Mobile AR Hardware Futures

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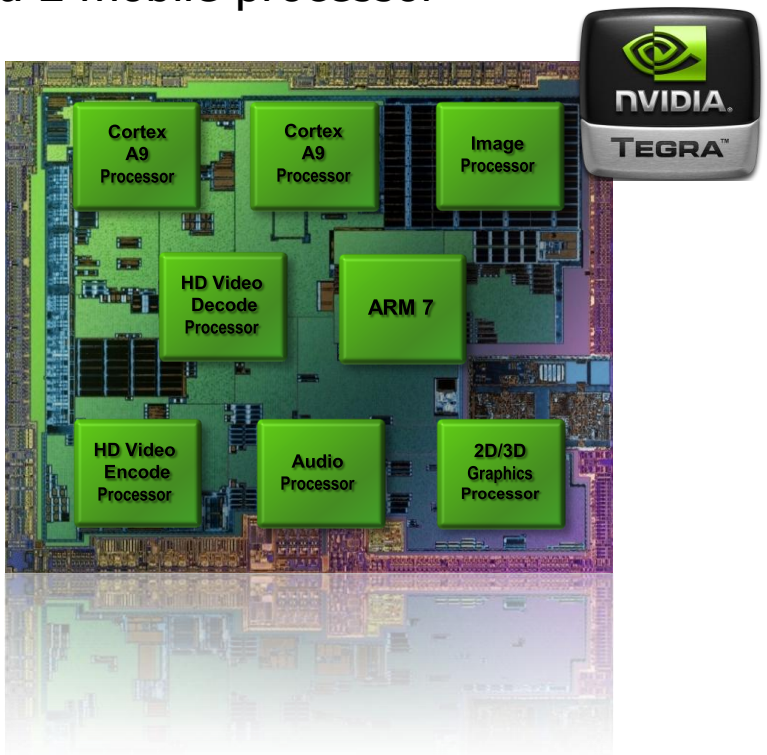
Two Perspectives

- **NVIDIA**
  - Tegra 2 mobile processor



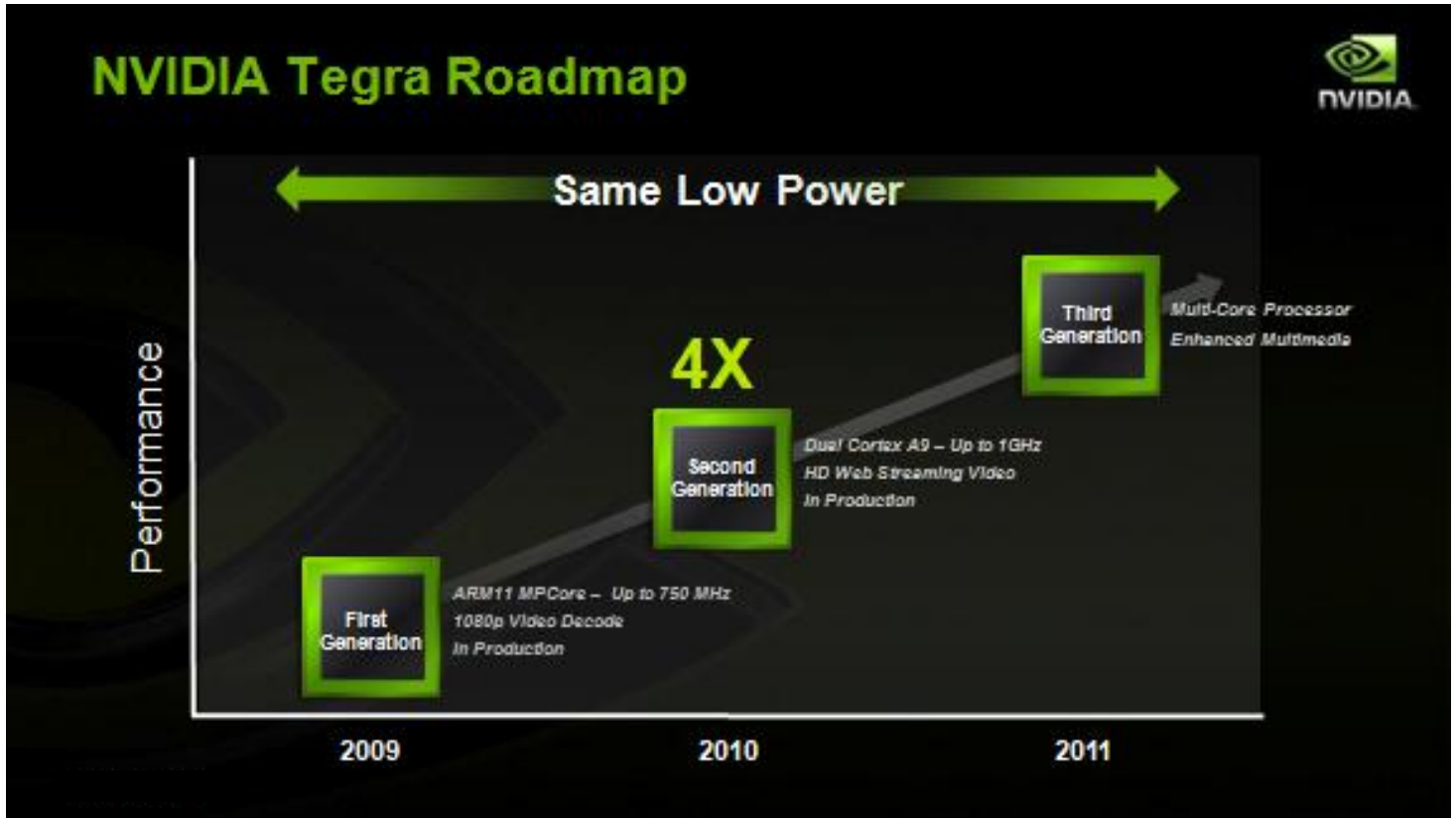
- **Khronos Group**
  - Industry consortium creating open, royalty-free API standards
  - At the silicon/software interface to enable software to leverage acceleration
  - Graphics, video, image, audio and compute acceleration APIs

