OpenCL Overview

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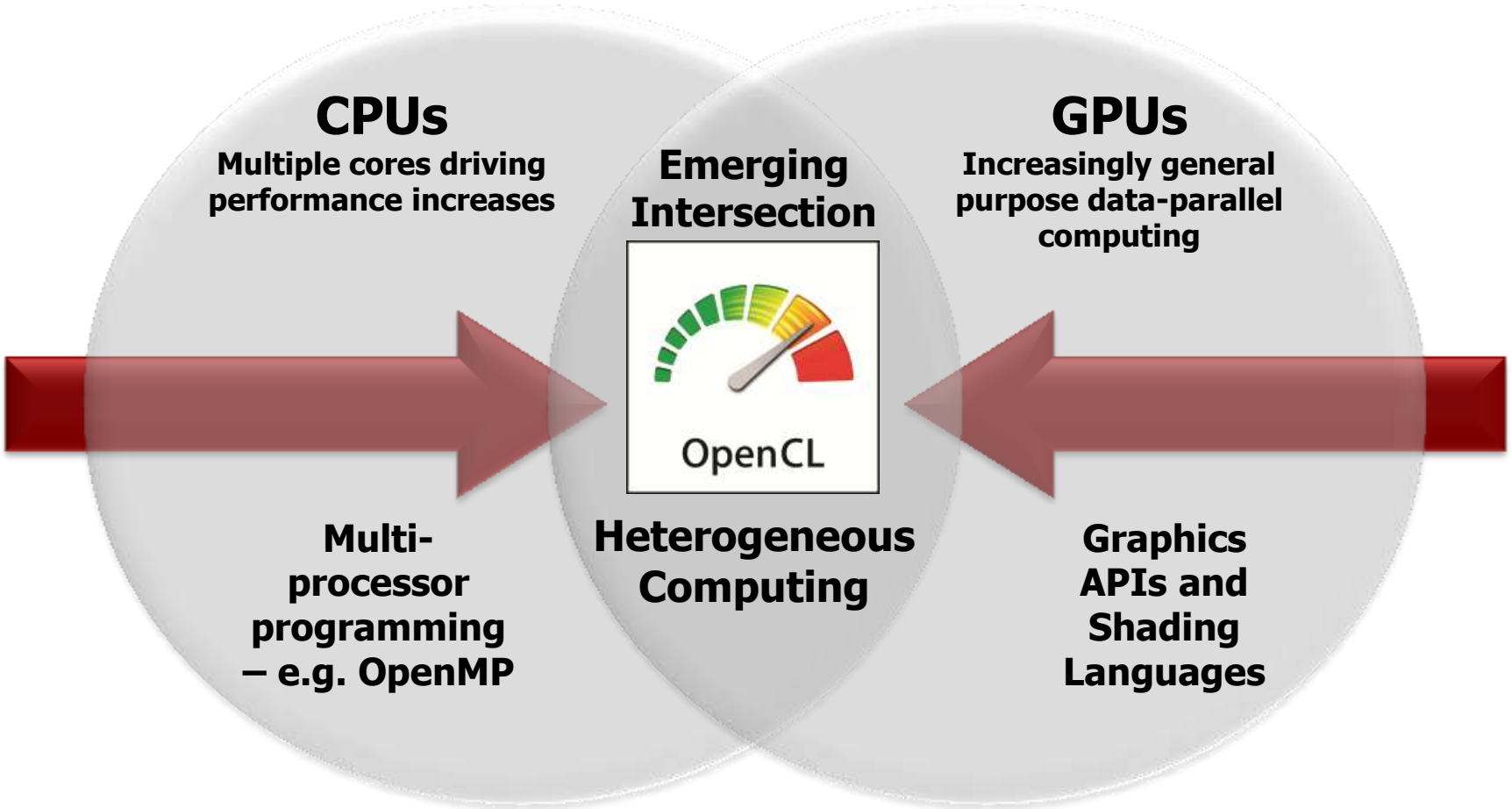
Neil Trevett
President, The Khronos Group
Vice President Mobile Content, NVIDIA

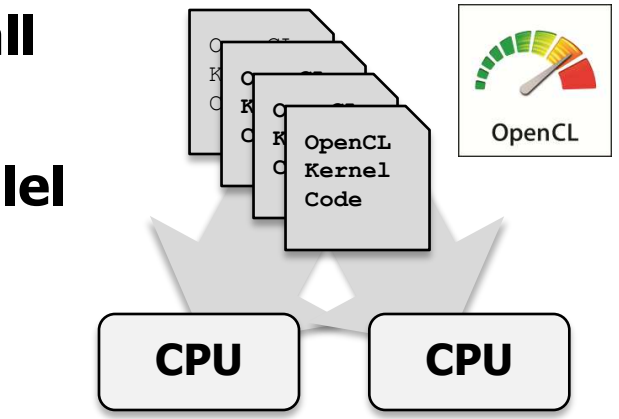
Processor Parallelism

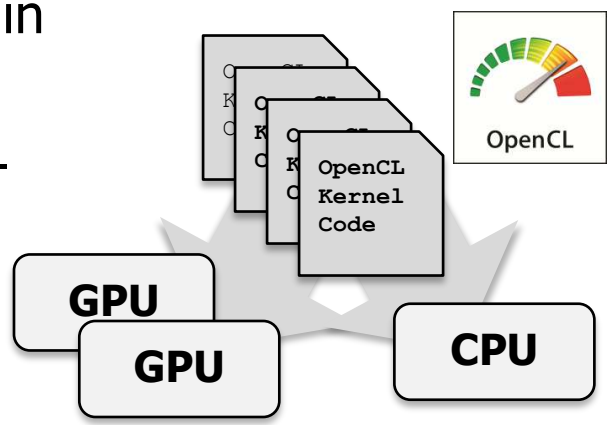


OpenCL is a programming framework for heterogeneous compute resources

OpenCL – Heterogeneous Computing

- **Cross-platform/vendor standard for harnessing all system compute resources**
- **Native framework for programming diverse parallel computing resources**
  - CPU, GPU, DSP – as well as hardware blocks(!)
- **Define N-dimensional computation domain**
  - Execute 'C' kernel at each point in computation domain
- **Powerful, low-level flexibility**
  - Foundational access to compute resources for higher-level engines, frameworks and languages
- **Embedded profile**
  - No need for a separate "ES" spec
  - Reduces precision requirements





One code tree can be executed on CPUs or GPUs

OpenCL Working Group Members

- **Diverse industry participation – many industry experts**
  - Processor vendors, system OEMs, middleware vendors, application developers
  - Academia and research labs, FPGA vendors
- **NVIDIA is chair, Apple is specification editor**

OpenCL Overview

- **C Platform Layer API**
  - Query, select and initialize compute devices
- **Kernel Language Specification**
  - Subset of ISO C99 with language extensions
  - Well-defined numerical accuracy - IEEE 754 rounding with specified max error
  - Rich set of built-in functions: cross, dot, sin, cos, pow, log …
- **C Runtime API**
  - Runtime or build-time compilation of kernels
  - Execute compute kernels across multiple devices

