Delivering Compelling User Experiences via Open Standard APIs and State-of-the-art Mobile Silicon

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NVIDIA Automotive Business Unit

Enabling Compelling Mobile Experiences

Processing Power

To deliver rich content – on battery power!

OS Flexibility

To support sophisticated applications

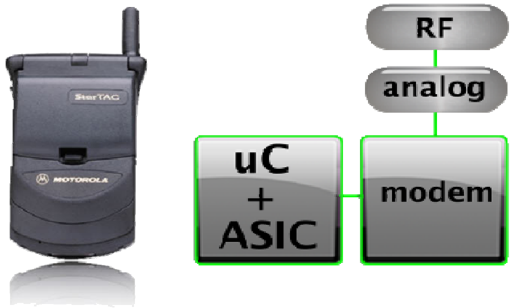
Rich Media Functionality

Not just audio and video but real-time 3D - with open standard acceleration APIs

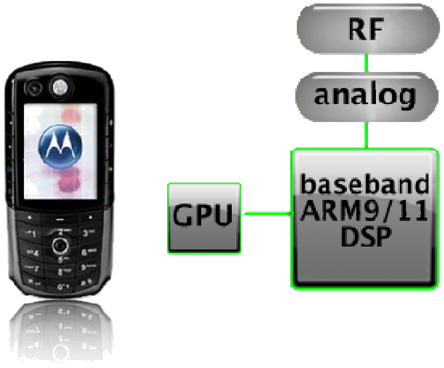
User Accessibility

Compelling user experiences and intuitive user interface

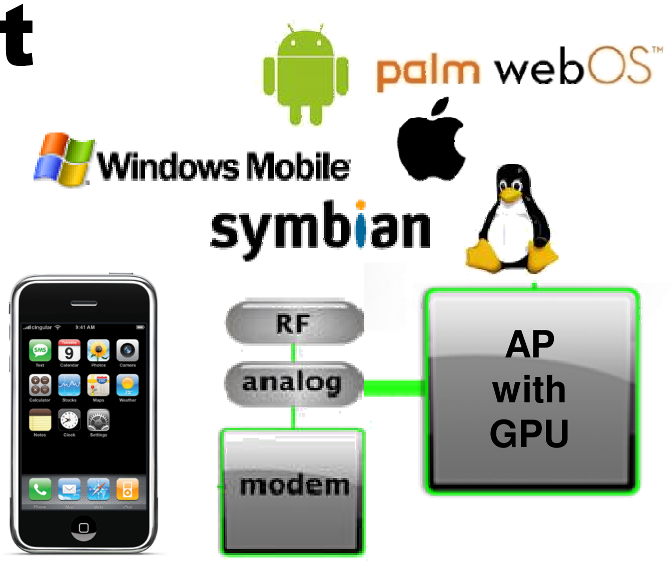
Phone Architecture Shift



1997 – E.g. StarTAC
- Basic OS running on modem
- Limited Performance and functionality
- No media capabilities



2004 – E.g. Motorola E1000
- Baseband processor integrates CPU and modem
- Higher-capability OS
- GPU media acceleration *sometimes* available as a separate device

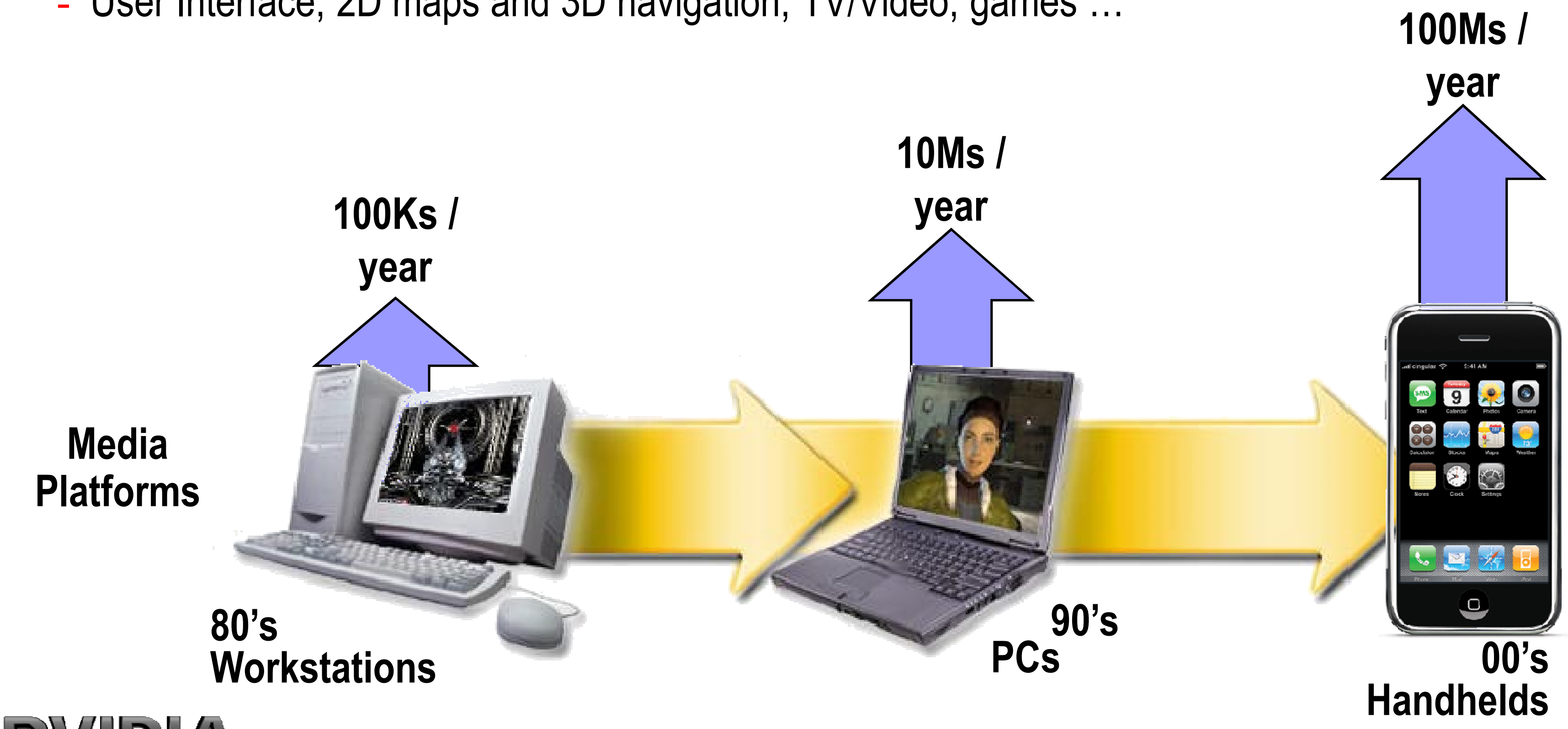


2009 – E.g. IPhone
- Application Processor integrates fast, capable CPU with full GPU media processing on one chip
- Modem is a peripheral to decouple OS/applications from wireless transitions
- Full multi-tasking OS

A full computer in the palm of your hand!

Pervasive Mobile Media Computing

- **Handsets are becoming personal computing devices - not “just” phones**
  - Your most personal computer – mobility, connectedness and numerous sensors
- **Sophisticated media processing will be central to handheld revolution**
  - Graphics and media will become as pervasive as it is on the PC
- **Diverse applications will drive the need for handheld accelerated media**
  - User Interface, 2D maps and 3D navigation, TV/Video, games …



Media Platforms

100Ks / year

80’s Workstations

10Ms / year

90’s PCs

100Ms / year

00’s Handhelds

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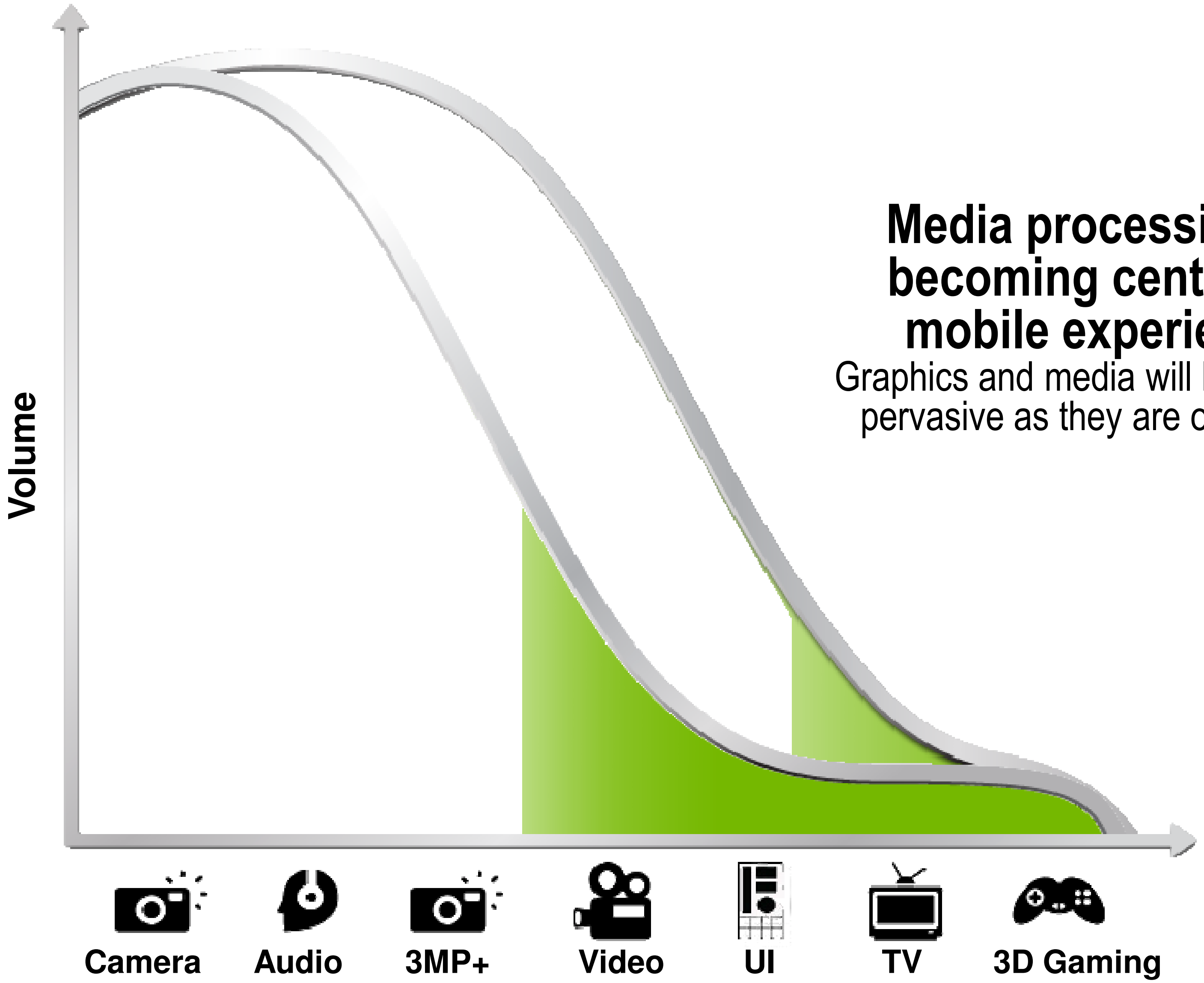
Mobile Platform Media Evolution