OpenMAX
OpenGL
OpenGL ES
COLLADA
WebGL

Standards being worked on today often show the future of hardware tomorrow

Silicon Processor Roadmaps

- Moore's Law is alive and well
- The new mantras are parallelism and low power



AR – The 'Ultimate Mobile App'

- **Visual AR needs advanced hardware**
  - Camera
  - Image processing
  - Location sensors
  - Parallel computing
  - Graphics rendering and composition
- **Special challenge for hardware community**
  - Need consistent APIs to define and access advanced capabilities across platforms

  AND
  - Reliable interop *between* acceleration processing blocks

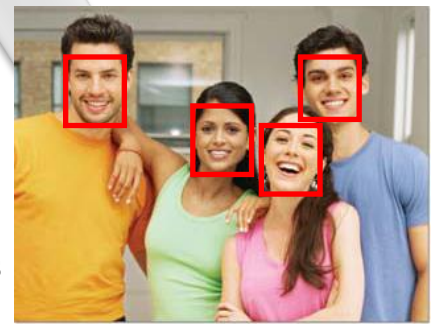
Mobile Platform Evolution

Sensor-based Applications
Making GPS and Compass widely available

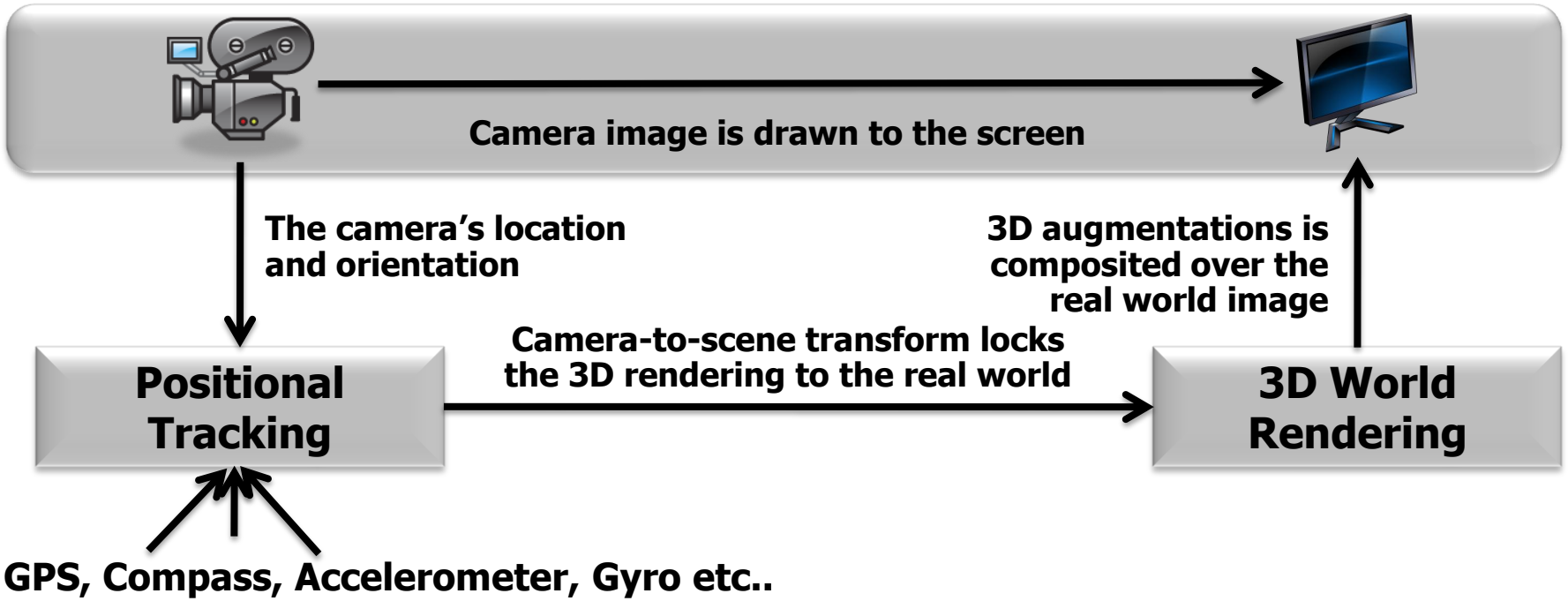
But AR needs more!
More sensors, more processing, more interop flexibility

Gaming
Driving Advanced 3D rendering into mobile devices

Camera Applications
Driving quality and availability of image sensors



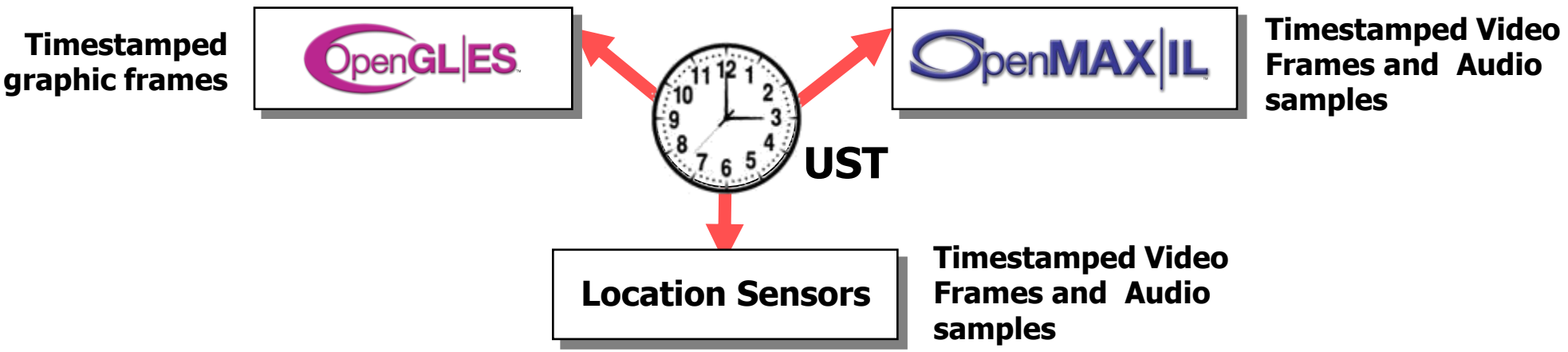
Visual-based AR Dataflow



- Synchronization of the sensors, cameras and rendering?
- Advanced camera control?
- Enough processing power for advanced image processing and tracking?
- Sophisticated composition of graphics and video?

