Microsoft® Research

Faculty Summit

10

YEAR ANNIVERSARY

Microsoft Research

UC Berkeley Par Lab Overview

David Patterson

intel

Microsoft

NATIONAL INSTRUMENTS

NEC

NOKIA

NVIDIA

SAMSUNG

Par Lab's original research "bets"

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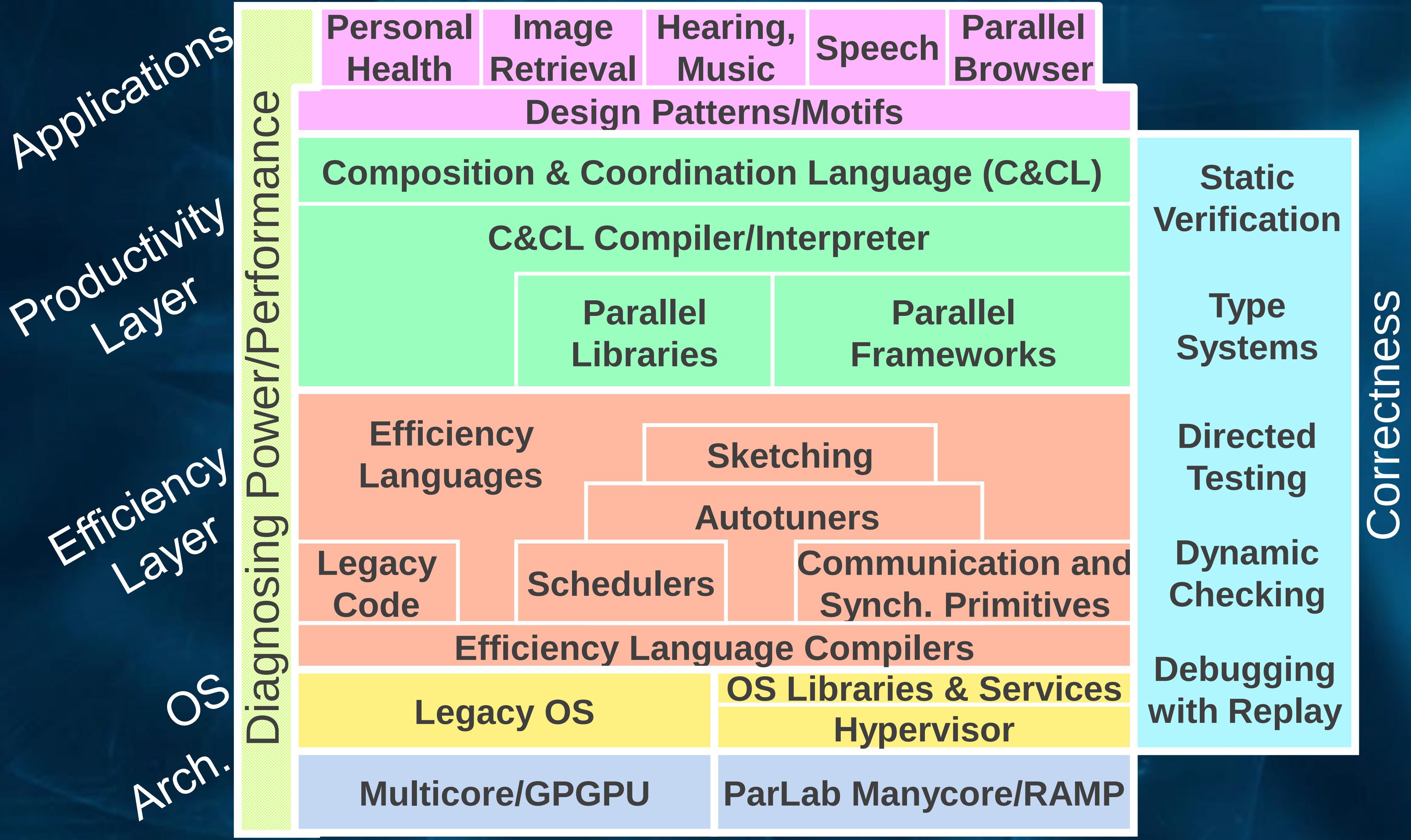
- Software platform: data center + mobile client
- Let compelling applications drive research agenda
- Identify common programming patterns
- Productivity versus efficiency programmers
- Autotuning and software synthesis
- Build correctness + power/performance diagnostics into stack
- OS/Architecture support applications, provide primitives not pre-packaged solutions
- FPGA simulation of new parallel architectures: RAMP

Above all, no preconceived big idea –
see what works driven by application needs

Par Lab Research Overview

Microsoft Research

Easy to write correct programs that run efficiently on manycore



Dominant Application Platforms

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- Data Center or Cloud ("Server")
- Laptop/Handheld ("Mobile Client")
- Both together ("Server+Client")
  - New ParLab-RADLab collaborations
- Par Lab focuses on mobile clients
  - But many technologies apply to data center