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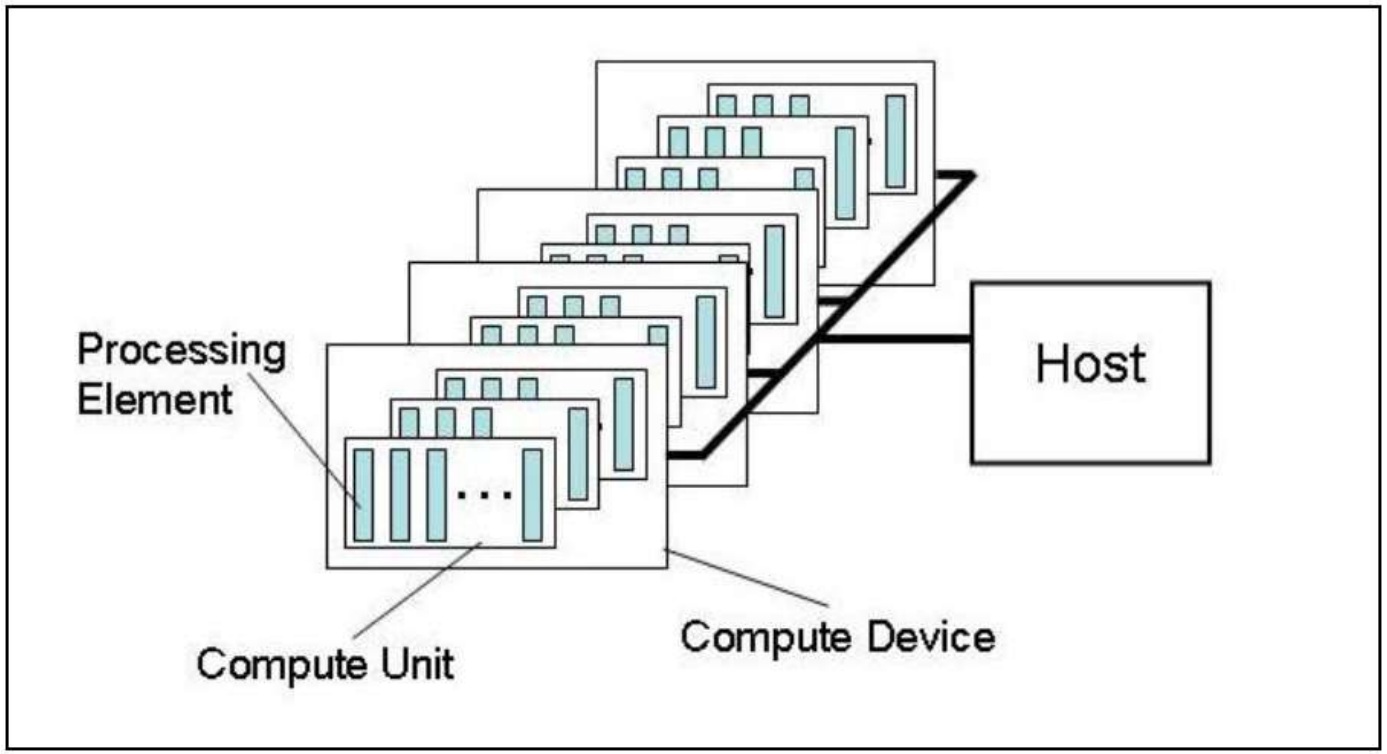
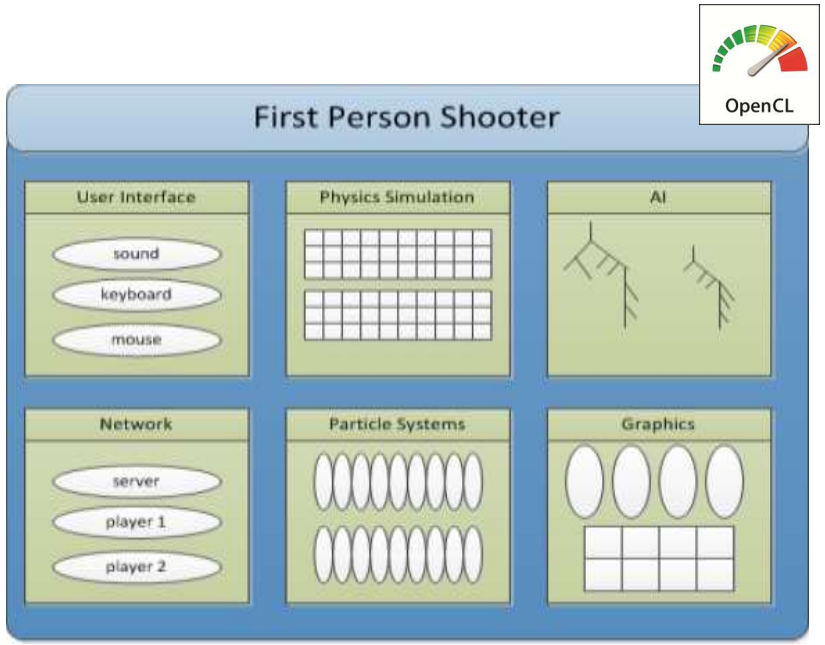
OpenCL Platform Model

- **One Host + one or more Compute Devices**
  - Each Compute Device is composed of one or more Compute Units
    - Each Compute Unit is further divided into one or more Processing Elements



OpenCL Execution Model Details

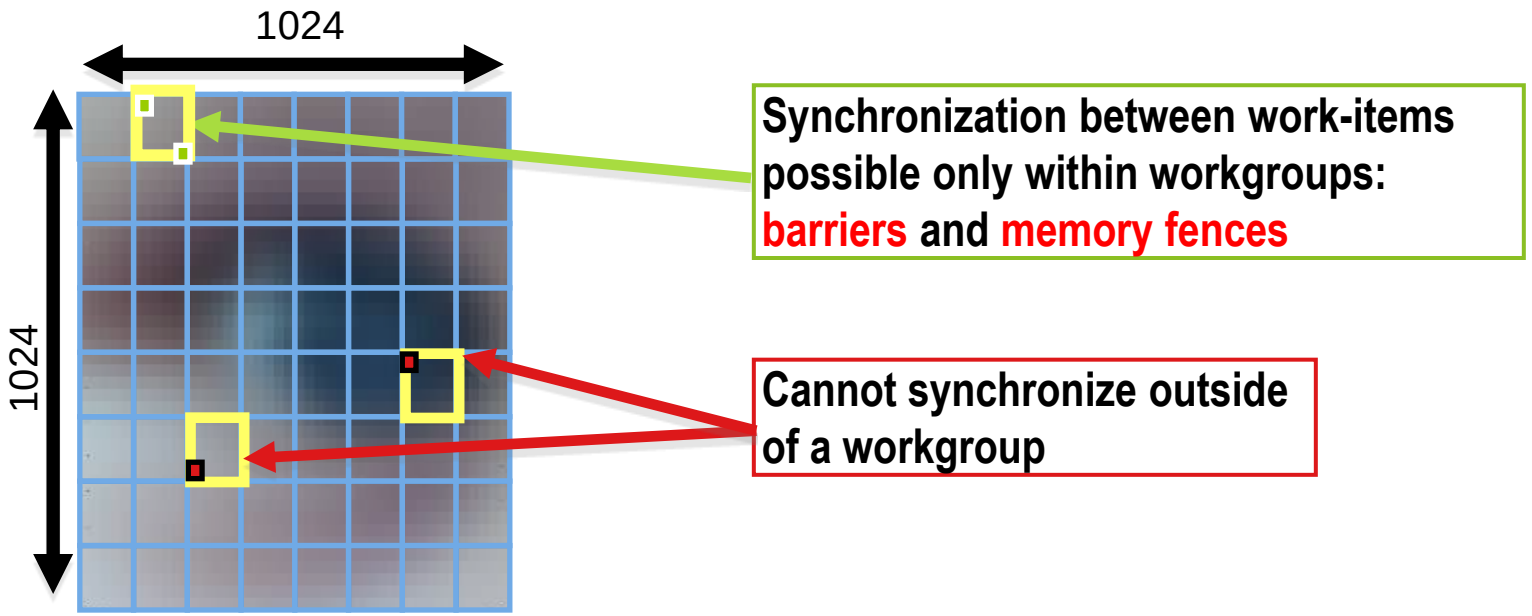
- **Kernel**
  - Basic unit of executable code ~ C function
  - Data-parallel or task-parallel
- **Program**
  - Collection of kernels and functions ~ dynamic library with run-time linking
- **Command Queue**
  - Applications queue kernels & data transfers
  - Performed in-order or out-of-order
- **Work-item**
  - An execution of a kernel by a processing element ~ thread
- **Work-group**
  - A collection of related work-items that execute on a single compute unit ~ core