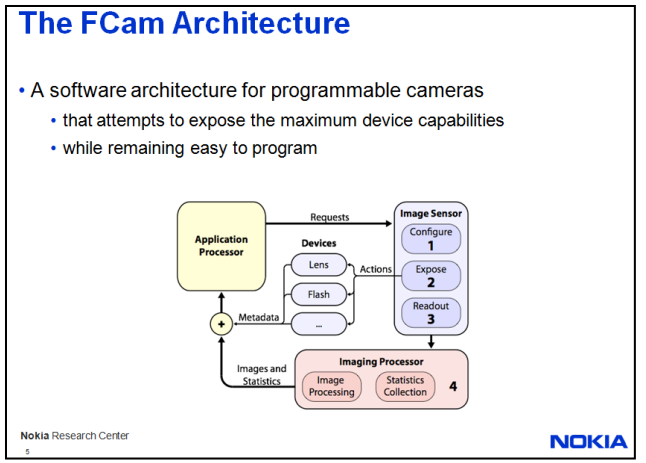
Sensors/System Synchronization

- **Timestamp EVERYTHING in a system**
  - Camera frames, Audio samples, Sensor samples, Display buffer switch times
- **App can then detect and compensate for sensor/pipeline/rendering delays**
  - Complete control and flexibility
- **Concept of Universal System Time defined by SGI**
  - Incorporated into OpenML Khronos standard
- **Broaden UST into a AR-wide synch API standard?**



Advanced Camera and Sensor Control

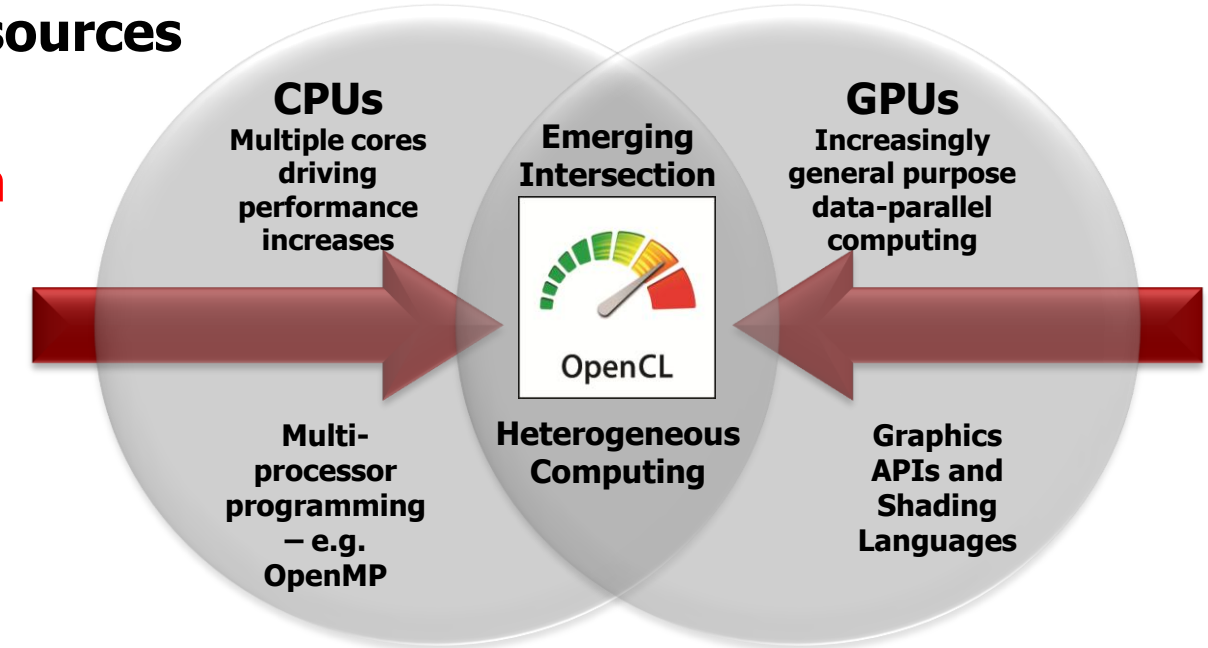
- **Connect OpenMAX IL modules to create arbitrary multimedia pipelines**
  - Wide variety of building blocks for imaging, video and audio
  - Encode, decode, apply an effect, capture, render, split, mix, etc
- **OpenMAX IL has camera control module**
  - Simple exposure, capture control
- **Nokia discussing bringing FCam research into OpenMX IL**
  - Advancing camera control flexibility
- **AR-capable camera control API?**
  - Fisheye region extraction, adaptive focus etc. etc…