Media processing is becoming central to mobile experience

Graphics and media will become as pervasive as they are on the PC

Mobile Media Fragmentation

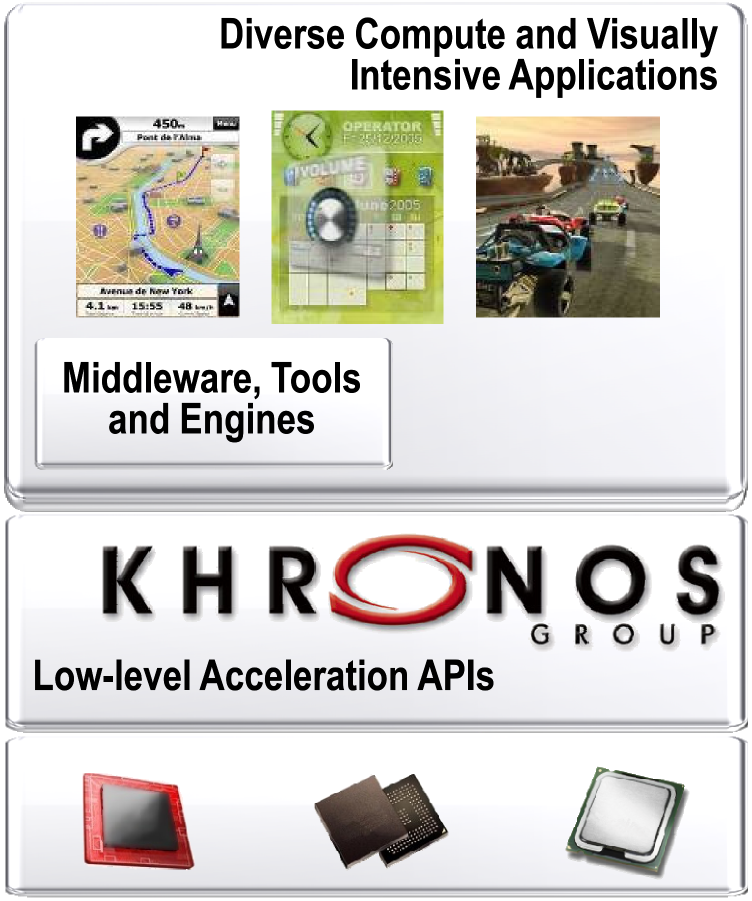
- **Every handset is unique from the programmers perspective**
  - Differences in operating system functions, Java implementations and media functionality

Symbian 7, 8, 9, UIQ, S60
PocketPC / Windows Mobile / WinCE
Linux variants – Android, Limo
Java MIDP-1, MIDP-2, JSR fragmentation
RTOS – Nucleus, Synergy
Brew, WIPI, MAC OS X

Severe platform fragmentation
ISVs need to port to and support 100s (even 1000s) of source variants of each title

Khronos API Standards

- “Foundation-Level” acceleration APIs
  - Needed on every platform to support an ecosystem of middleware and applications
- Low-level access to processor silicon
  - Designed with strong silicon vendor participation
- Cross-vendor software portability
  - API abstractions just high enough to hide implementation specifics
- Established focus on graphics, media and parallel compute acceleration
  - 3D, vector 2D, video, imaging, audio, heterogenous parallel programming APIs…



Diverse Compute and Visually Intensive Applications

Middleware, Tools and Engines

Low-level Acceleration APIs

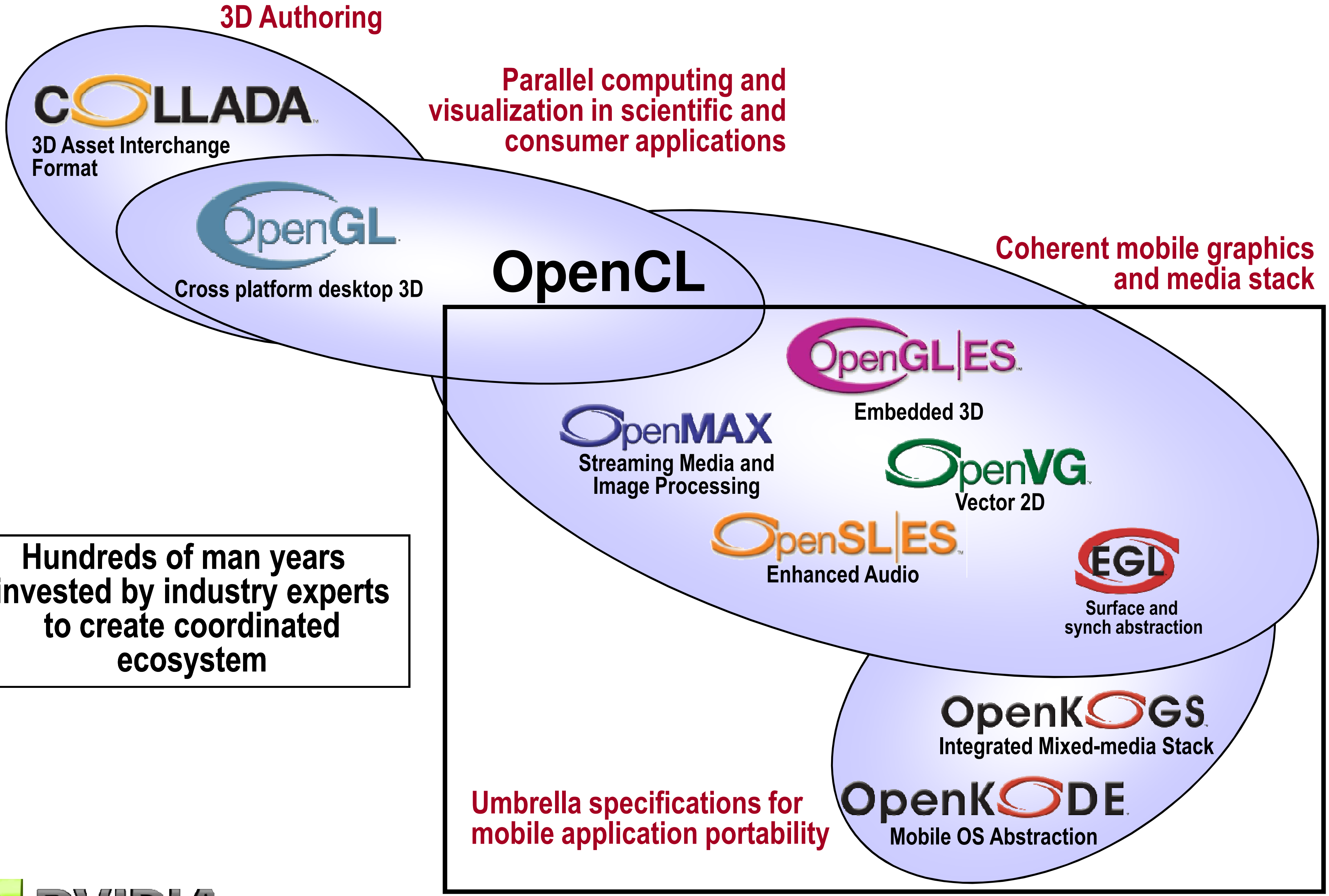
Khronos APIs create the foundation of an ecosystem that enable applications to be PORTABLE and ACCELERATED on diverse silicon platforms