Example of parallelism types

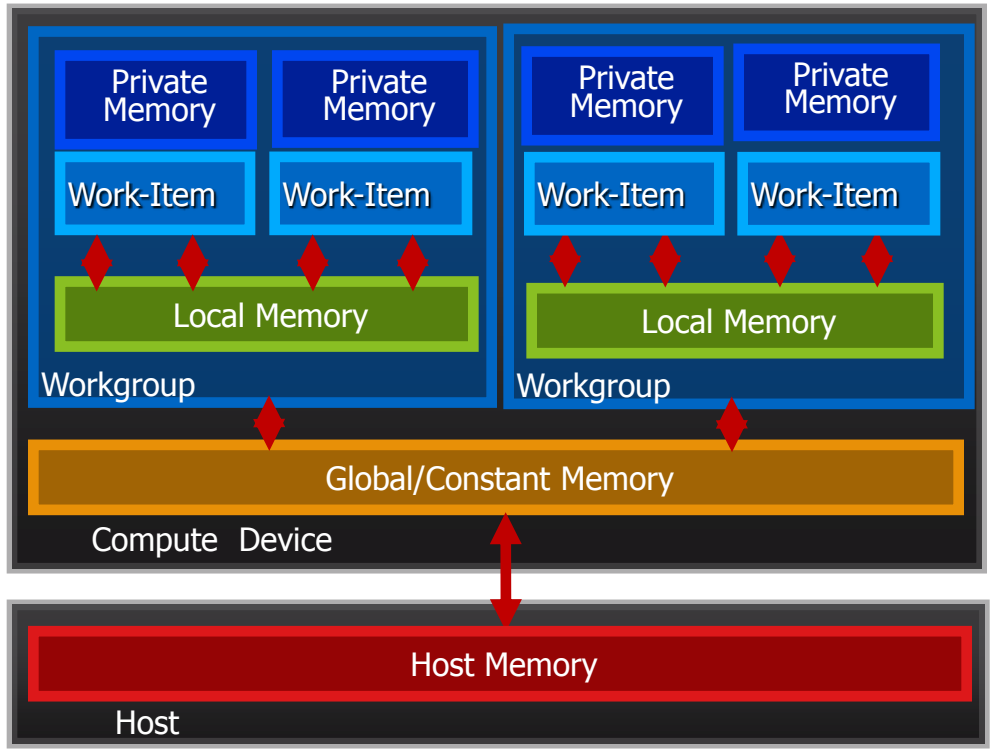
An N-dimension domain of work-items

- **Kernels executed across a global domain of *work-items***
- **Work-items grouped into local *workgroups***
- **Define the "best" N-dimensioned index space for your algorithm**
  - Global Dimensions: 1024 x 1024 (whole problem space)
  - Local Dimensions: 128 x 128 (work group … executes together)



OpenCL Memory Model

- **Private Memory**
  - Per work-item
- **Local Memory**
  - Shared within a workgroup
- **Global/Constant Memory**
  - Visible to all workgroups
- **Host Memory**
  - On the CPU



Memory management is Explicit

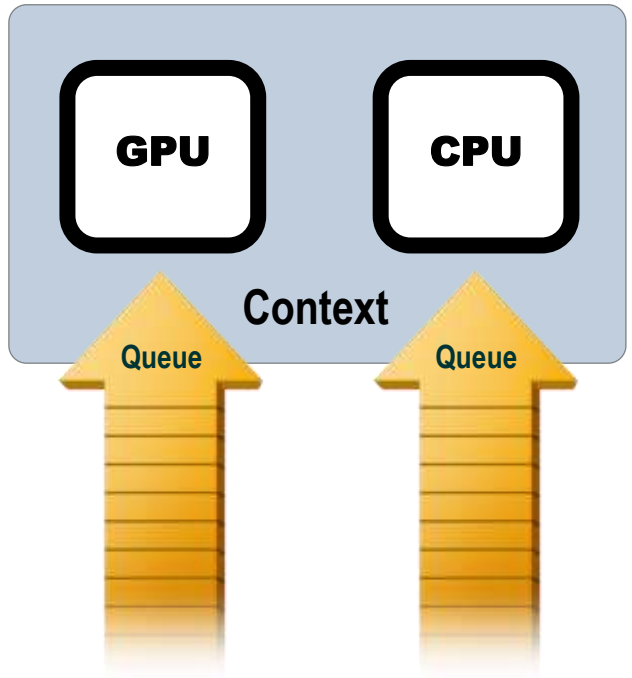
You must move data from host -> global -> local … *and* back

Programming Kernels: OpenCL C

- **Derived from ISO C99**
  - But without some C99 features such as standard C99 headers, function pointers, recursion, variable length arrays, and bit fields
- **Language Features Added**
  - Work-items and workgroups
  - Vector types
  - Synchronization
  - Address space qualifiers
- **Also includes a large set of built-in functions**
  - Image manipulation
  - Work-item manipulation,
  - Math functions, etc.

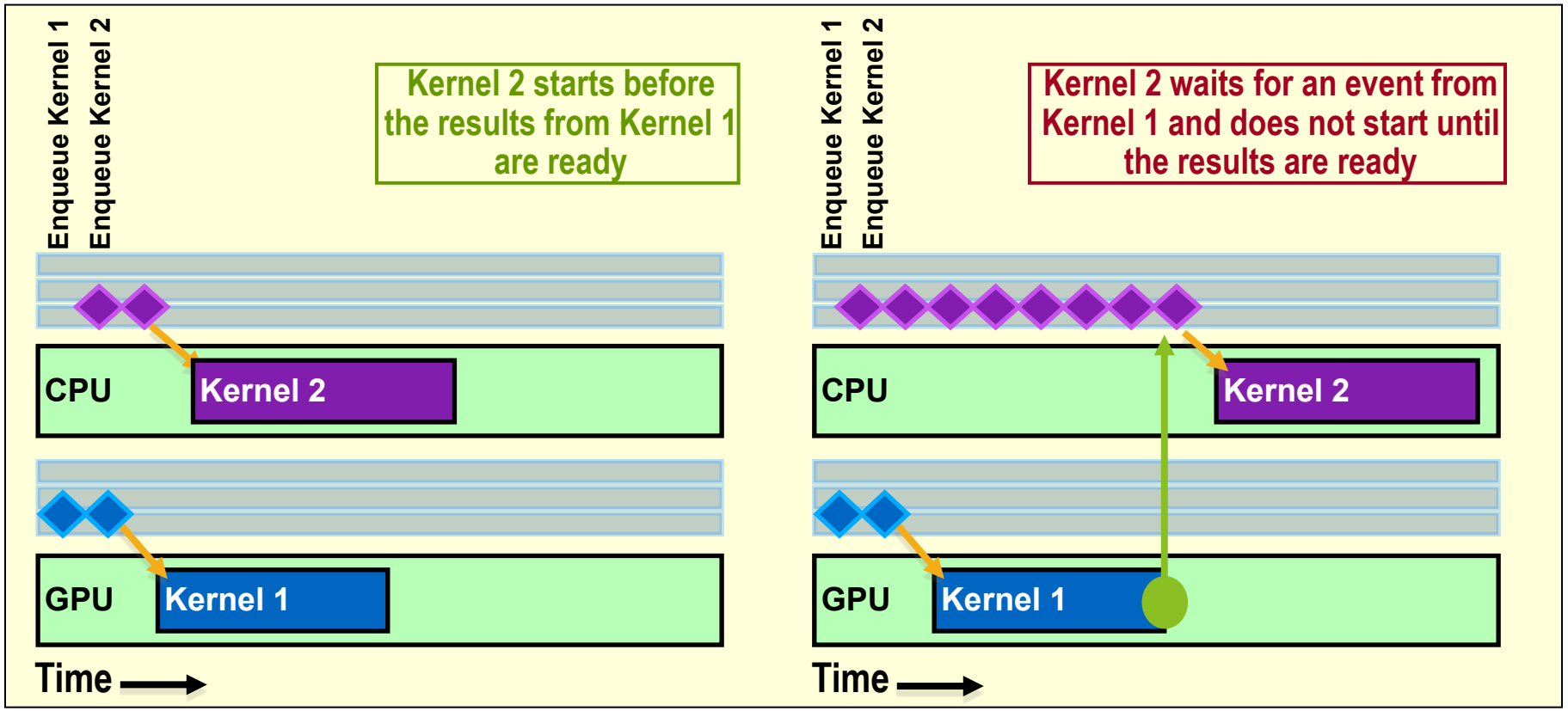
OpenCL Execution Model

- **OpenCL application runs on a host which submits work to the compute devices**
- **Context - the environment within which work-items execute**
  - Includes devices and their memories and command queues
- **Applications queue kernel execution**
  - Executed in-order or out-of-order