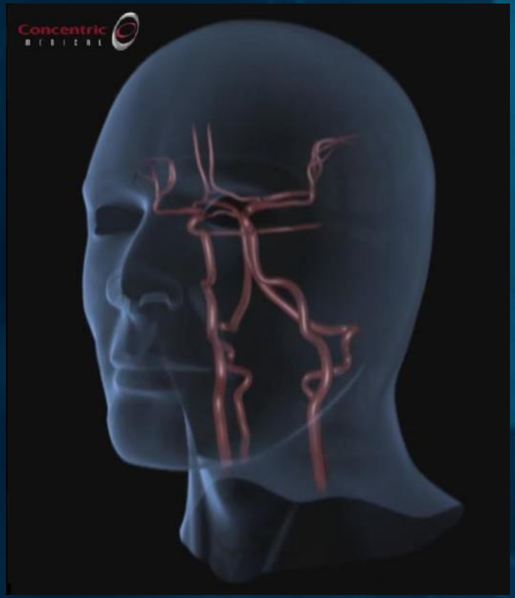
Music and Hearing Application (David Wessel)

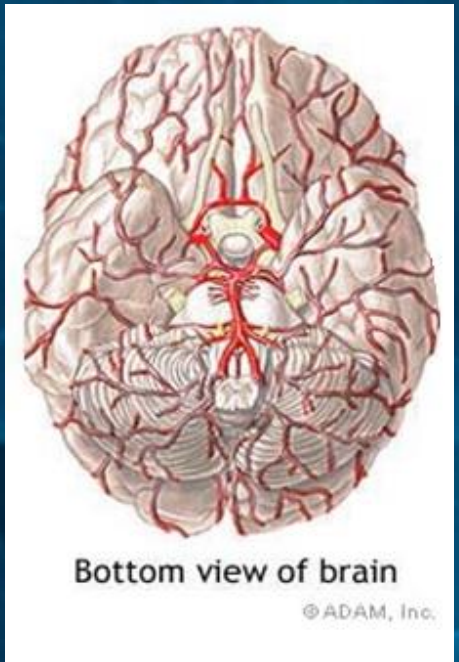
- Musicians have an insatiable appetite for computation + real-time demands
  - More channels, instruments, more processing, more interaction!
  - Latency must be low (5 ms)
  - Must be reliable (No clicks!)

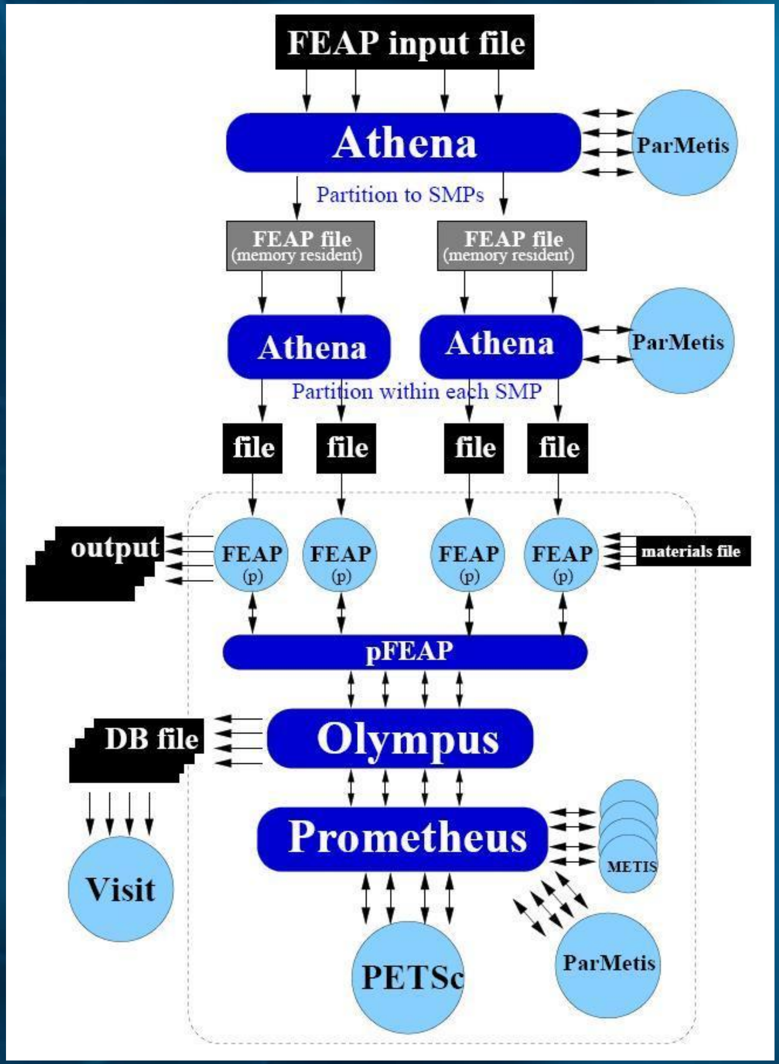
1. Music Enhancer
   - Enhanced sound delivery systems for home sound systems using large microphone and speaker arrays
   - Laptop/Handheld recreate 3D sound over ear buds
2. Hearing Augmenter
   - Handheld as accelerator for hearing aid
3. Novel Instrument User Interface
   - New composition and performance systems beyond keyboards
   - Input device for Laptop/Handheld