3D Inc.
ABB
Acrodea
Activision
Blizzard
Adobe
ALT Software Inc.
Analog Devices
Antix
Aplix Corporation
ARC
ArcSoft
ARDITES
austriamicrosystems
Autodesk
BEATNIK
BitFlash
Broadcom
codeplay
Conexant
Core Logic
Creative
Daimler
DAZ
Dell
digia
DMP
Dolby
EA
france telecom
AMD
ARM
intel
IBM
Sony Computer Entertainment
Samsung
Imagination Technologies
KHRONOS GROUP
Ericsson
freescale semiconductor
Motorola
Nokia
nVIDIA
Sun microsystems
Texas Instruments
FhG
Fujitsu
Futuremark Corporation
GiQuila
Google
graphicREMEDY
Hantro
HI Corp.
HiSilicon
hooked wireless
HUONE Innovation Partner
incoras
ideaworks3D!
imec
SK innoace
LG
matrox
Marvell
Mentor Graphics
Micron
Mitsubishi Electric
Monotype
movidia
NDS
NEC
Nexus Chips
NXP
OmeGame
Panasonic
QNX Software Systems
Qualcomm
RapidMind
Renesas
S3 Graphics
sasken
Scaleform
Seaweed Systems
Siemens
SiRF
SK telecom
SmithMicro Software
SoftBank
Sony Ericsson
ST
Sunplus
symbian
Takumi
tat
TES Electronic Solutions
Toshiba
TransGaming Technologies
TTPCOM
Tungsten Graphics
Universität Karlsruhe (TH)
Umeå Universitet
Vincent
Vivante
Yamaha
Yumetech

Over 100 companies creating authoring and acceleration standards

Board of Promoters

The Khronos Mobile API Ecosystem



3D Authoring

COLLADA

3D Asset Interchange Format

Parallel computing and visualization in scientific and consumer applications

OpenGL

Cross platform desktop 3D

OpenCL

Coherent mobile graphics and media stack

OpenGL|ES

Embedded 3D

OpenMAX

Streaming Media and Image Processing

OpenVG

Vector 2D

OpenSL|ES

Enhanced Audio

EGL

Surface and synch abstraction

OpenKOGS

Integrated Mixed-media Stack

OpenKODE

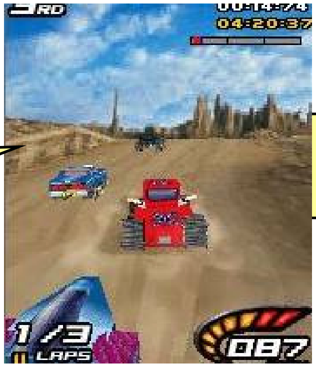
Mobile OS Abstraction

Umbrella specifications for mobile application portability

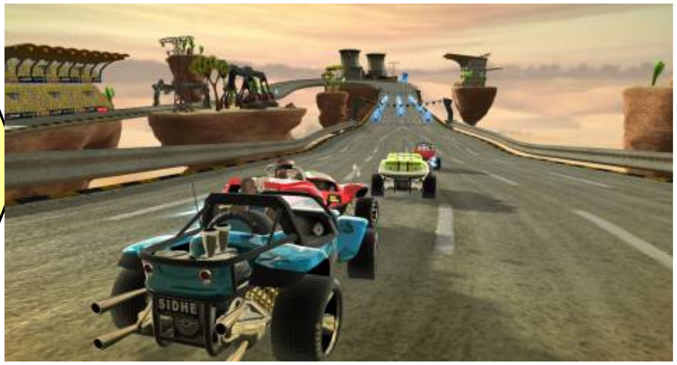
Hundreds of man years invested by industry experts to create coordinated ecosystem

Advantages of Mobile Graphics Acceleration

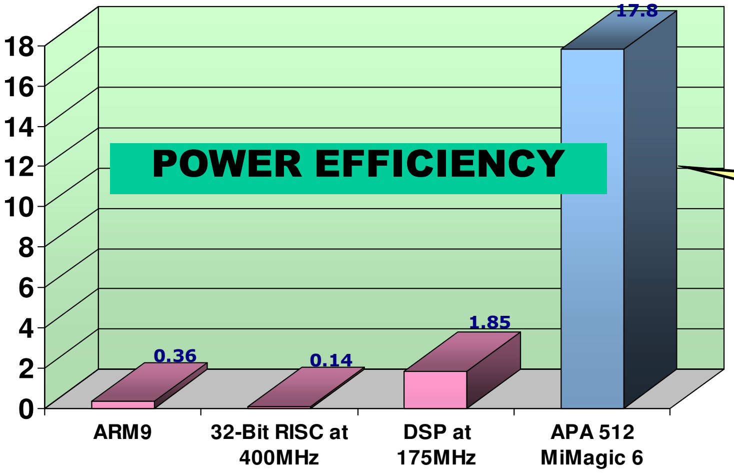
Faster Performance at Higher Quality
Hardware delivers smoother interaction with much better looking graphics



Software 3D



Accelerated 3D



Less Power
Hardware accelerators exploit media pipeline parallelism and caching for a x10 increase in power efficiency over software

Better User Experience
Smaller screens need more advanced graphics processing per pixel

OpenGL ES

- **The leading 3D rendering API for mobile devices**
  - Based on desktop OpenGL – but optimized for mobile / handheld devices
  - Removes redundancy & rarely used features - adds mobile-friendly data types
  - The power of OpenGL distilled into a much smaller package
- **A smashing success!**
  - Widely used in mobile phone handsets from every major handset manufacturer
  - Personal Navigation, Personal Media Player, Automotive, Set-Top Box, Mobile Internet Device
  - Brew, Windows Mobile, Symbian, Android, iPhone OS, Limo
- **OpenGL ES has become the most widely deployed 3D API**
  - Used in diverse applications, devices and markets

Windows Mobile
palm webOS
brew
OpenGL|ES
symbian

Mobile OS that have adopted OpenGL ES as their native 3D API

OpenMAX IL – Streaming Media

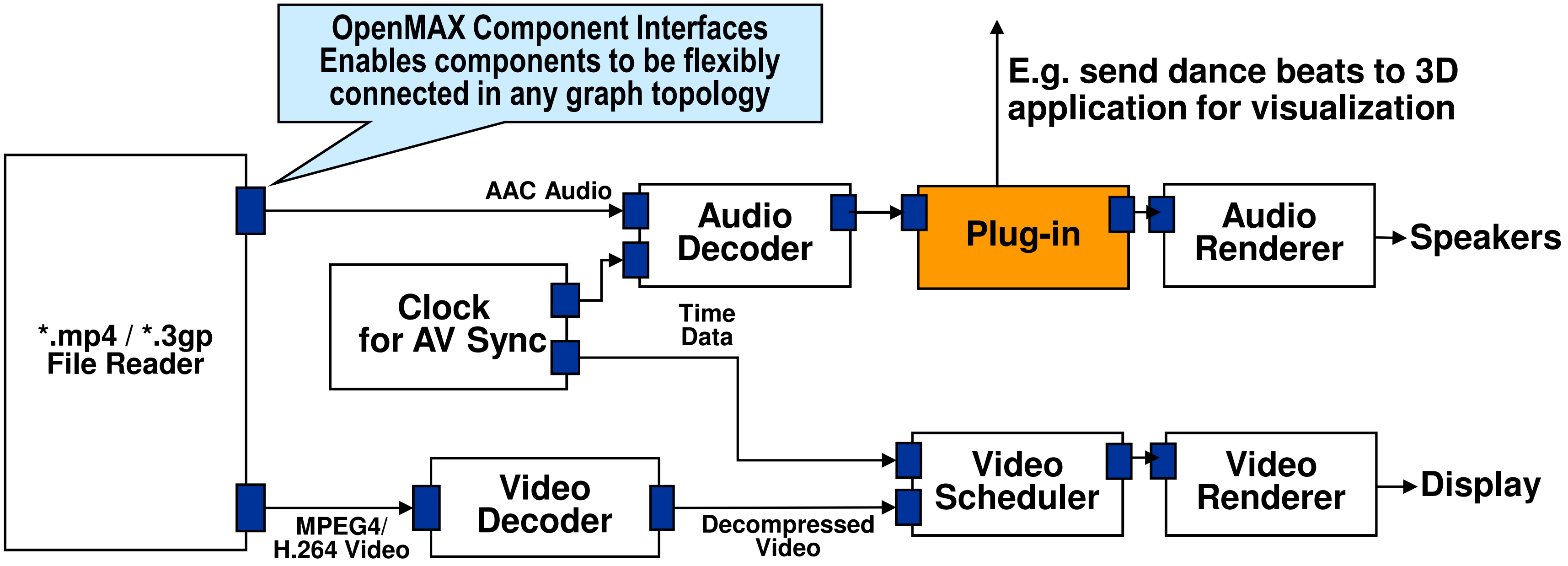
- **Enables arbitrary multimedia pipelines by plugging blocks together**
  - Componentized architecture abstracts multimedia functionality block interfaces
- **Wide variety of building blocks for imaging, video and audio functions**
  - Encode, decode, apply an effect, capture, render, split, mix, etc
- **Enables blocks from different sources to work together**
  - Blocks can be implemented in software or hardware

Portable & Re-usable streaming media building blocks

OpenMAX™

OpenMAX IL Example Graph

- Standardized component interfaces enable flexible media graphs
- Includes multi-stream synchronization
- Allows for custom plug-ins



OpenMAX Component Interfaces Enables components to be flexibly connected in any graph topology
E.g. send dance beats to 3D application for visualization
*.mp4 / *.3gp File Reader
AAC Audio
Audio Decoder
Plug-in
Audio Renderer
Speakers
Clock for AV Sync
Time Data
Video Scheduler
Video Renderer
Display
MPEG4/ H.264 Video
Video Decoder
Decompressed Video