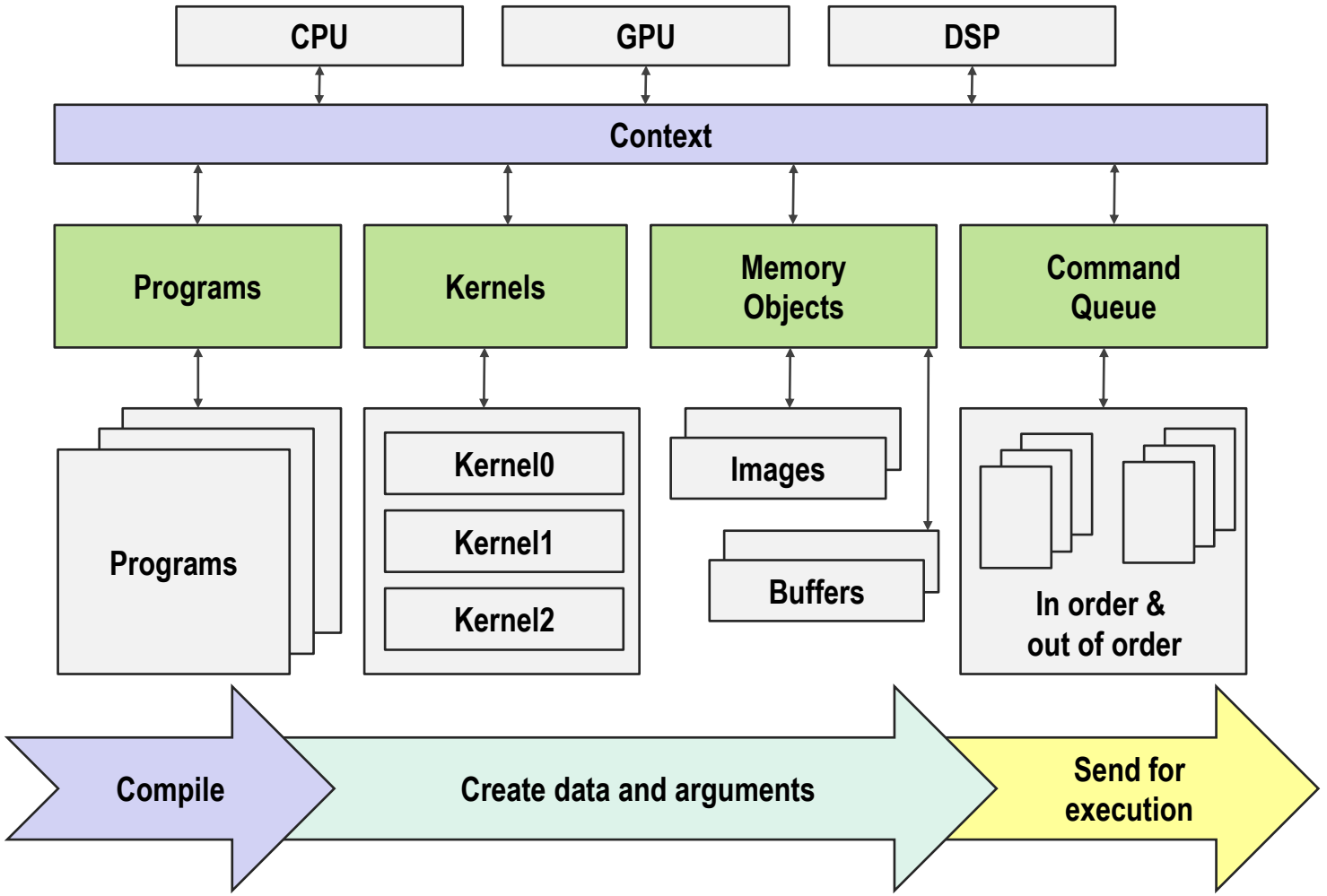


Synchronization: Queues & Events

- Events can be used to synchronize kernel executions between queues
- Example: 2 queues with 2 devices

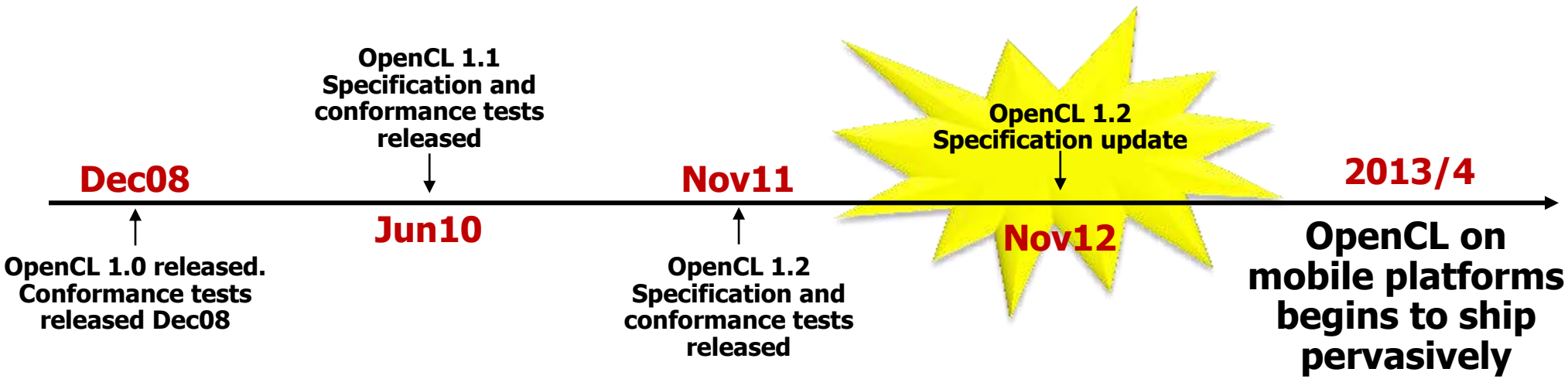


Creating an OpenCL Program



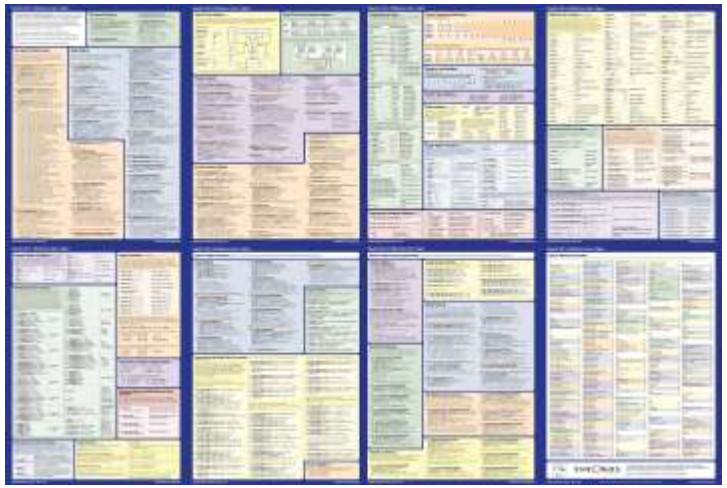
OpenCL Milestones

- **Six months from proposal to released OpenCL 1.0 specification**
  - Due to a strong initial proposal and a shared commercial incentive
- **Multiple conformant implementations shipping on desktop**
  - For CPUs and GPUs on multiple OS
- **18 month cadence between dot releases**
  - Backwards compatibility protects software investment