Berkeley Center for New Music and Audio Technology (CNMAT) created a compact loudspeaker array: 10-inch-diameter icosahedron incorporating 120 tweeters.

Health Application: Stroke Treatment
(Tony Keaveny)



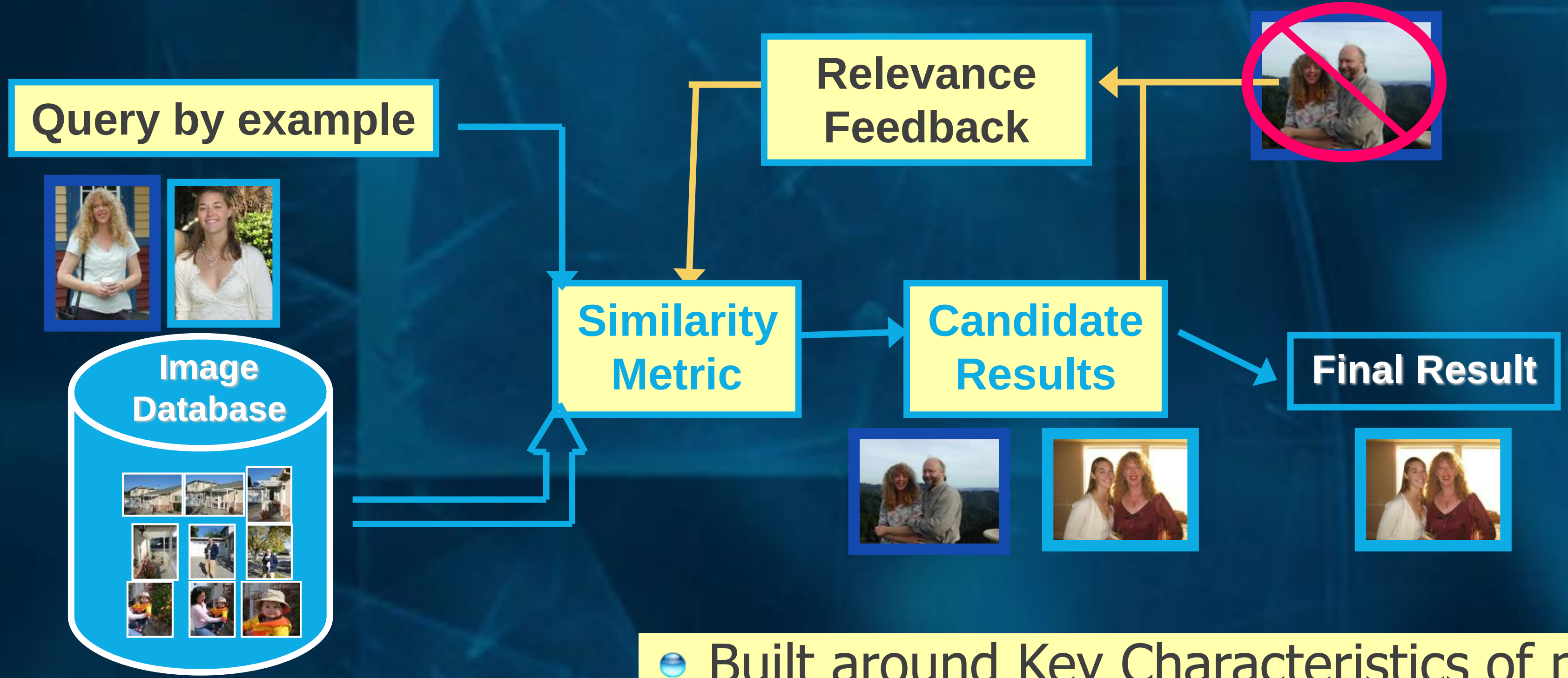




- Stroke treatment time-critical, need supercomputer performance in hospital
- Goal: First true 3D Fluid-Solid Interaction analysis of Circle of Willis
- Based on existing codes for distributed clusters