Example: MPEG-4 video synchronized with AAC audio decode

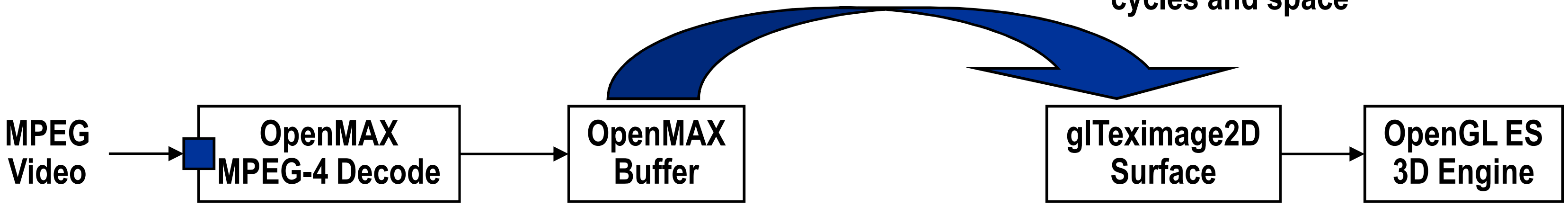
EGL

- **EGL abstracts access to rendering surfaces**
  - Interfaces Khronos rendering APIs to native platform window system
  - A derivative of the WGL Windows abstraction API
- **Emerging role as a communication hub between handheld APIs**
  - Sharing images via EGLImage extensions
  - EGLSync objects for inter-API fences and other signalling
- **Can create rendering surfaces into which multiple client APIs can draw**
  - Enables high-performance, accelerated, mixed-mode 2D and 3D rendering
  - Using OpenGL ES and OpenVG
- **EGL 1.3 was released in December 2006 – supports OpenGL ES**
  - OpenKODE 1.0 uses EGL 1.3 PLUS EGL extensions to integrate OpenVG PLUS
  - Lock Surface EGL extension for direct blitting of software rendering applications to the screen
- **EGL 1.4 integrated OpenVG and Lock Surface into core EGL**
  - In spring 2008

Directions for EGL 1.5

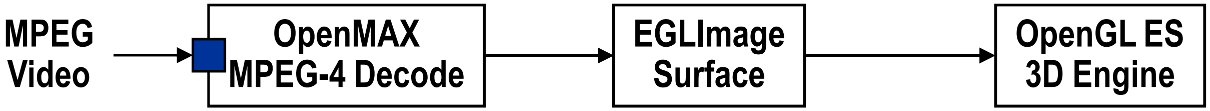
- **Create EGLImage within EGL**
  - Pre-declare uses => guaranteed image compatibility
- **Share images with OpenMAX**
  - Add EGLImage video data formats (YUV)
- **Stream images between APIs**
  - Queue of images with producer/consumer operations
- **EGLSync objects**
  - Inter-API fences and other signalling

Without EGLImage the game must copy the OpenMAX buffer into an OpenGL ES texture



Data copy wastes cycles and space

An EGLImage surface can be used as both the destination of the decode and a texture without copying the data



Mobile Umbrella Specifications

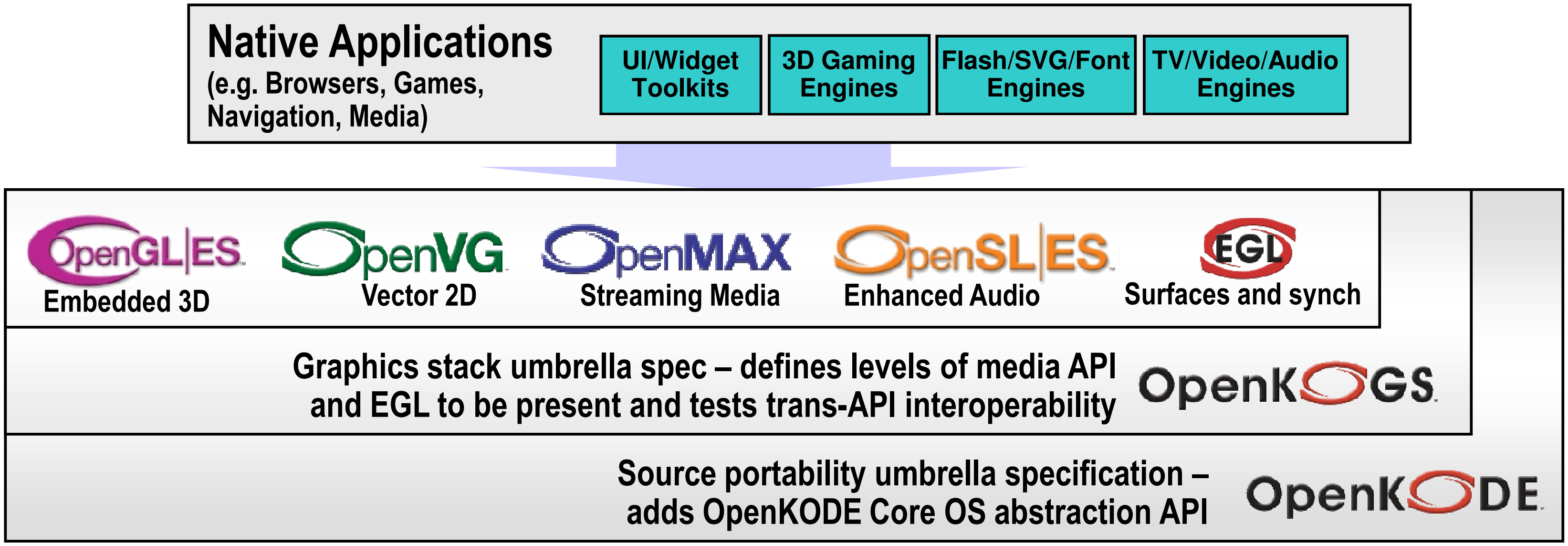
- **Individual APIs define domain specific media acceleration**
  - OpenGL ES for 3D, OpenMAX for video and images etc.
- **Latest mobile applications want to MIX media types**
  - E.g. route live video into a composited 3D user interface
- **For portability of mixed-media need to define how the APIs work *together***
  - E.g. how to transfer video data from OpenMAX into OpenGL ES
- **Umbrella specs define and CONFORMANCE TEST trans-API operation**
  - Creates a reliable, cross-vendor media-stack definition

OpenKOGS™

OpenKODE™

Khronos Mobile Umbrella Specs

- **Platform vendors can choose to ship more than just individual APIs**
  - Provide *conformance tested* multi-API programming platforms
- **1. OpenKOGS = integrated media stack**
  - Defines reliable trans-API interoperability through EGL for OpenGL ES, OpenVG, OpenMAX
- **2. OpenKODE = OpenKOGS *plus* OS abstraction API**
  - OpenKODE Core is Posix-like API for application portability across mobile operating systems



Native Applications
(e.g. Browsers, Games, Navigation, Media)

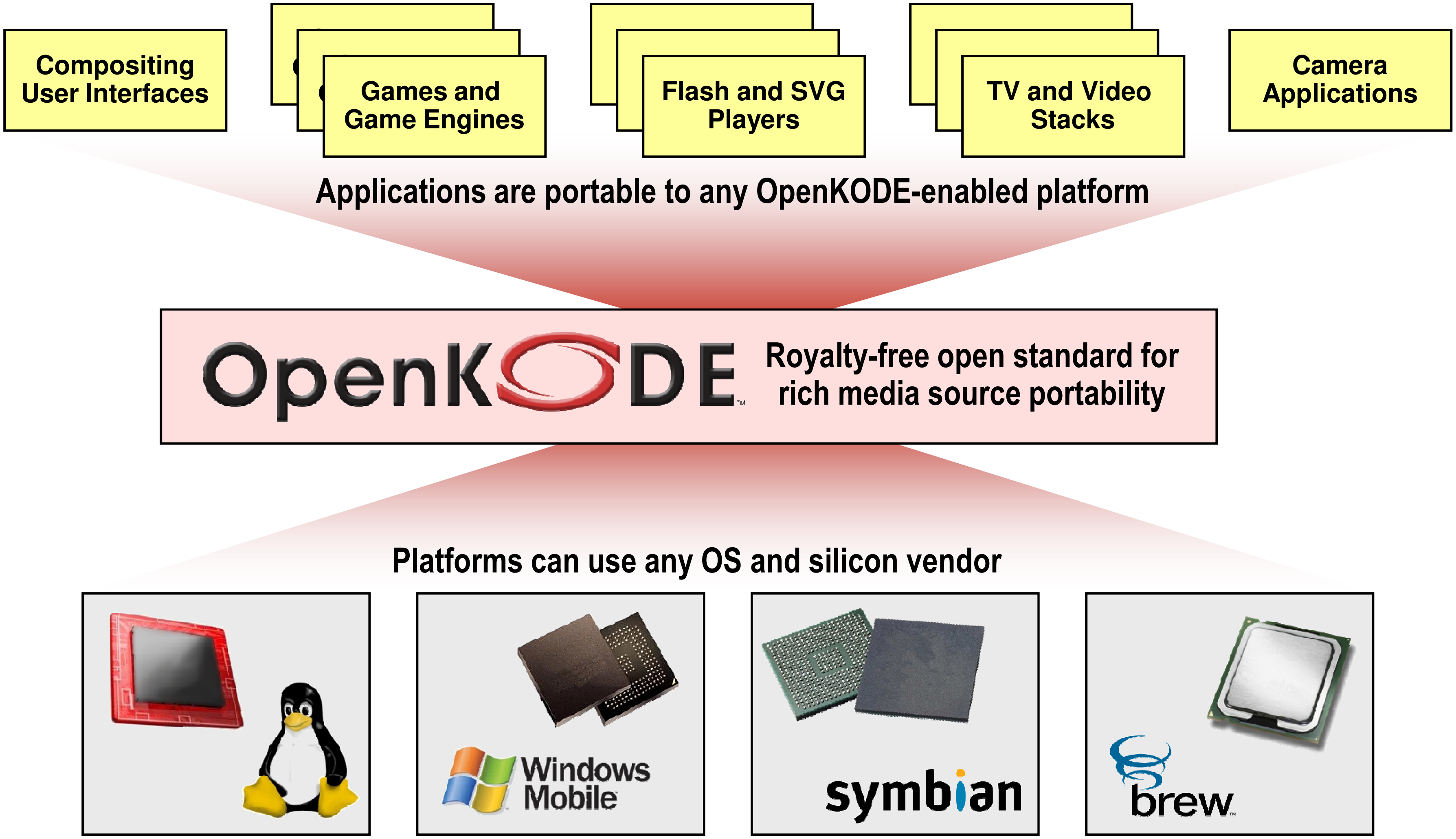
UI/Widget Toolkits | 3D Gaming Engines | Flash/SVG/Font Engines | TV/Video/Audio Engines