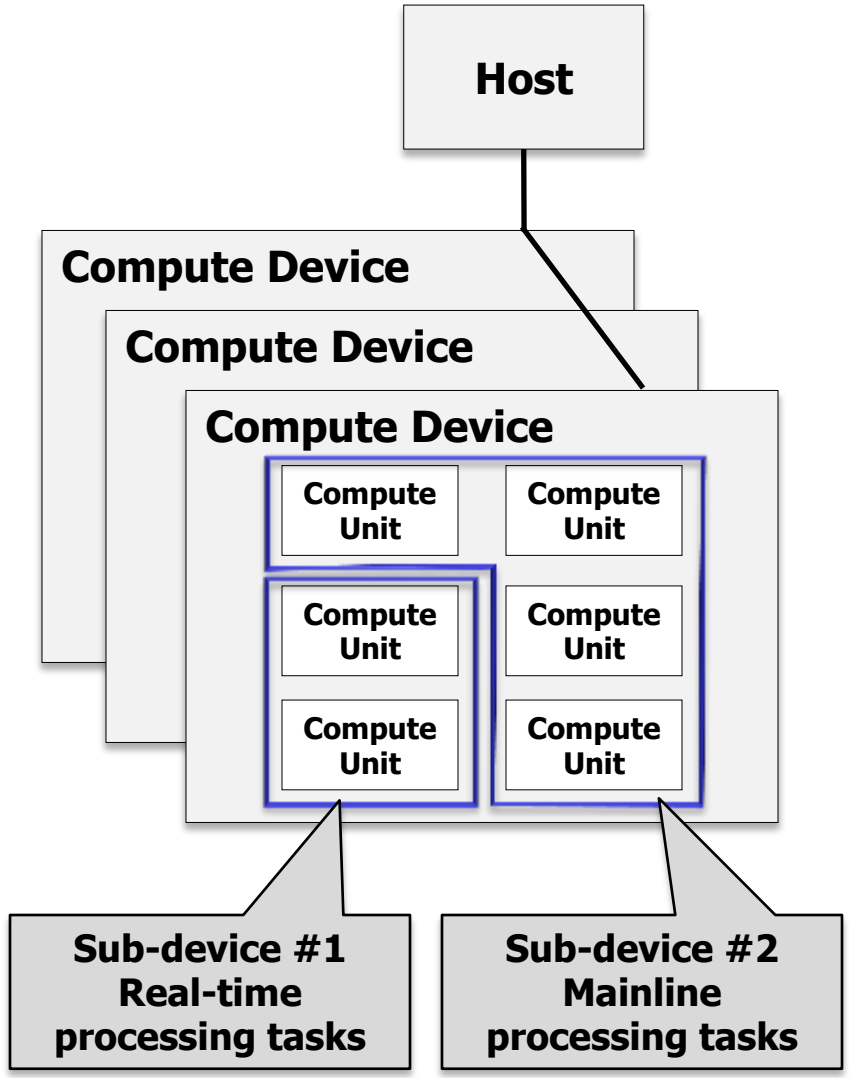
OpenCL 1.2 Announced in December 2011

- **Significant updates - Khronos being responsive to developer requests**
  - Updated OpenCL 1.2 conformance tests available
  - Multiple implementations underway
- **Backward compatible upgrade to OpenCL 1.1**
  - OpenCL 1.2 will run any OpenCL 1.0 and OpenCL 1.1 programs
  - OpenCL 1.2 platform can contain 1.0, 1.1 and 1.2 devices
  - Maintains embedded profile for mobile and embedded devices



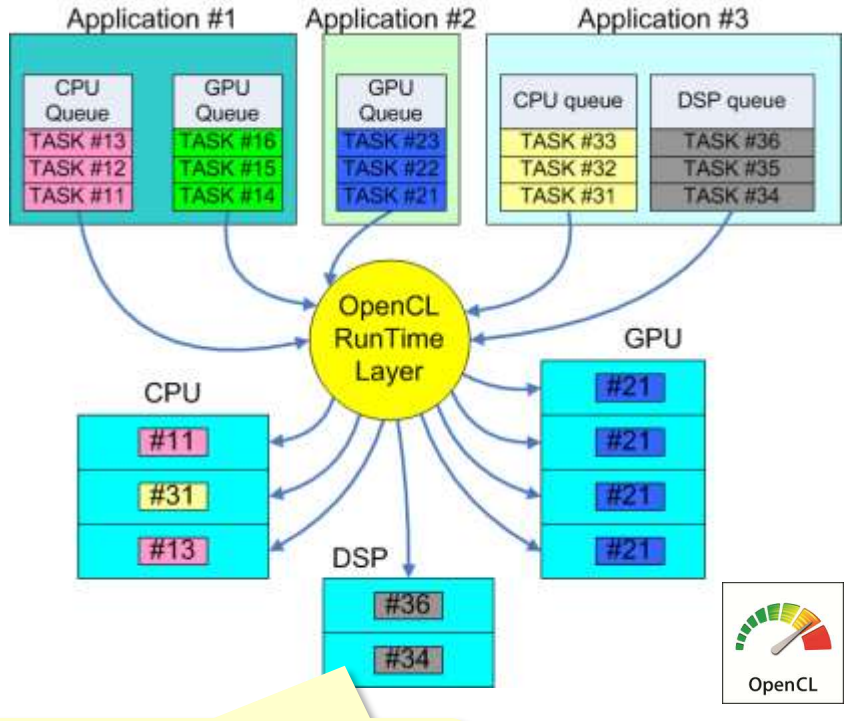
Partitioning Devices

- **Devices can be partitioned into sub-devices**
  - More control over how computation is assigned to compute units
- **Sub-devices may be used just like a normal device**
  - Create contexts, building programs, further partitioning and creating command-queues
- **Three ways to partition a device**
  - Split into equal-size groups
  - Provide list of group sizes
  - Group devices sharing a part of a cache hierarchy



OpenCL Built-in Kernels

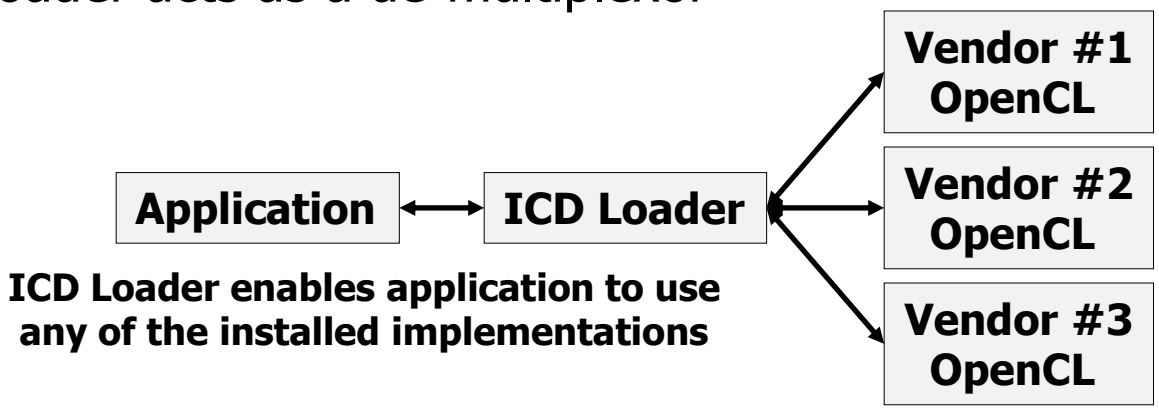
- **Used to control non-OpenCL C-capable resources on an SOC – 'Custom Devices'**
  - E.g. Video encode/decode, Camera ISP …
- **Represent functions of Custom Devices as an OpenCL kernel**
  - Can enqueue Built-in Kernels to Custom Devices alongside standard OpenCL kernels
- **OpenCL run-time a powerful coordinating framework for ALL SOC resources**
  - Programmable *and* custom devices controlled by one run-time



Built-in kernels enable control of specialized processors and hardware from OpenCL run-time

Installable Client Driver

- **Analogous to OpenGL ICDs in use for many years**
  - Used to handle multiple OpenGL implementations installed on a system
- **Optional extension**
  - Platform vendor will choose whether to use ICD mechanisms
- **Khronos OpenCL installable client driver loader**
  - Exposes multiple separate vendor installable client drivers (Vendor ICDs)
  - Open source released! http://www.khronos.org/registry/cl/
- **Application can access all vendor implementations**
  - The ICD Loader acts as a de-multiplexor



ICD Loader enables application to use any of the installed implementations

ICD Loader ensures multiple implementations are installed cleanly

Other Major New Features in OpenCL 1.2

- **Separate compilation and linking of objects**
  - Provides the capabilities and flexibility of traditional compilers
  - Create a library of OpenCL programs that other programs can link to
- **Enhanced Image Support**
  - Added support for 1D images, 1D & 2D image arrays
  - OpenGL sharing extension now enables an OpenCL image to be created from an OpenGL 1D texture, 1D and 2D texture arrays
- **DX9 Media Surface Sharing**
  - Efficient sharing between OpenCL and DirectX 9 or DXVA media surfaces
- **DX11 surface sharing**
  - Efficient sharing between OpenCL and DirectX 11 surfaces
- **And many other updates and additions..**