Content-Based Image Retrieval

(Kurt Keutzer)



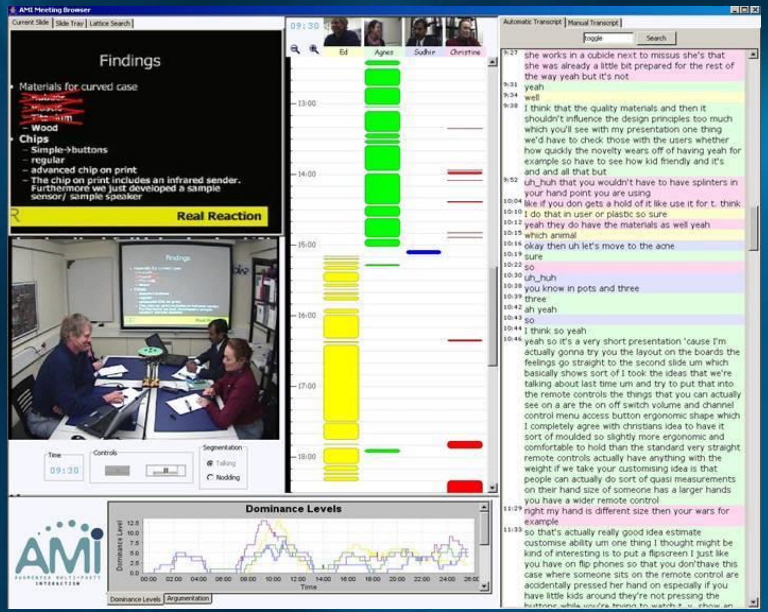
1000’s of images

- Built around Key Characteristics of personal databases
  - Very large number of pictures (>5K)
  - Non-labeled images
  - Many pictures of few people
  - Complex pictures including people, events, places, and objects

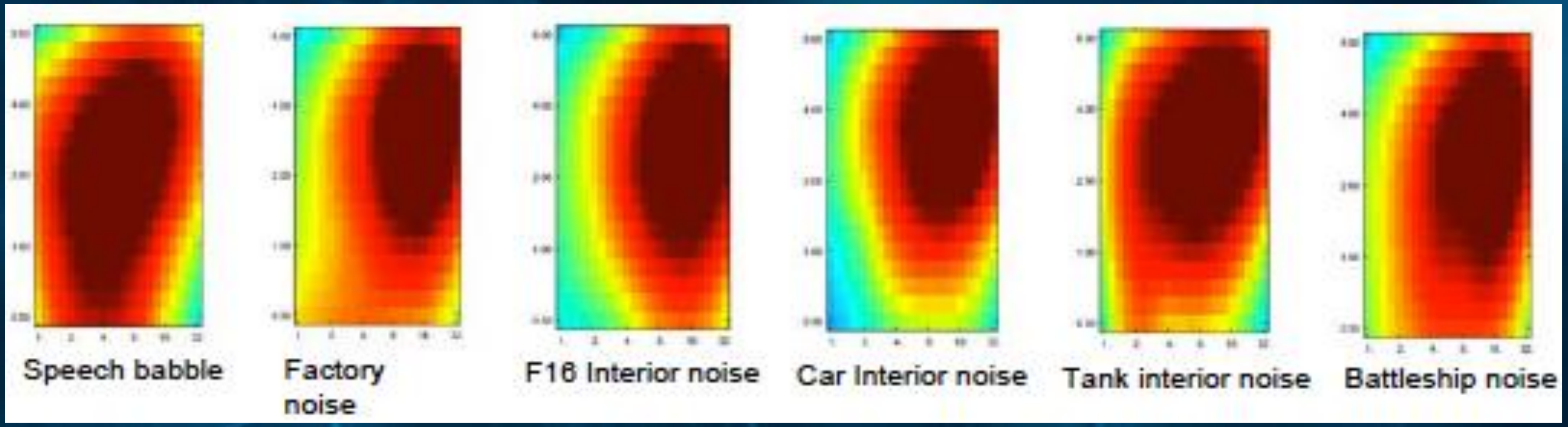
Robust Speech Recognition

(Nelson Morgan)

- Meeting Diarist
  - Laptops/ Handhelds at meeting coordinate to create speaker identified, partially transcribed text diary of meeting



- Use cortically-inspired manystream spatio-temporal features to tolerate noise



Parallel Browser
(Ras Bodik)