OpenGL ES – Embedded 3D
OpenVG – Vector 2D
OpenMAX – Streaming Media
OpenSL ES – Enhanced Audio
EGL – Surfaces and synch

Graphics stack umbrella spec – defines levels of media API and EGL to be present and tests trans-API interoperability – OpenKOGS

Source portability umbrella specification – adds OpenKODE Core OS abstraction API – OpenKODE

OpenKODE – Source Portability



Compositing User Interfaces

Games and Game Engines

Flash and SVG Players

TV and Video Stacks

Camera Applications

Applications are portable to any OpenKODE-enabled platform

OpenKODE™

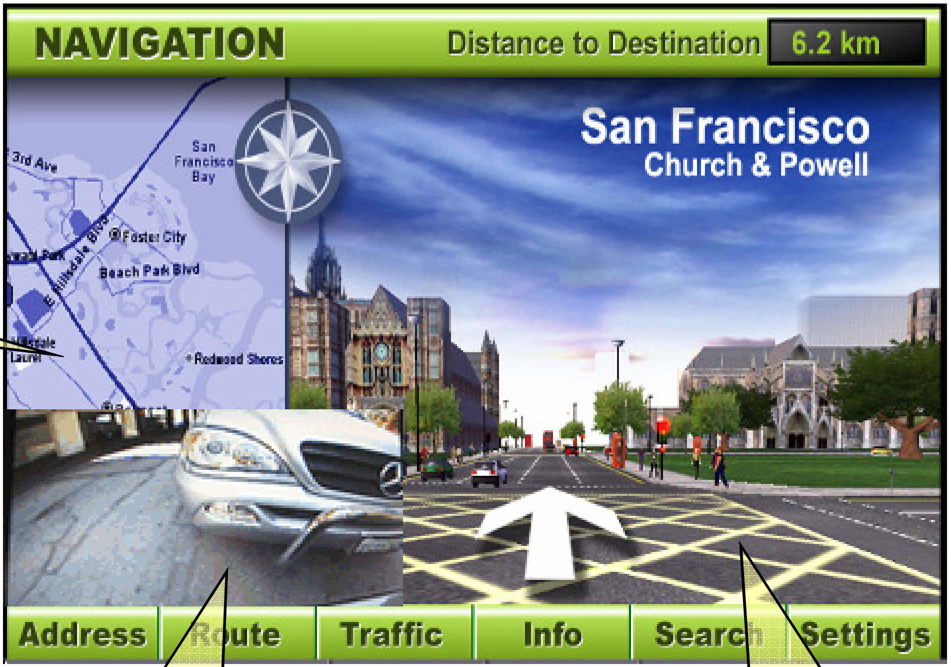
Royalty-free open standard for rich media source portability

Platforms can use any OS and silicon vendor

Raising 2D and 3D Visual Quality

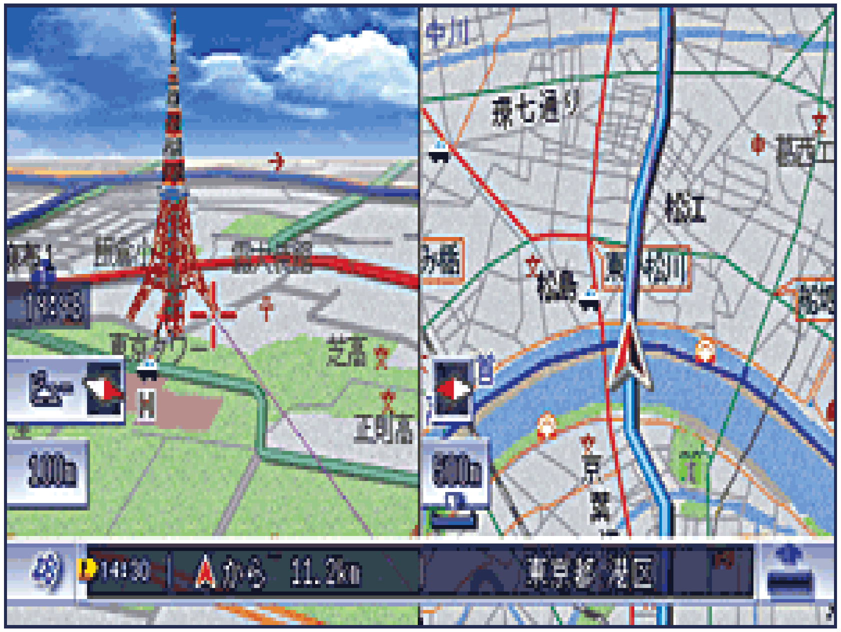
State-of-the-art APIs enable compelling consumer displays
Advanced functionality, fast interactivity and extremely high quality

High-quality 2D graphics and text using OpenVG



Video and image processing with OpenMAX

High-quality 3D displays using OpenGL ES



Older generation APIs
Provide rudimentary graphics functionality and quality

Processing Power
To deliver rich content –
on battery power!

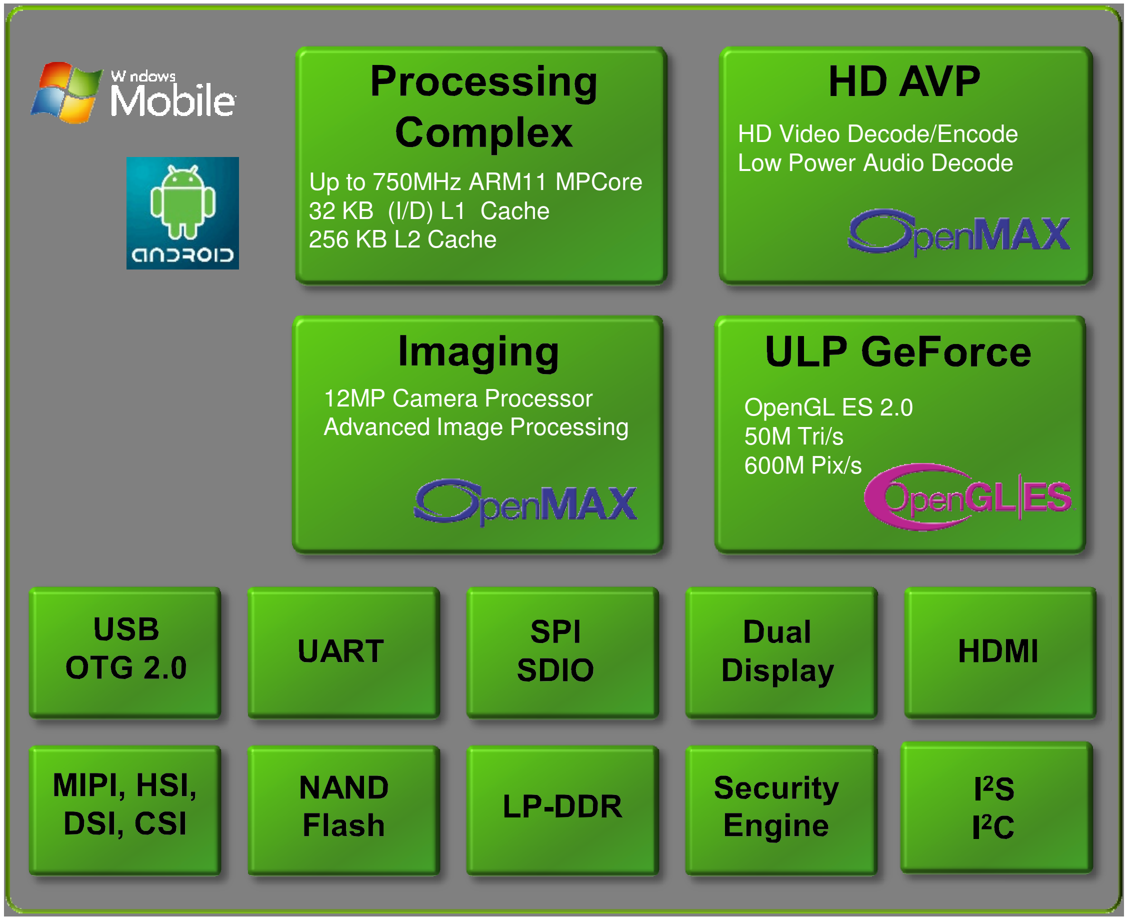
OS Flexibility
To support sophisticated applications

Alpine Run
You Tube

Rich Media Functionality
Not just audio and video but real-time 3D
- with open standard APIs

User Accessibility
Compelling user experiences and
intuitive user interface

Tegra – Computer on a Chip



Processing Complex
Up to 750MHz ARM11 MPCore
32 KB (I/D) L1 Cache
256 KB L2 Cache

HD AVP
HD Video Decode/Encode
Low Power Audio Decode

Imaging
12MP Camera Processor
Advanced Image Processing

ULP GeForce
OpenGL ES 2.0
50M Tri/s
600M Pix/s

USB OTG 2.0

UART

SPI SDIO

Dual Display

HDMI

MIPI, HSI, DSI, CSI

NAND Flash

LP-DDR

Security Engine

I²S I²C

- **Windows Mobile 6.X / WinCE and Android**
- **Unified memory - up to 512MB 166MHz LP-DDR (x16 or x32)**
- **Ultra low-power GeForce core - Xbox performance/PS3 functionality - at a few hundred milliwatts. 45 FPS Quake 3 Arena, WVGA with 5x CSAA, 8x anisotropic**
- **H.264 1080p 30fps decode/encode**
- **Ultra low power audio acceleration AAC, AMR, WMA, MP3, PCM, MIDI**
- **Dual Display HDMI 1.2, TV-out, LCD, CRT**
- **Baseband Interface HSI, SPI, UART**