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OpenCL 1.2 Update – Optional Extensions

- **Create an OpenCL image from a OpenGL multi-sampled texture**
  - Provides more flexibility in interoperating 3D graphics and compute
- **Create 2D images from an OpenCL buffer**
  - Process memory structures using the advanced properties of OpenCL images
- **Security features for WebCL implementations layered over OpenCL**
  - Initialize local and private memory before a kernel begins execution
  - Query and API to terminate an OpenCL context to ensure a long running kernel does not affect system stability
- **Load an OpenCL program object from a Standard Portable Intermediate Representation (SPIR) instance**
  - Increased tool chain flexibility and avoids the need to ship kernel source in commercial applications

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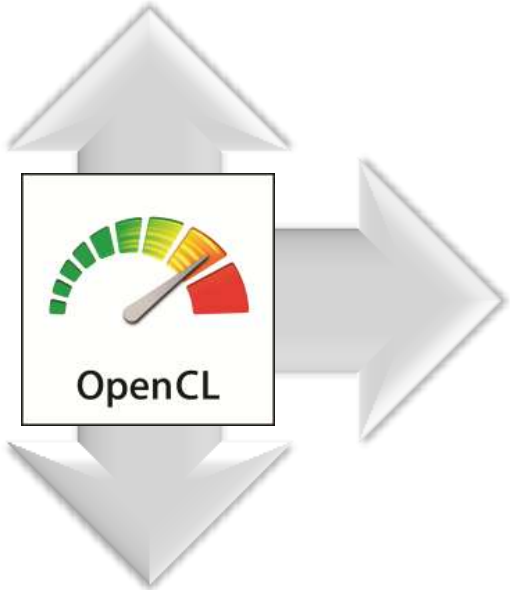
OpenCL Roadmap

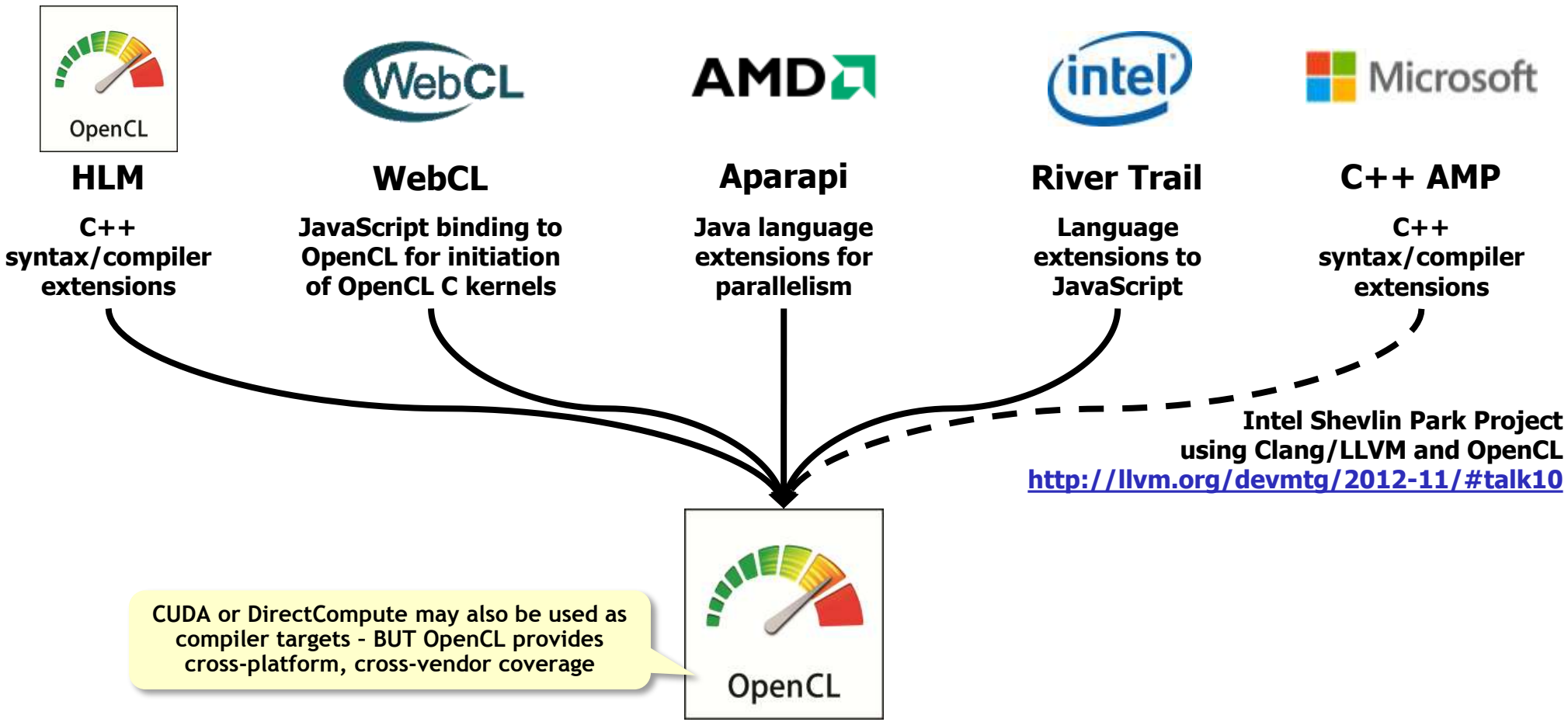
OpenCL-HLM (High Level Model)
Exploring high-level programming model, unifying host and device execution environments through language syntax for increased usability and broader optimization opportunities



Long-term Core Roadmap
Significant enhancements to memory and execution model:
- Better handle irregular work loads
- Reduce overhead of host/device data exchange
- Better image handing and API interop
- Enhanced language constructs and built-in functions for ease of use

OpenCL-SPIR (Standard Parallel Intermediate Representation)
Exploring LLVM-based, low-level Intermediate Representation for code obfuscation/security and to provide target back-end for alternative high-level languages

OpenCL as Parallel Compute Foundation



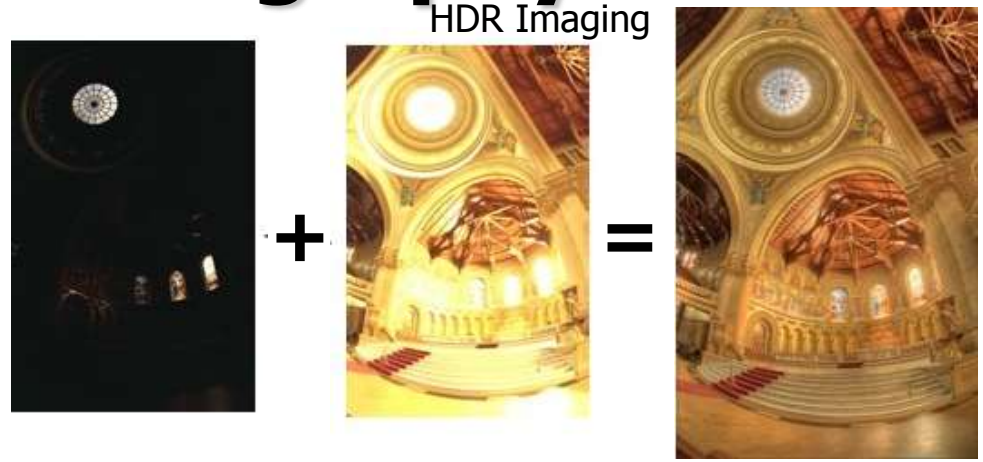
Mobile Computational Photography

- **Many advanced photo apps today run on a single CPU**
  - Suboptimal performance and power
- **OpenCL is a platform to harness CPUs/GPUs for advanced imaging**
  - Even if code is 'branchy'

"The tablet … has new multimedia capabilities, including a computational camera, which lets devs tap directly into its computational capability through new application programming interfaces such as OpenCL. That access enables next-generation use cases such as light-field cameras for mobile devices."