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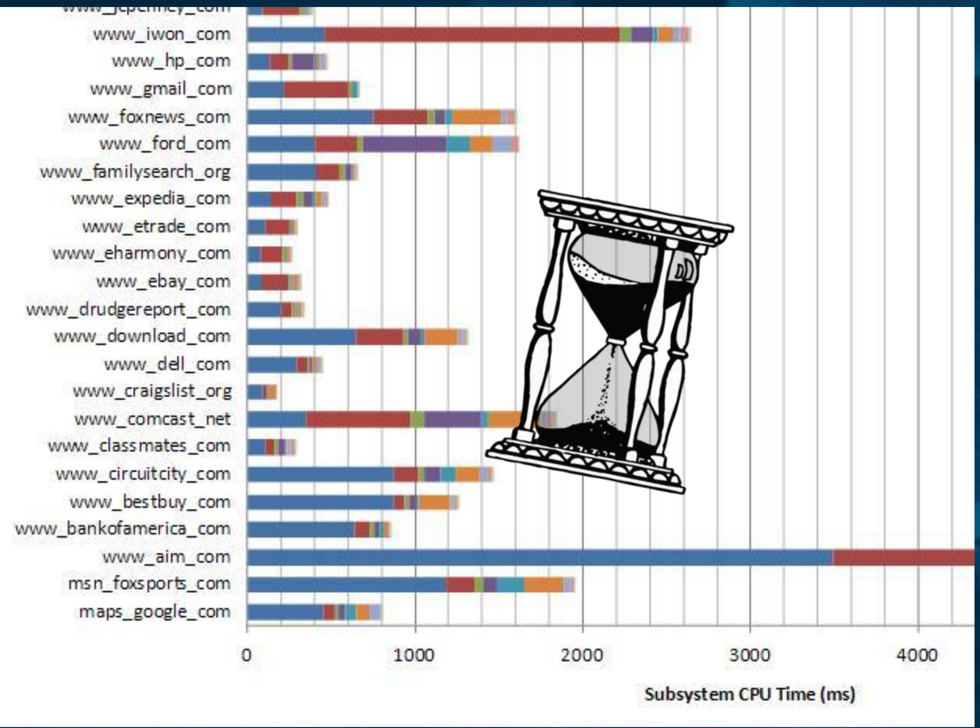
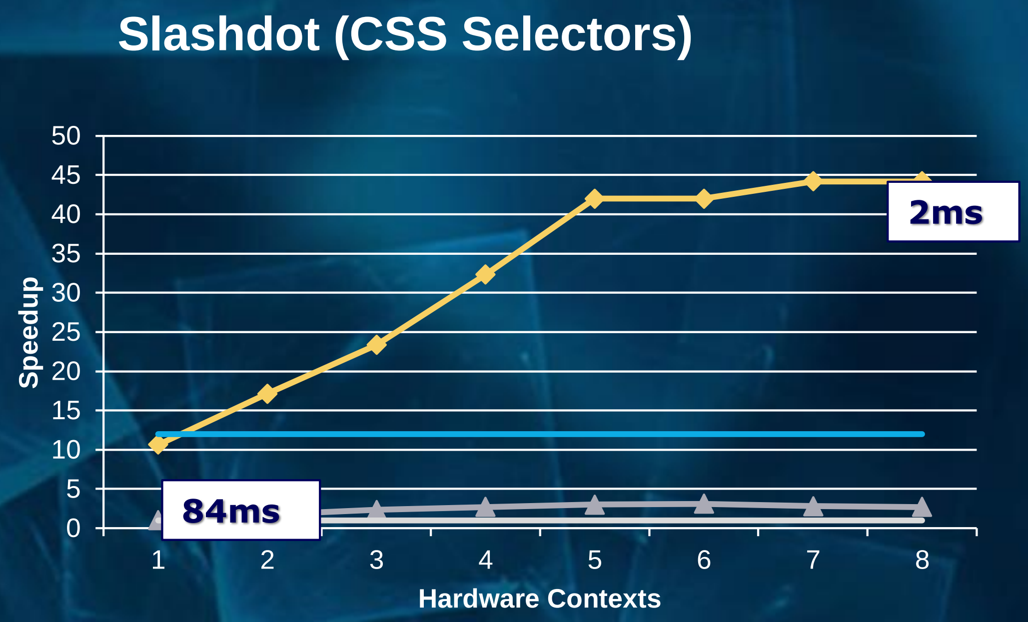
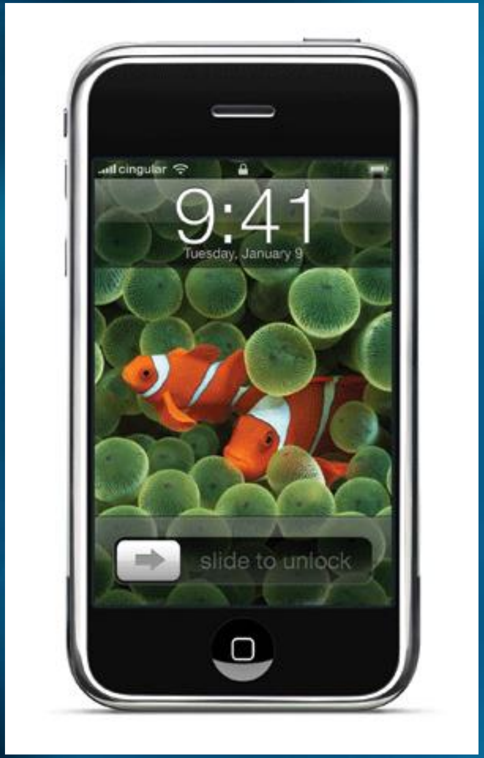
- Goal: Desktop quality browsing on handhelds
  - Enabled by 4G networks, better output devices
- Bottlenecks to parallelize
  - Parsing, Rendering, Scripting