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OS Flexibility

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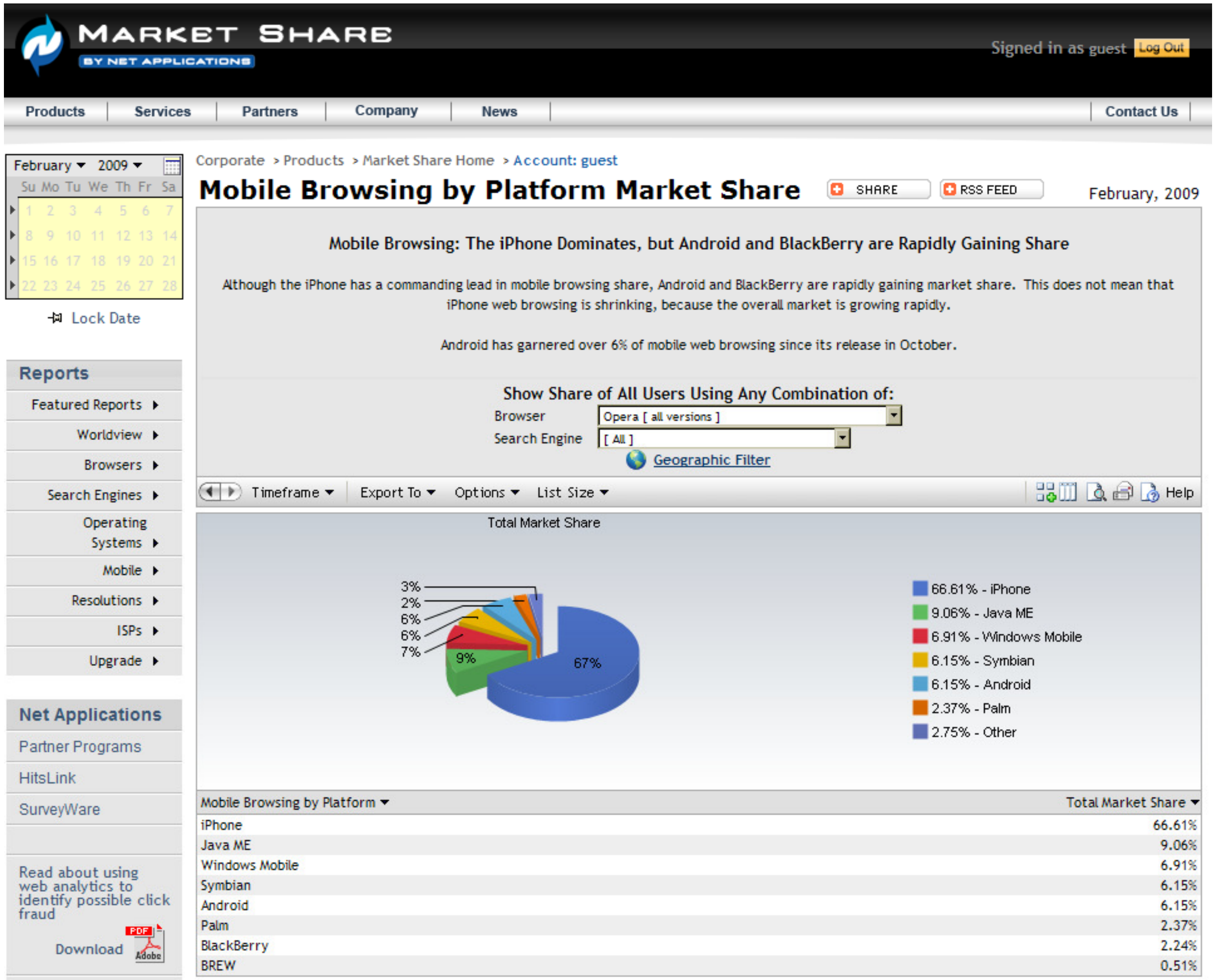
Usability Matters!

- **The iPhone demonstrates the importance of good UI**
  - Ease of discovery and use of device capabilities and resources drives revenue



Mobile Browsing by Platform Market Share

February, 2009

Mobile Browsing: The iPhone Dominates, but Android and BlackBerry are Rapidly Gaining Share

Although the iPhone has a commanding lead in mobile browsing share, Android and BlackBerry are rapidly gaining market share. This does not mean that iPhone web browsing is shrinking, because the overall market is growing rapidly.

Android has garnered over 6% of mobile web browsing since its release in October.

Show Share of All Users Using Any Combination of:

Browser: Opera [all versions]

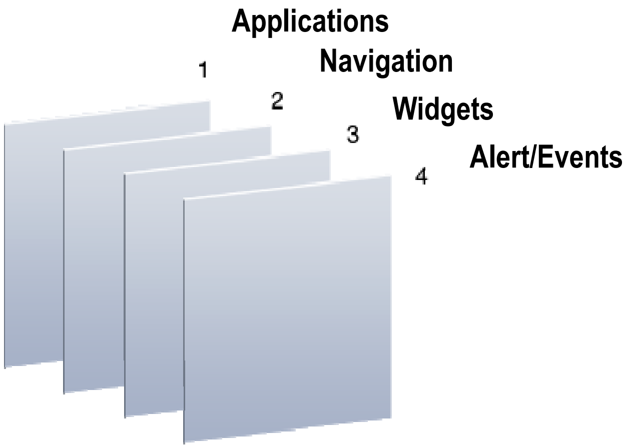
Search Engine: [All]

Geographic Filter

Mobile Browsing by Platform	Total Market Share
iPhone	66.61%
Java ME	9.06%
Windows Mobile	6.91%
Symbian	6.15%
Android	6.15%
Palm	2.37%
BlackBerry	2.24%
BREW	0.51%

Composited User Interfaces

- **Multiple accelerated applications render off-screen**
  - Bring multiple screen elements together with software flexibility onto the display
- **Uses 3D GPU to composite application outputs and UI elements to screen**
  - Needs multi-process-capable OpenGL ES graphics acceleration
- **Composition enables unlimited multiple virtual UI layers**
  - With software driven blending, merging and 3D transitions