QUALCOMM

HDR Imaging



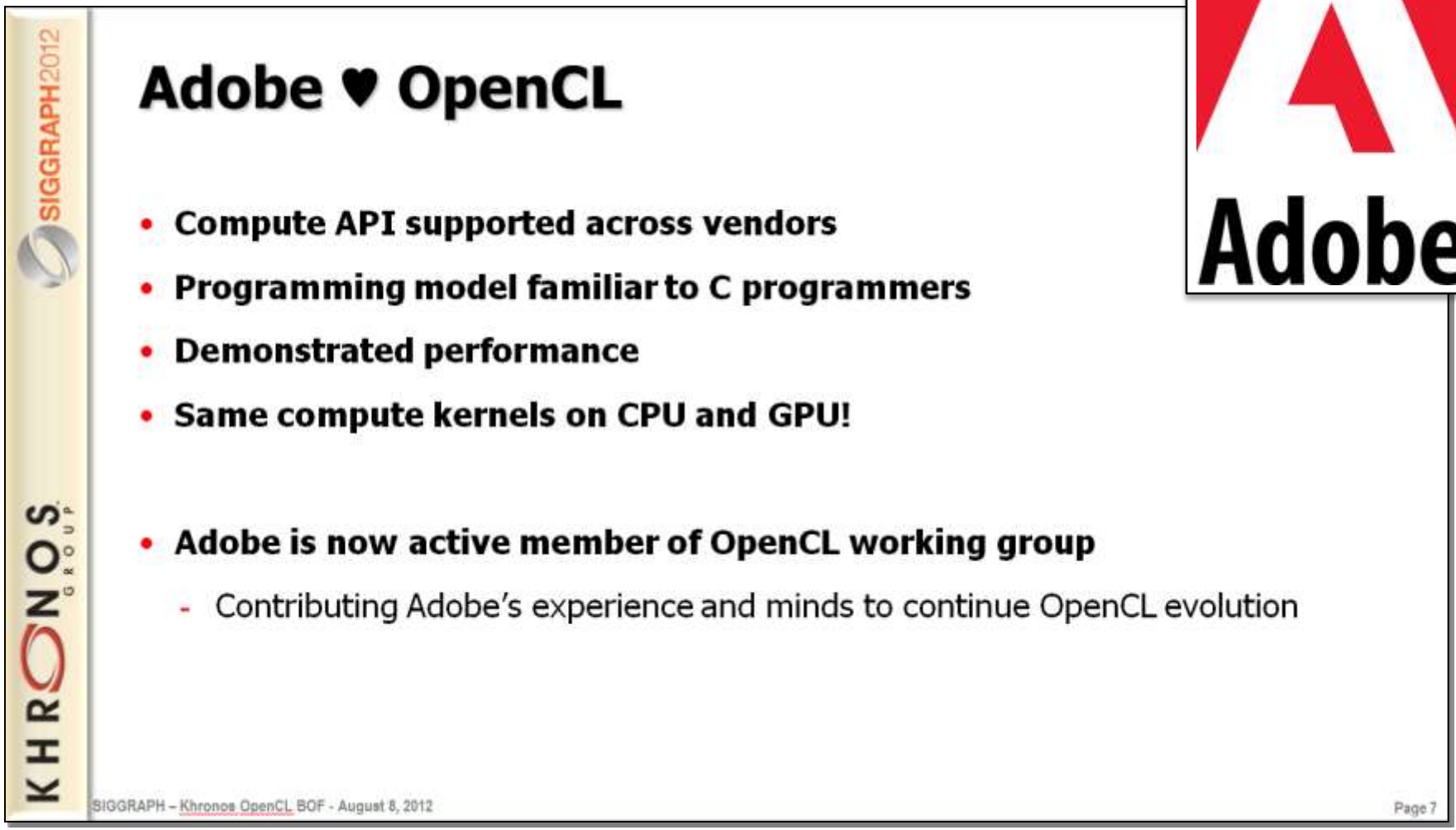
Panorama Stitching

Flash / no-flash imaging

OpenCL Rollout on Mobile Starting

If you're looking to create that perfect multi-threaded, NFC, GPS-based OpenCL app (and who isn't?), but found your development board options too limited, Samsung has good news. It's just launched the Arndale community development board around its Exynos 5 Dual SoC, with the ARM Cortex-A15 dual-core CPU and ARM Mali T604 GPU. Those specs give the board "an order of magnitude lift in performance" from the last model and full profile OpenCL capability, according to Samsung, on top of NFC, GPS and camera sensor features. That'll let developers go to town on new games, security and multimedia apps next month for $250 -- if that's you, check the PR after the break or coverage below.

Adobe at SIGGRAPH 2012



Adobe

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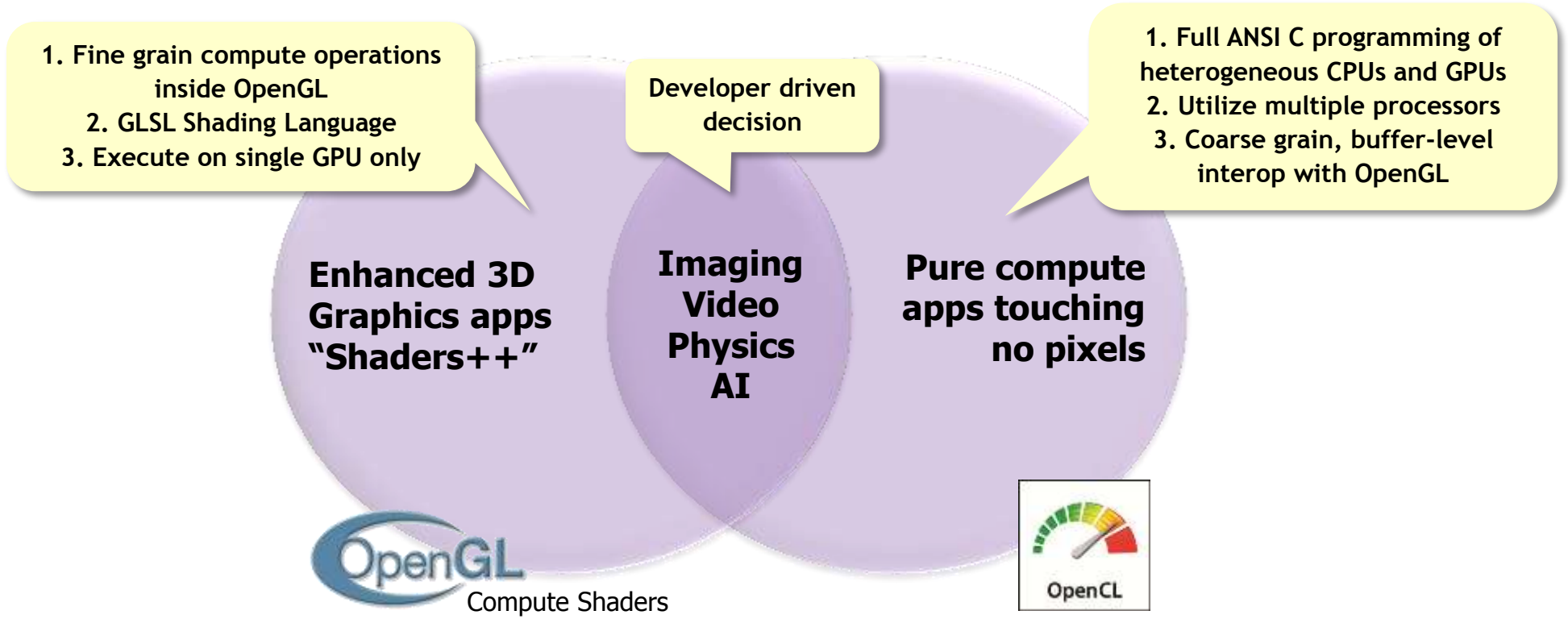
OpenCL and OpenGL Compute Shaders

- **OpenGL compute shaders provide access from GLSL to all GL pipe memory**
  - Memory buffer and textures
- **OpenGL compute shaders and OpenCL support different use cases**
  - OpenCL provides a significantly more powerful and complete compute solution