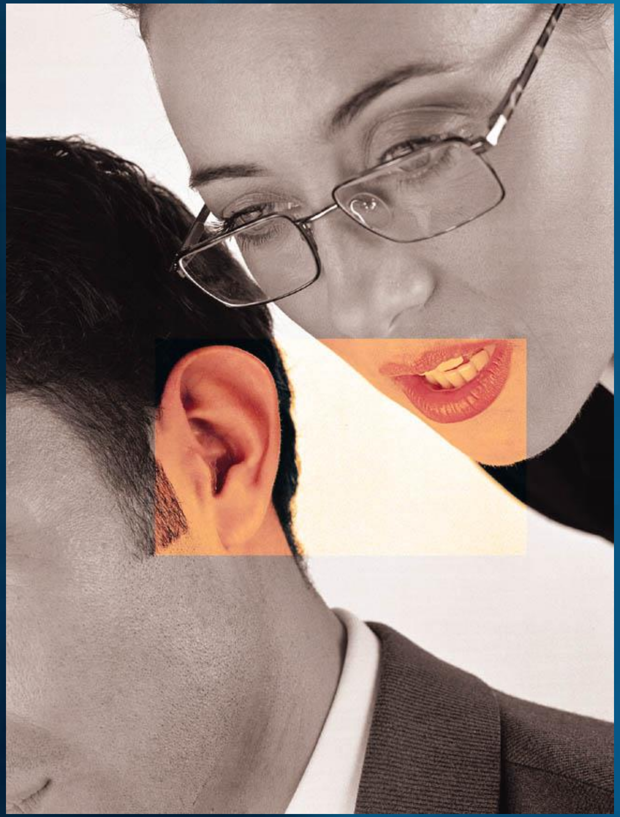






Compelling Apps in a Few Years

- Name Whisperer
  - Built from Content Based Image Retrieval
  - Like Presidential Aid
- Handheld scans face of approaching person
- Matches image database
- Whispers name in ear, along with how you know him



Architecting Parallel Software with Patterns (Kurt Keutzer/Tim Mattson)

Our initial survey of many applications brought out common recurring patterns:

"Dwarfs" -> Motifs

- Computational patterns
- Structural patterns

Insight: Successful codes have a comprehensible software architecture:

- Patterns give human language in which to describe architecture

Motif (nee "Dwarf") Popularity
(Red Hot \ Blue Cool)