http://graphics.stanford.edu/projects/camera-2.0/

Processor Parallelism

- **We need lots of processing power!**
  - Image processing, tracking, AI, Physics engines
- **Phones going multi-core**
  - Multi-core CPUs and programmable GPUs
- **OpenCL enables distribution of parallel code over *both CPU and GPU* compute resources**
- **Port CV/AR/Tracking libraries over OpenCL for cross-platform parallel acceleration?**



Pervasive OpenGL ES

- **The leading 3D rendering API for mobile devices**
  - Essential power of desktop OpenGL distilled into a much smaller package
  - Removes redundancy & rarely used features - adds mobile-friendly data types
- **OpenGL ES has become the most widely deployed 3D API**
  - Smartphones, games consoles, GPS, media players, automotive, Smartbooks…

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

EGL Becoming an Interoperability Hub

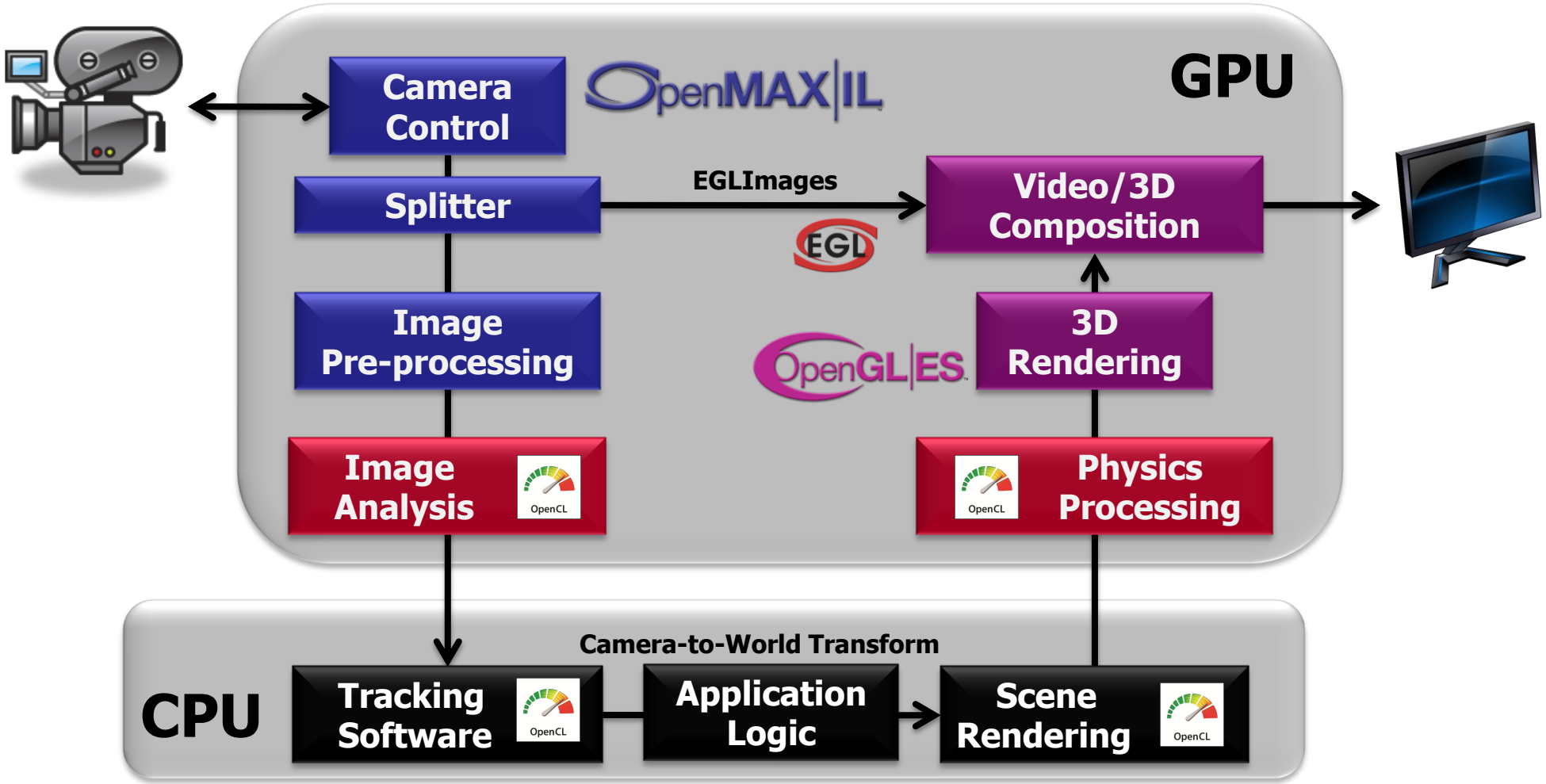
Buffers, textures and video streams flow efficiently between any combination of client APIs

