/registry/gles

WebGL function calls behave identically to their OpenGL ES counterparts unless otherwise noted.

The WebGL Context and getContext() [2.5]

This object manages OpenGL state and renders to the a drawing buffer, which must is also be created at the same time of as the context creation. Create the WebGLRenderingContext object and drawing buffer by calling the getContext method of a given HTMLCanvasElement object with the exact string 'webgl'. The drawing buffer is also created by getContext.

For example:

```
<!DOCTYPE html>
<html><body>
  <canvas id="c"></canvas>
  <script type="text/javascript">
    var canvas = document.getElementById("c");
    var gl = canvas.getContext("webgl");
    gl.clearColor(1.0, 0.0, 0.0, 1.0);
    gl.clear(gl.COLOR_BUFFER_BIT);
  </script>
</body></html>
```

Interfaces

Interfaces are optional requests and may be ignored by an implementation. See getContextAttributes for actual values.

WebGLContextAttributes [5.2]

This interface contains requested drawing surface attributes and is passed as the second parameter to getContext.

Attributes:

alpha — If true, requests a drawing buffer with an alpha channel for the purposes of performing OpenGL destination alpha operations and compositing with the page.	Default: true
depth — If true, requests drawing buffer with a depth buffer of at least 16 bits.	Default: true
stencil — If true, requests a stencil buffer of at least 8 bits.	Default: false
antialias — If true, requests drawing buffer with antialiasing using its choice of technique (multisample/supersample) and quality.	Default: true
premultipliedAlpha — If true, requests drawing buffer which contains colors with premultiplied alpha. (Ignored if Alpha is false.)	Default: true
preserveDrawingBuffer — If true, requests that contents of the drawing buffer remain in between frames, at potential performance cost.	Default: false

WebGLObject [5.3]

This is the parent interface for all WebGL resource objects.

Resource interface objects:

WebGLBuffer [5.4]	OpenGL Buffer Object.
WebGLProgram [5.6]	OpenGL Program Object.
WebGLRenderbuffer [5.7]	OpenGL Renderbuffer Object.
WebGLShader [5.8]	OpenGL Shader Object.
WebGLTexture [5.9]	OpenGL Texture Object.
WebGLUniformLocation [5.10]	Location of a uniform variable in a shader program.
WebGLActiveInfo [5.11]	Information returned from calls to getActiveAttrib and getActiveUniform. Has the following read-only properties: name, location, size, type.

WebGLRenderingContext [5.13]

This is the principal interface in WebGL. The functions listed on this reference card are available within this interface.

Attributes:

canvas — A reference to the canvas element which created this context.	Type: HTMLCanvasElement
drawingBufferWidth — The actual width of the drawing buffer, which may differ from the width attribute of the HTMLCanvasElement if the implementation is unable to satisfy the requested width or height.	Type: GLsizei
drawingBufferHeight — The actual height of the drawing buffer, which may differ from the height attribute of the HTMLCanvasElement if the implementation is unable to satisfy the requested width or height	Type: GLsizei

ArrayBuffer and Typed Arrays [5.12]

Data is transferred to WebGL using ArrayBuffer and views. Buffers represent unstructured binary data, which can be modified using one or more typed array views.

Buffers

ArrayBuffer(ulong byteLength)
ulong byteLength: read-only, length of view in bytes.
Creates a new buffer. To modify the data, create one or more views referencing it.

Views

In the following, ViewType may be Int8Array, Int16Array, Int32Array, Uint8Array, Uint16Array, Uint32Array, Float32Array.

ViewType(ulong length)
Creates a view and a new underlying buffer.
ulong length: Read-only, number of elements in this view.

ViewType(ViewType other)
Creates new underlying buffer and copies 'other' array.

ViewType(type[] other)
Creates new underlying buffer and copies 'other' array.

ViewType(ArrayBuffer buffer, [optional] ulong byteOffset, [optional] ulong length)
Create a new view of given buffer, starting at optional byte offset, extending for optional length elements.
ArrayBuffer buffer: Read-only, buffer backing this view
ulong byteOffset: Read-only, byte offset of view start in buffer
ulong length: Read-only, number of elements in this view

Other Properties
ulong byteLength: Read-only, length of view in bytes.
const ulong BYTES_PER_ELEMENT: element size in bytes.

Methods
view[i] = get/set element i
set(ViewType other, [optional] ulong offset)
set(type[] other, [optional] ulong offset)
Replace elements in this view with those from other, starting at optional offset.
ViewType subset(long begin, [optional] long end)
Return a subset of this view, referencing the same underlying buffer.

Per-Fragment Operations [5.13.3]

void blendColor(float red, float green, float blue, float alpha)
void blendEquation(enum mode)
mode: See modeRGB for blendEquationSeparate
void blendEquationSeparate(enum modeRGB, enum modeAlpha)
modeRGB, and modeAlpha: FUNC_ADD, FUNC_SUBTRACT, FUNC_REVERSE_SUBTRACT
void blendFunc(enum sfactor, enum dfactor)
sfactor: Same as for dfactor, plus SRC_ALPHA_SATURATE
dfactor: ZERO, ONE, [ONE_MINUS_]SRC_COLOR, [ONE_MINUS_]DST_COLOR, [ONE_MINUS_]SRC_ALPHA, [ONE_MINUS_]DST_ALPHA, [ONE_MINUS_]CONSTANT_COLOR, [ONE_MINUS_]CONSTANT_ALPHA
Note: Src and dst factors may not both reference constant color
void blendFuncSeparate(enum srcRGB, enum dstRGB,

Whole Framebuffer Operations [5.13.3]

void clear(ulong mask) [5.13.11]
mask: Bitwise OR of {COLOR, DEPTH, STENCIL}_BUFFER_BIT
void clearStencil(int s)
void colorMask(bool red, bool green, bool blue, bool alpha)
void depthMask(bool flag)