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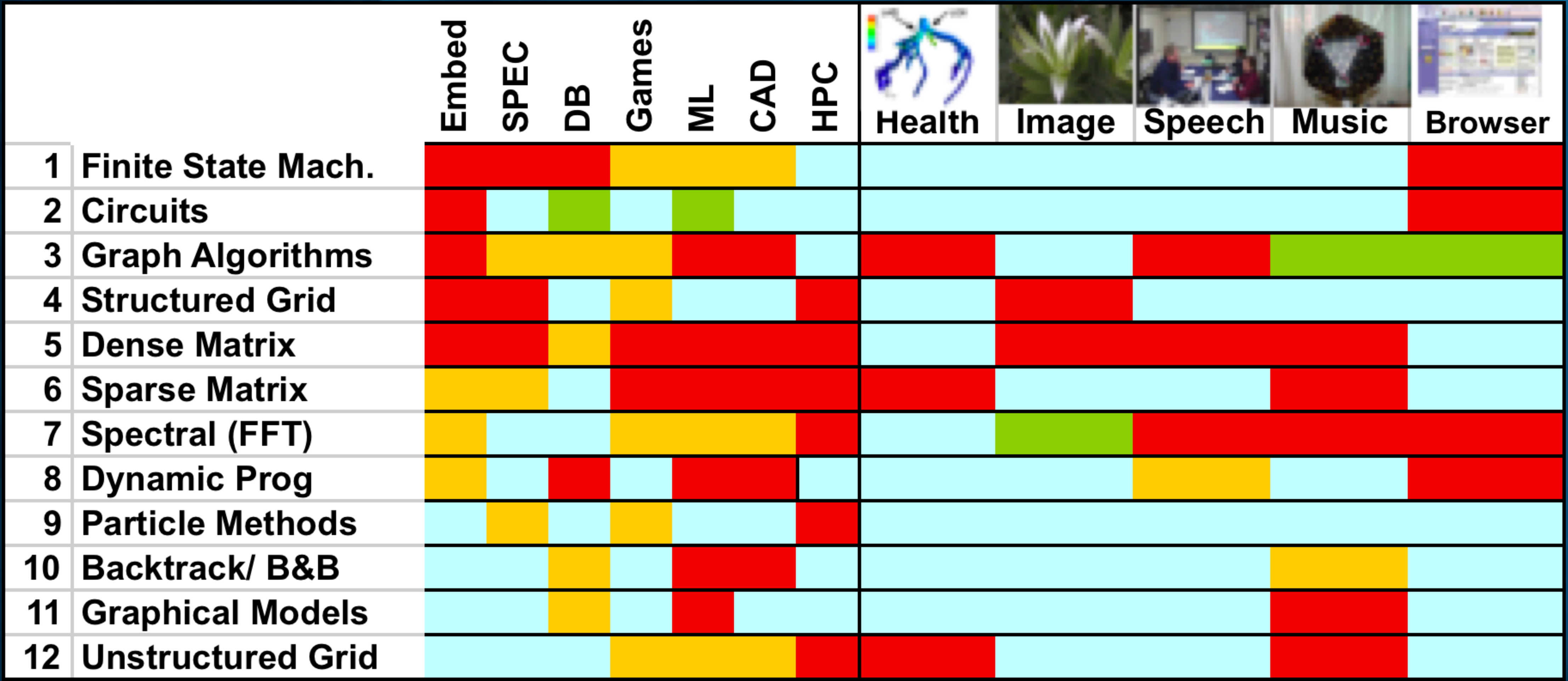
- How do compelling apps relate to 12 motifs?



Architecting Parallel Software

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Decompose Tasks/Data

Order tasks **Identify Data Sharing and Access**

Identify the Software Structure

- Pipe-and-Filter
- Agent-and-Repository
- Event-based
- Bulk Synchronous
- MapReduce
- Layered Systems
- Arbitrary Task Graphs

Identify the Key Computations

- Graph Algorithms
- Dynamic programming
- Dense/Spare Linear Algebra
- (Un)Structured Grids
- Graphical Models
- Finite State Machines
- Backtrack Branch-and-Bound
- N-Body Methods
- Circuits
- Spectral Methods

People, Patterns, and Frameworks

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	 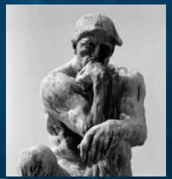 Design Patterns	  Frameworks
Application Developer 	Uses application design patterns (e.g. feature extraction) to architect the application	Uses application frameworks (e.g. CBIR) to implement the application
Application-Framework Developer 	Uses programming design patterns (e.g. Map/Reduce) to architect the application framework	Uses programming frameworks (e.g MapReduce) to implement the application framework

Productivity/Efficiency and Patterns

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1 — Domain Experts + Application patterns and frameworks → End-user, application programs

2 — Domain-literate programming gurus (1% of the population) + Parallel patterns and programming frameworks → Application frameworks

3 — Parallel programming gurus (1-10% of programmers) → Parallel programming frameworks

The hope is for Domain Experts to create parallel code with little or no understanding of parallel programming

Leave hardcore "bare metal" efficiency-layer programming to the parallel programming experts