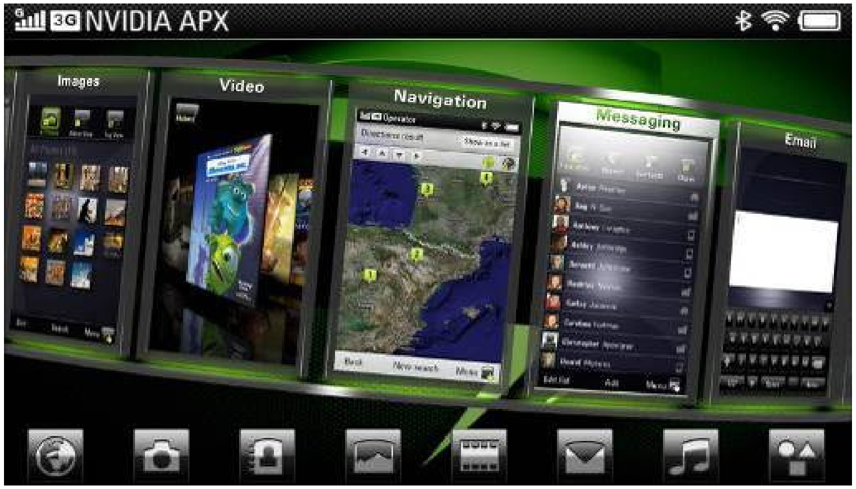


1 **Applications**

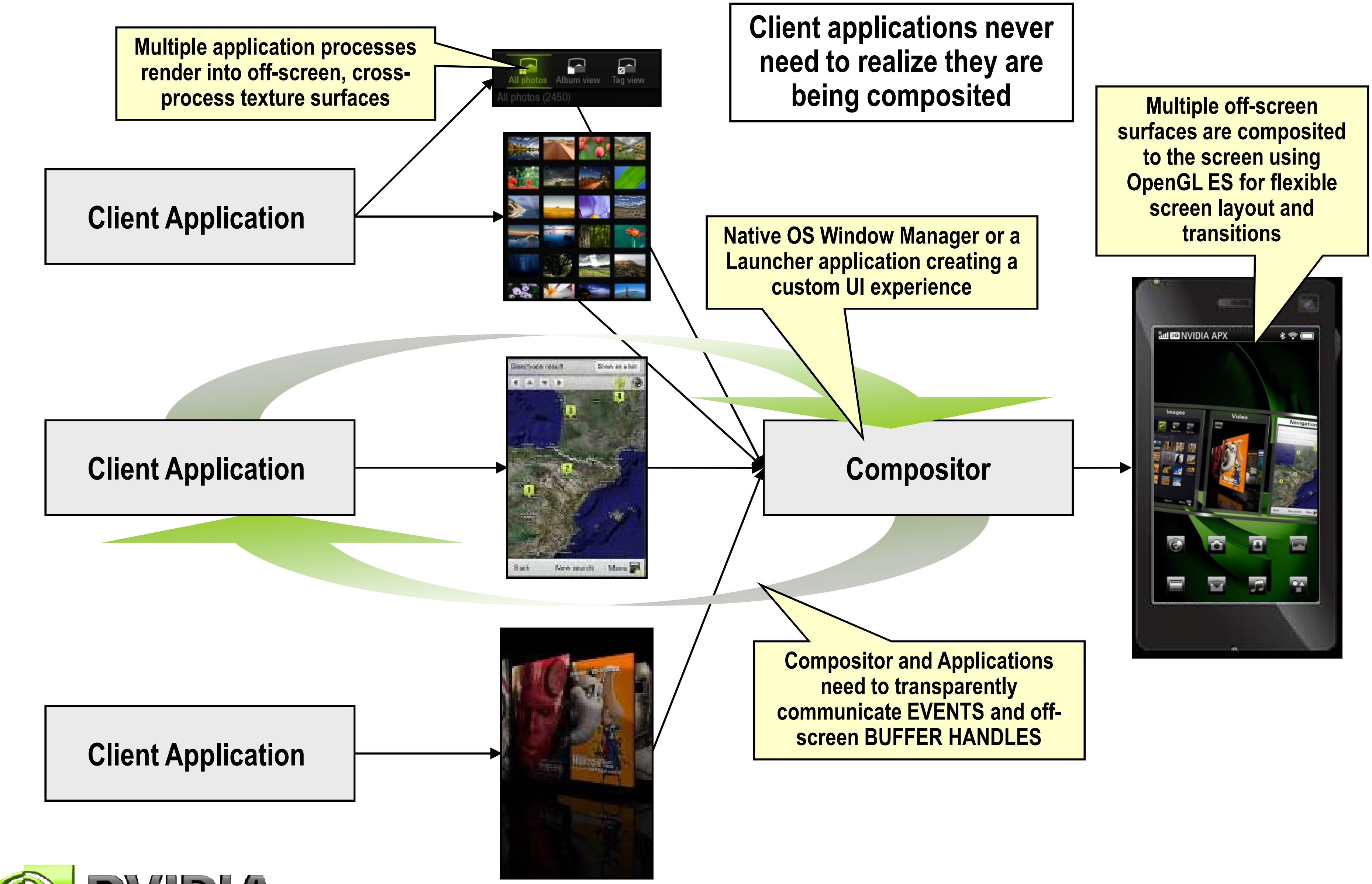
2 **Navigation**

3 **Widgets**

4 **Alert/Events**



Screen Composition



Multiple application processes render into off-screen, cross-process texture surfaces

Client applications never need to realize they are being composited

Multiple off-screen surfaces are composited to the screen using OpenGL ES for flexible screen layout and transitions

Native OS Window Manager or a Launcher application creating a custom UI experience

Client Application

Client Application

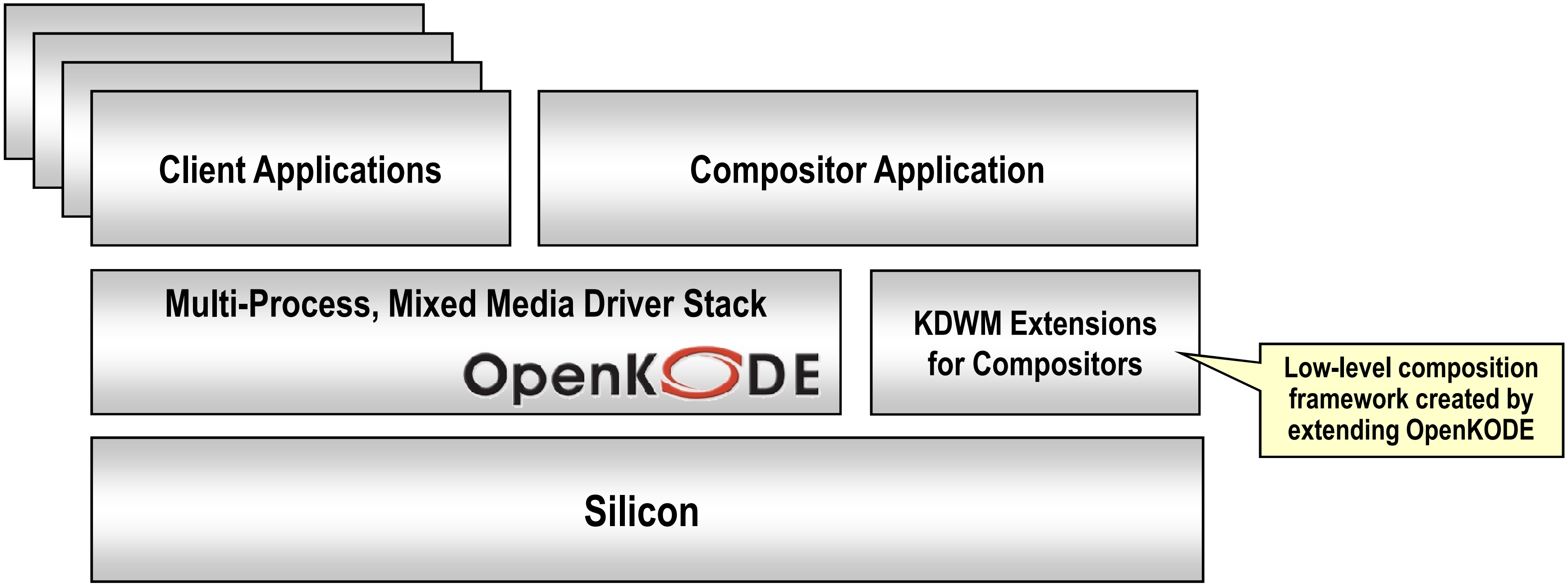
Client Application

Compositor

Compositor and Applications need to transparently communicate EVENTS and off-screen BUFFER HANDLES

Khronos Composition UI Initiative

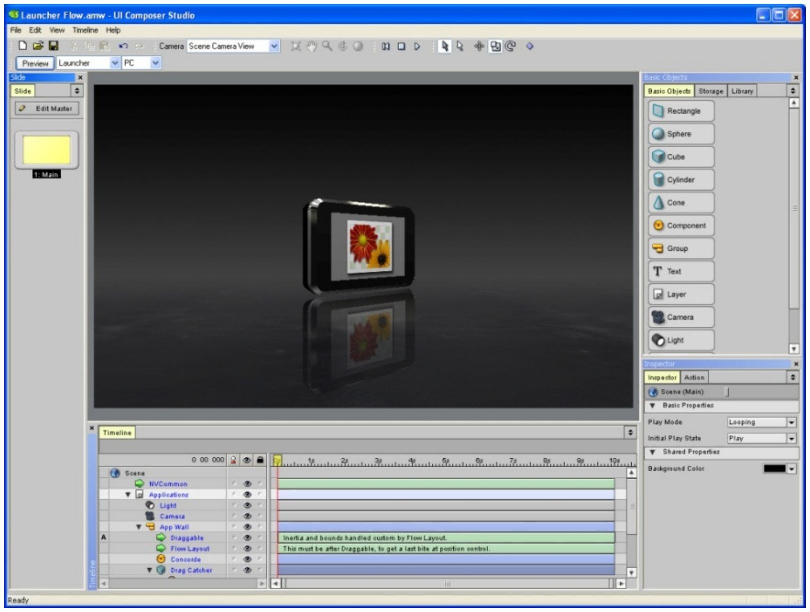
- **KDWM – “the Compositors OpenKODE”**
  - Extensions to OpenKODE Core - based on existing EGL and OpenKODE mechanisms
  - Off-screen surface allocation and cross process surface handle communication
  - Cross-process event dispatch
- **Developed by NVIDIA – contributed for standardization by Khronos**


Client Applications
Compositor Application
Multi-Process, Mixed Media Driver Stack
OpenKODE
KDWM Extensions for Compositors
Silicon

Low-level composition framework created by extending OpenKODE

3D UI Authoring Tools

- **Many device OEMs now demanding 3D UI**
  - Provides powerful capabilities compared to “2.5D”
  - Genuine lighting, animation and camera control enables emergent UI properties
  - Increased user context and navigational awareness
  - Emotionally compelling touch interaction
  - WOW-factor differentiation
- **But 3D coding expertise is rare**
  - Expensive, time consuming to program content
- **2D UI Solutions have great tools**
  - Enable the designer / creative talent
- **3D UI needs intuitive authoring**
  - Arrange assets in 3D
  - Animate in 3D
  - Link to user inputs



Camera: Scene Camera View

Launcher | PC

Play Mode: Looping

Initial Play State: Play

Background Color

Inertia and bounds handled custom by Flow Layout.