Inter-API Synchronization events enable efficient resource sharing

EGL Interoperability Conformance Tests being created to ensure that client APIs can cleanly communicate

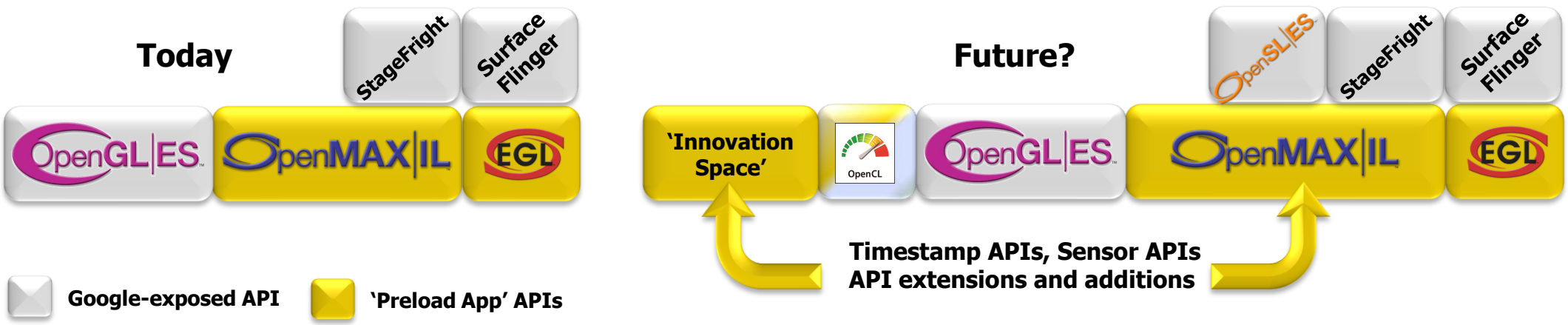
Enabling the Khronos individual APIs to interoperate as a coherent ecosystem