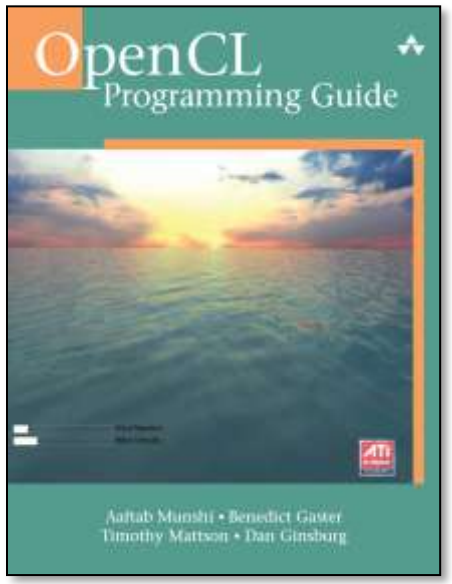


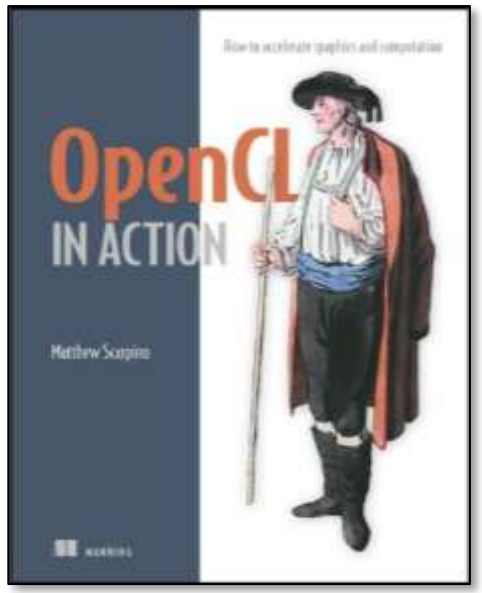
OpenCL Desktop Implementations

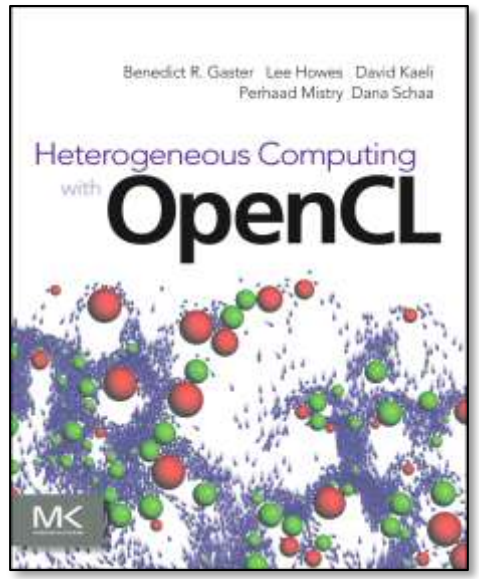
- http://developer.amd.com/zones/OpenCLZone/
- http://software.intel.com/en-us/articles/opencl-sdk/
- http://developer.nvidia.com/opencl

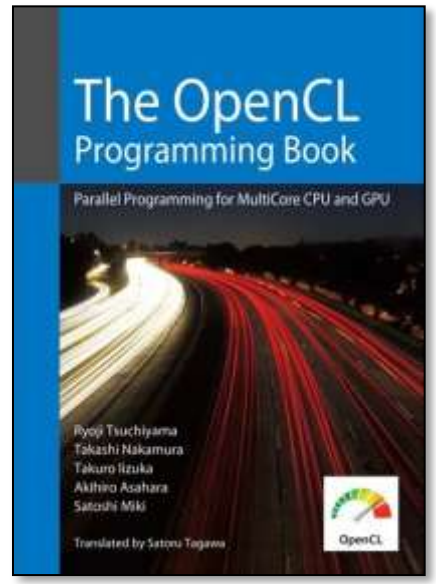
OpenCL Books – Available Now!

- **OpenCL Programming Guide - The "Red Book" of OpenCL**
  - http://www.amazon.com/OpenCL-Programming-Guide-Aaftab-Munshi/dp/0321749642
- **OpenCL in Action**
  - http://www.amazon.com/OpenCL-Action-Accelerate-Graphics-Computations/dp/1617290173/
- **Heterogeneous Computing with OpenCL**
  - http://www.amazon.com/Heterogeneous-Computing-with-OpenCL-ebook/dp/B005JRHYUS
- **The OpenCL Programming Book**
  - http://www.fixstars.com/en/opencl/book/









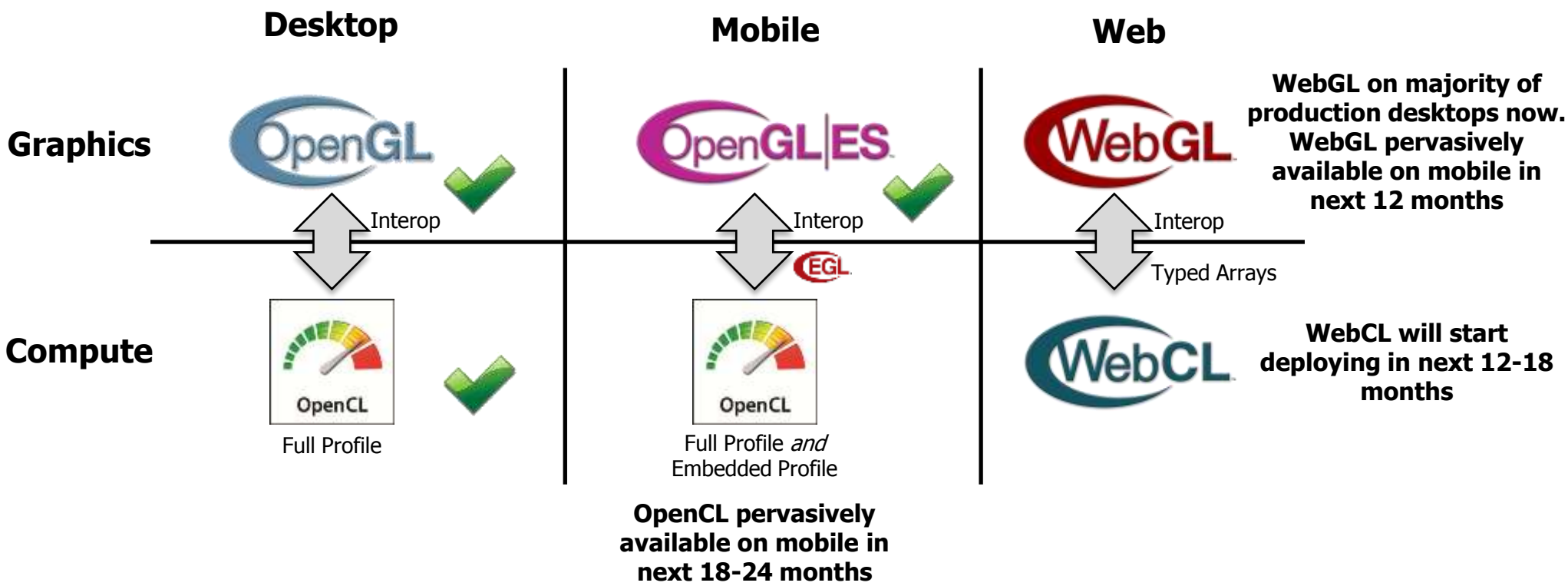
Spec Translations

- **Japanese OpenCL 1.1 spec translation available today**
  - http://www.cutt.co.jp/book/978-4-87783-256-8.html
  - Valued partnership between Khronos and CUTT in Japan
- **Working on OpenCL 1.2 specification translations**
  - Japanese, Korean and Chinese

Khronos OpenCL Resources

- **OpenCL is 100% free for developers**
  - Download drivers from your silicon vendor
- **OpenCL Registry**
  - www.khronos.org/registry/cl/
- **OpenCL 1.2 Reference Card**
  - PDF version
  - http://www.khronos.org/files/opencl-1-2-quick-reference-card.pdf
- **Online Man pages**
  - http://www.khronos.org/registry/cl/sdk/1.2/docs/man/xhtml/
- **OpenCL Developer Forums**
  - Give us your feedback!
  - www.khronos.org/message_boards/

Expanding Platform Reach for Graphics and Computation



Thank you

- **Any questions?**