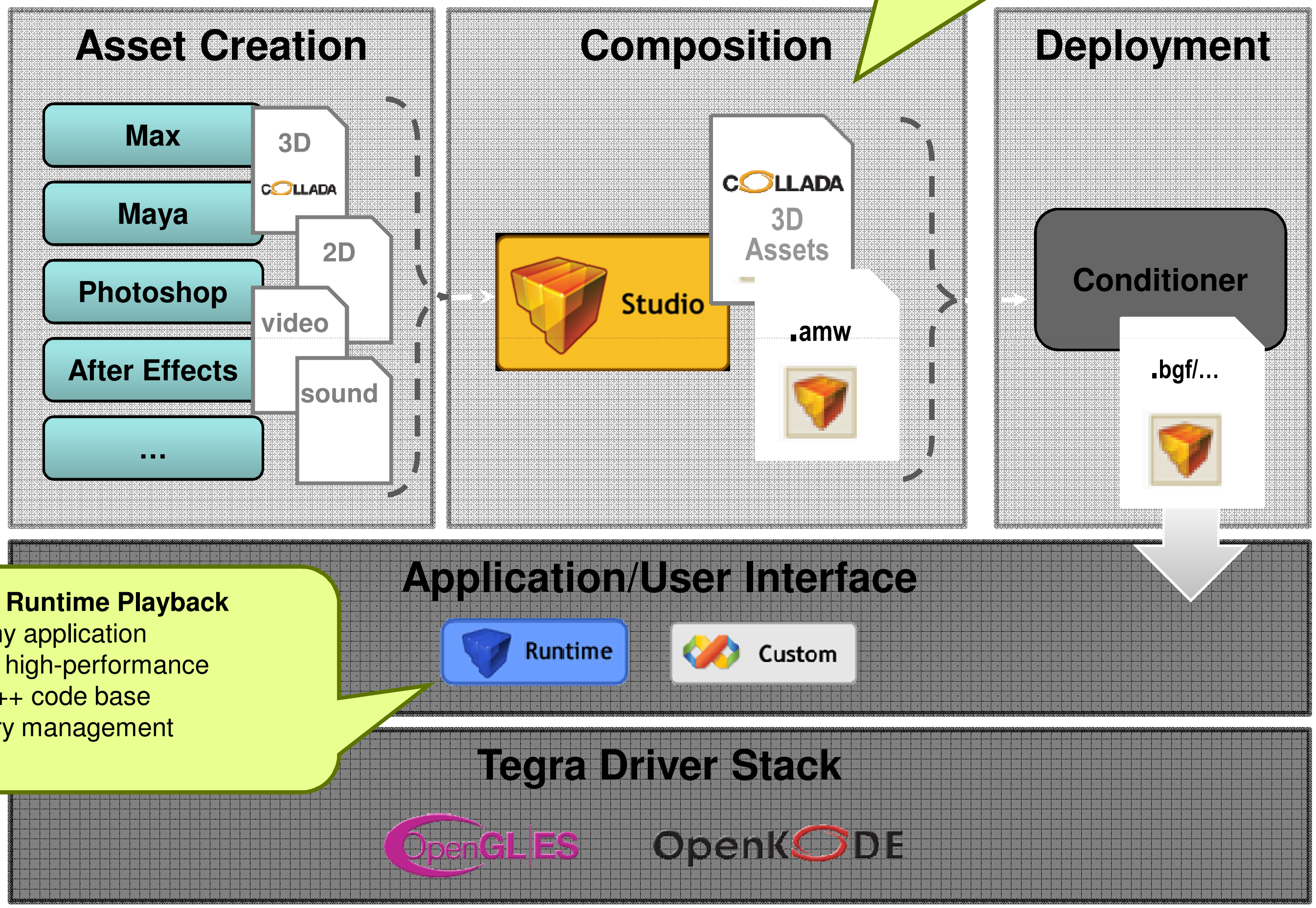
This must be after Draggable, to get a last bite at position control.

Ready

NVIDIA’s UI Composer 3D UI Authoring Tool

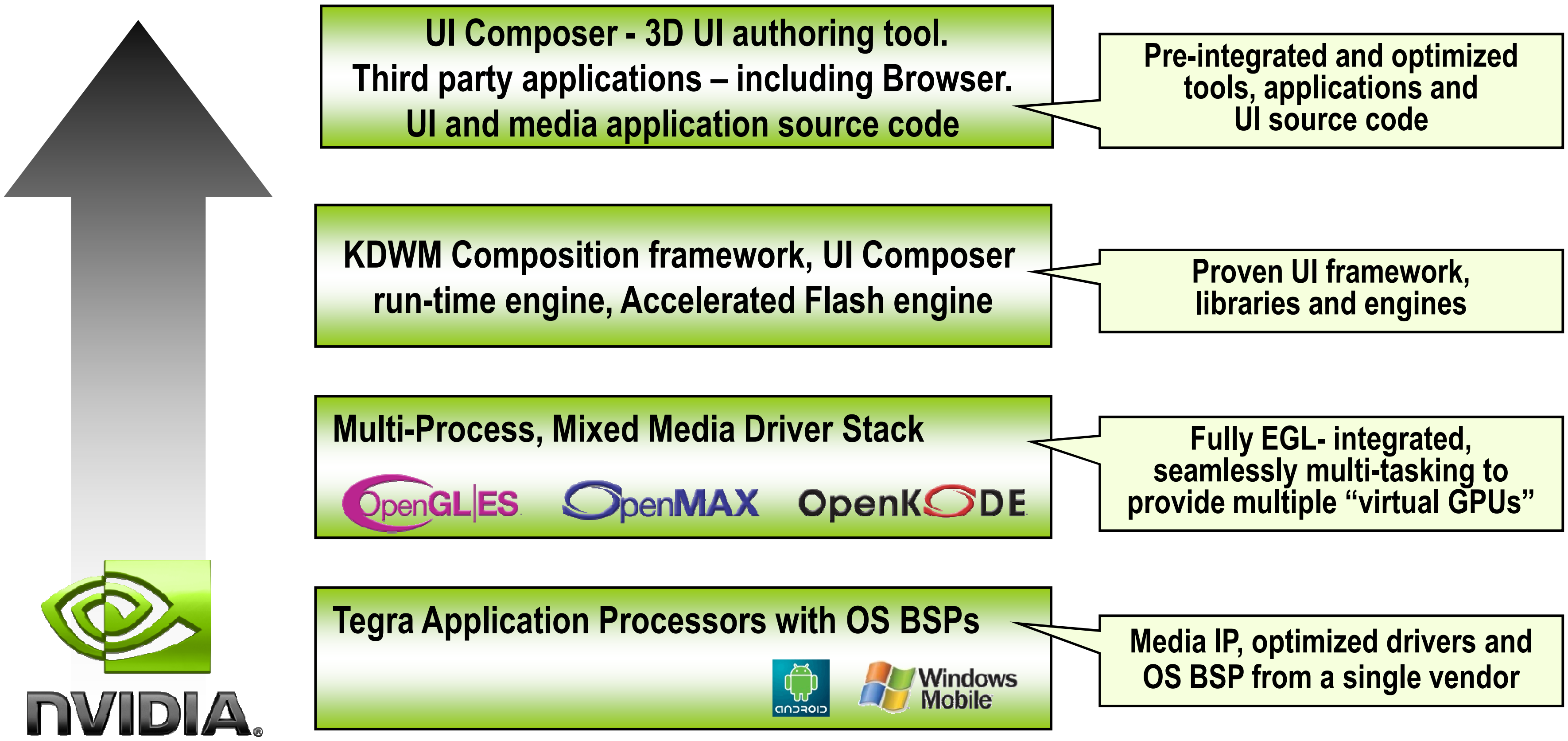
UI Composer Workflow

3D Asset Composition
Import multiple 3D assets
Arrange and animate in WYSIWYG 3D
Link animations to user inputs



UI Composer Runtime Playback
Embed into any application
Battle-proven, high-performance
Lightweight C++ code base
Strong memory management
Fully 3D

NVIDIA UI Stack



UI Composer - 3D UI authoring tool.
Third party applications – including Browser.
UI and media application source code

Pre-integrated and optimized tools, applications and UI source code

KDWM Composition framework, UI Composer run-time engine, Accelerated Flash engine

Proven UI framework, libraries and engines

Multi-Process, Mixed Media Driver Stack

OpenGL|ES OpenMAX OpenKODE

Fully EGL- integrated, seamlessly multi-tasking to provide multiple “virtual GPUs”

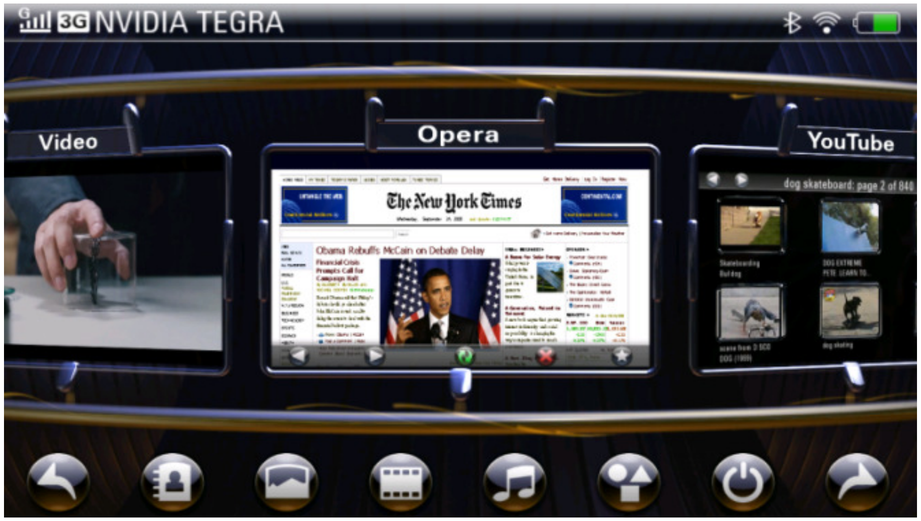
Tegra Application Processors with OS BSPs

android Windows Mobile

Media IP, optimized drivers and OS BSP from a single vendor

3D “Spinner” UI Demo

- **Running on Tegra Development System**
  - Projecting to 1280x768 resolution
- **Multi-process composition**
  - Uses OpenGL ES 2.0 for real-time screen composition
- **Fully implemented on OpenKODE open-standard APIs**
  - Using KDWM Composition framework
- **Fully virtualized 3D GPU and video acceleration**
  - Multiple OpenGL ES 2.0 and OpenMAX IL applications


3G NVIDIA TEGRA
Video
Opera
YouTube
dog skateboard: page 2 of 840
The New York Times
Obama Rebuffs McCain on Debate Delay

Conclusion

- Mobile phones are evolving into powerful, general-purpose computers with advanced media acceleration and user interfaces
- Soon many people in the world will be getting most of their pixels delivered in the palm of their hand
- Mobile silicon has the capability to deliver the high-end desktop graphics performance of just 2-3 years ago on a battery-powered device
- Delivering an advanced composition-based UI needs a full stack of drivers, engines and tools designed and tested to work together