Possible Visual AR Flow Using Khronos APIs



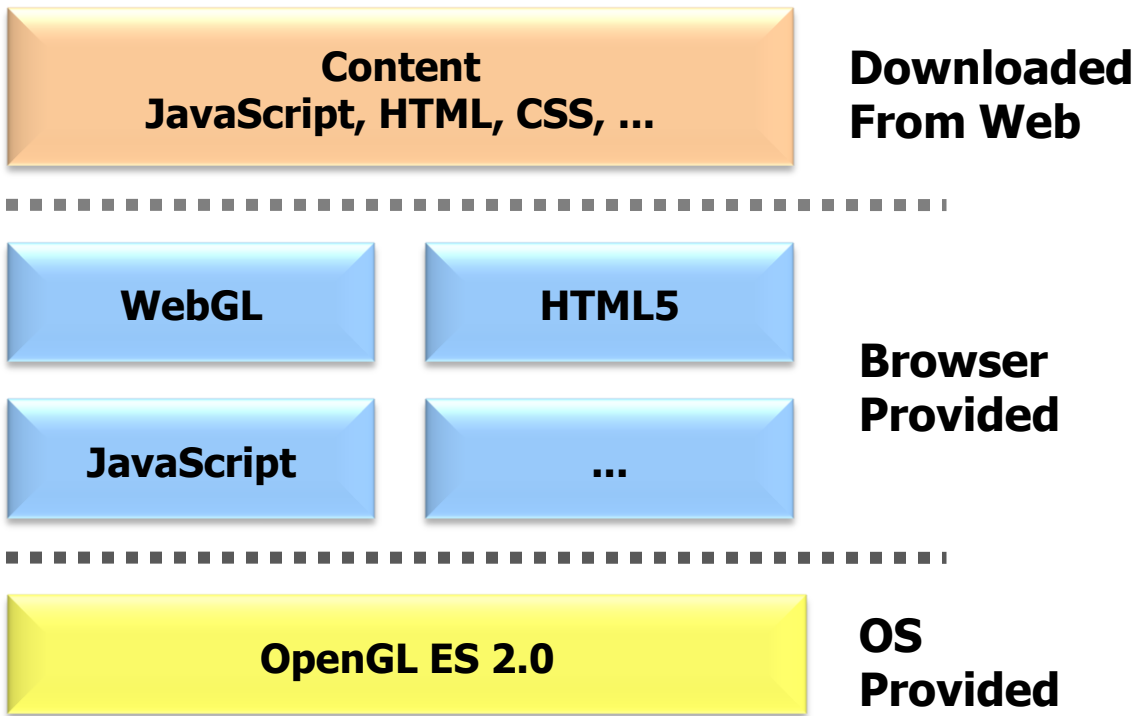
Driving API Innovation in Android

- **Android seems set to become the dominant mobile OS**
  - 'Apple Controlled Exquisite' vs. 'Darwinian Open Innovation'
- **The NDK enables new native APIs to be deployed for preload apps**
  - Use at developer's own risk – may not be on all systems
  - Not good for applications intended for Android Market
- **NDK can be proving ground for new functionality**
  - Available for platform adoption by Google to prevent fragmentation



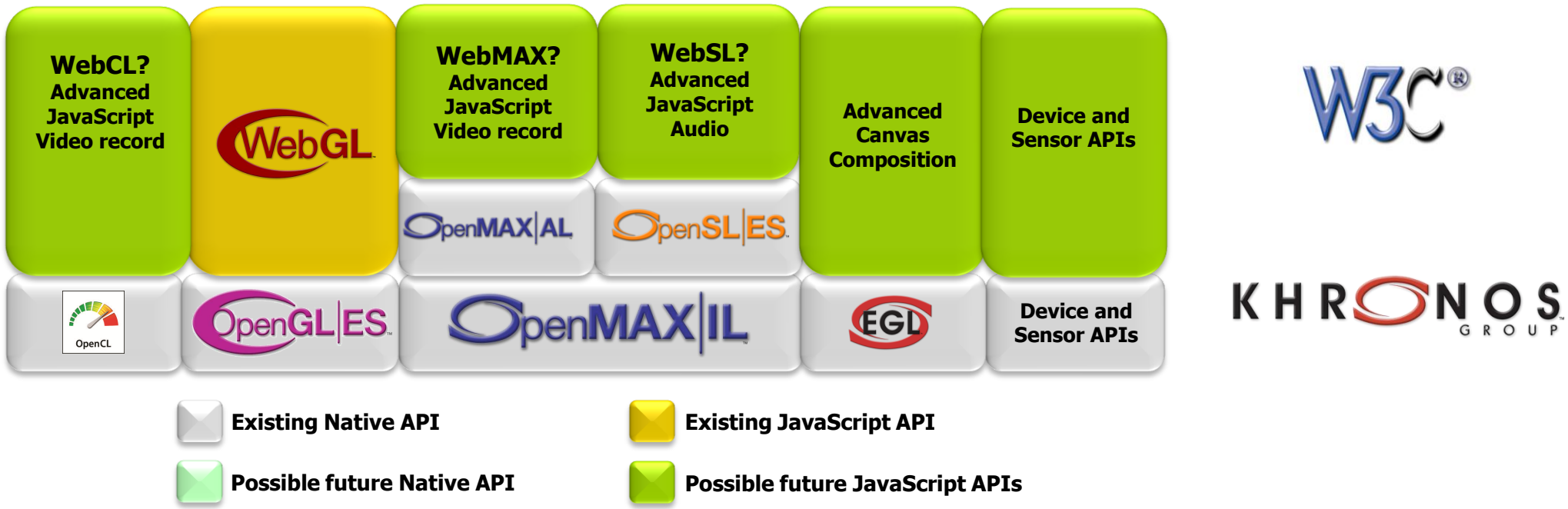
WebGL

- HTML <canvas> element
- Fully participates in browser compositing
- OpenGL ES 2.0-like API driven by JavaScript



Bringing Complete AR Capabilities to Web

- **Web is the most interesting platform of all – most widespread**
  - HTML 5 Canvas tag is opening the door to API innovation
- **JavaScript is now a viable language for visual computing**
  - Most native APIs enable local caching of geometry/configuration

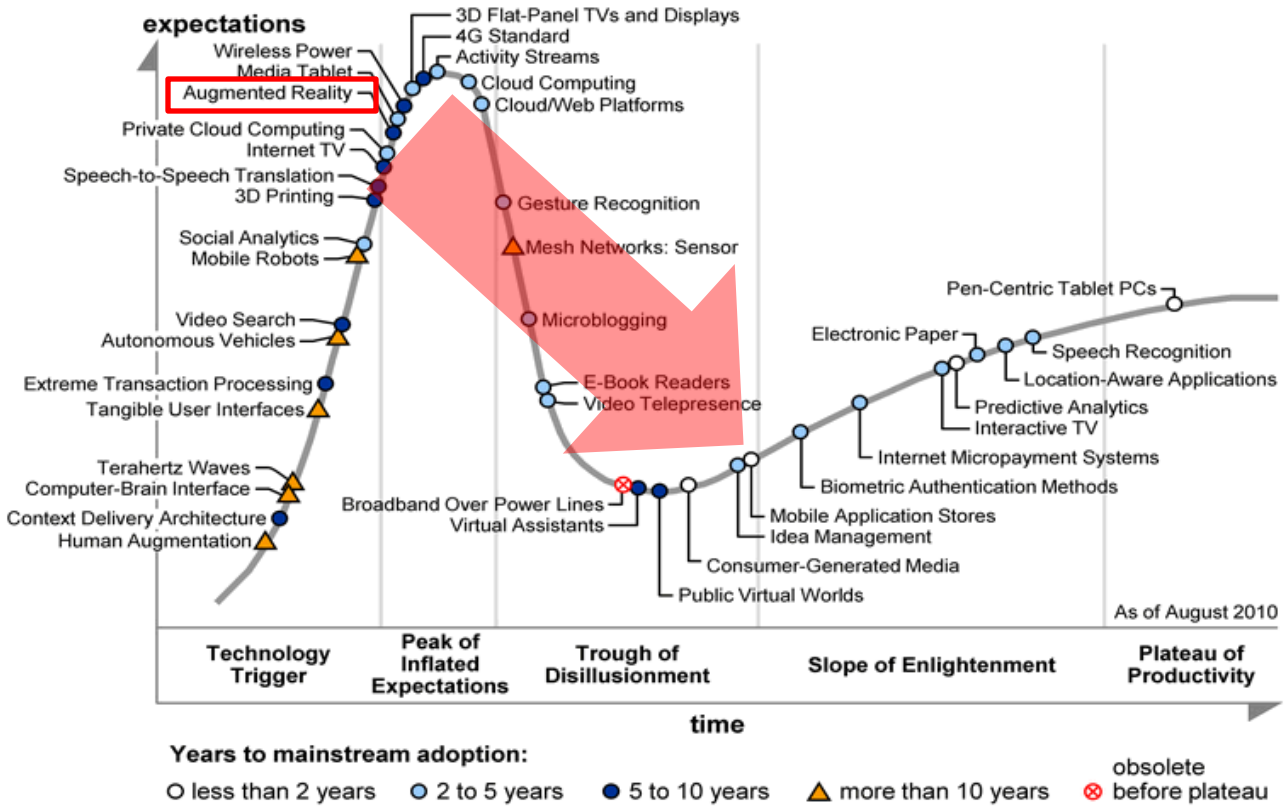


Tablets

- New computing paradigm
- Large screen touch
- All the sensor richness and connectivity of phones
- HD resolution screens
- Back and front cameras
- Some stereo back cameras

- A significant opportunity for application developers to create new classes of applications for tablets ….it's NOT just a large phone

Making the Future Happen



"The best way to predict the future is to invent it."
Alan Kay