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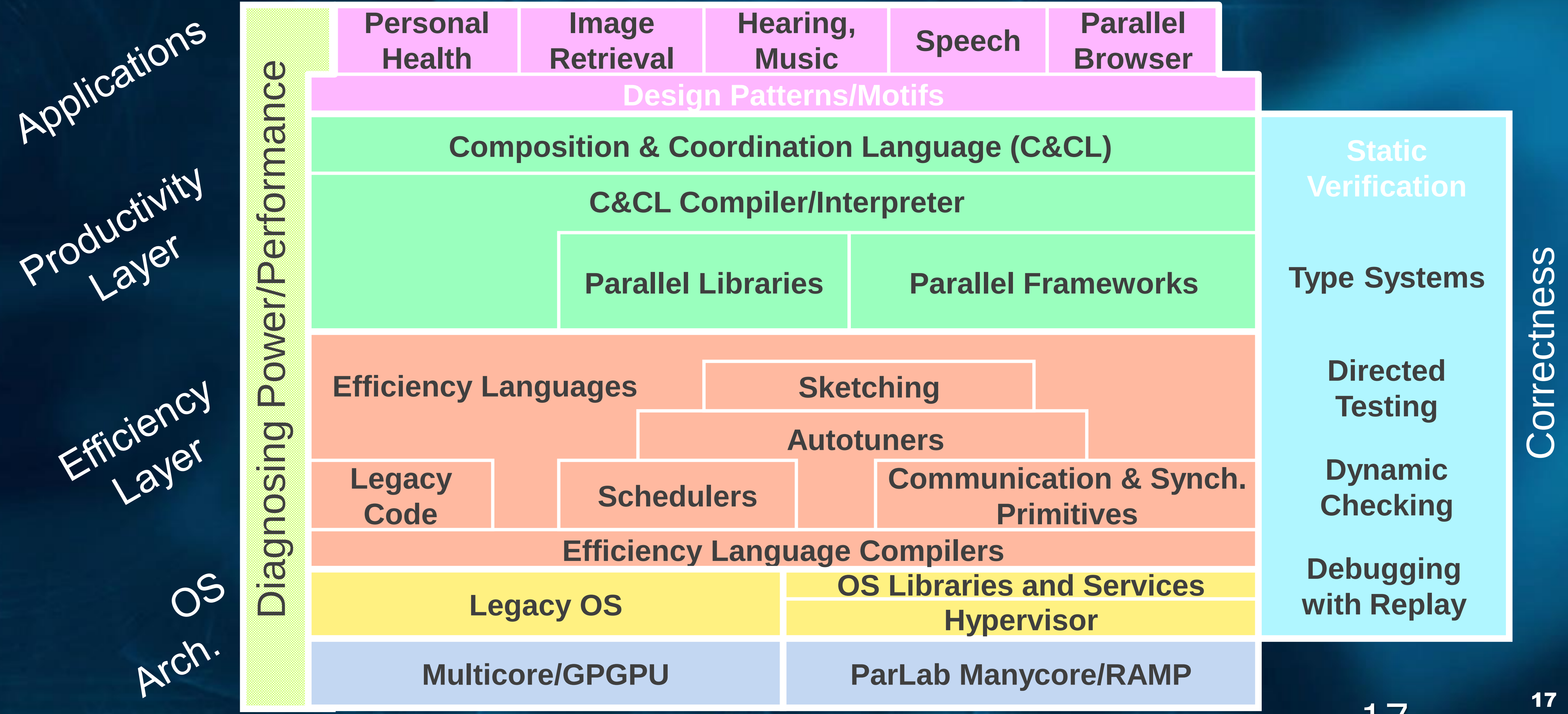

Par Lab is Multi-Lingual

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- Applications require ability to compose parallel code written in many languages and several different parallel programming models
  - Let application writer choose language/model best suited to task
  - High-level productivity code and low-level efficiency code
  - Old legacy code plus shiny new code
- Correctness through all means possible
  - Static verification, annotations, directed testing, dynamic checking
  - Framework-specific constraints on non-determinism
  - Programmer-specified semantic determinism
  - Require common spec between languages for static checker
- Common linking format at low level (Lithe) not intermediate compiler form
  - Support hand-tuned code and future languages & parallel models

Why Consider New Languages?

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- Most of work is in runtime and libraries
- Do we need a language? And a compiler?
  - If higher level syntax is needed for productivity
    - We need a language
  - If static analysis is needed to help with correctness
    - We need a compiler (front-end)
  - If static optimizations are needed to get performance
    - We need a compiler (back-end)
- Will prototype frameworks in conventional languages, but investigate how new languages or pattern-specific compilers can improve productivity, efficiency, and/or correctness

Selective Embedded Just-In-Time Specialization (SEJITS) for Productivity

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- Modern scripting languages (e.g., Python and Ruby) have powerful language features and are easy to use
- Idea: Dynamically generate source code in C within the context of a Python or Ruby interpreter, allowing app to be written using Python or Ruby abstractions but automatically generating, compiling C at runtime
- Like a JIT but
  - **Selective**: Targets a particular method and a particular language/platform (C+OpenMP on multicore or CUDA on GPU)
  - **Embedded**: Make specialization machinery productive by implementing in Python or Ruby itself by exploiting key features: introspection, runtime dynamic linking, and foreign function interfaces with language-neutral data representation

Selective Embedded Just-In-Time Specialization for Productivity

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- Case Study: Stencil Kernels on AMD Barcelona, 8 threads
- Hand-coded in C/OpenMP: 2-4 days
- SEJITS in Ruby: 1-2 hours
- Time to run 3 stencil codes:

Hand-coded (seconds)	SEJITS from cache (seconds)	Extra JIT-time 1st time executed (seconds)
0.74	0.74	0.25
0.72	0.70	0.27
1.26	1.26	0.27

Autotuning for Code Generation (Demmel, Yelick)

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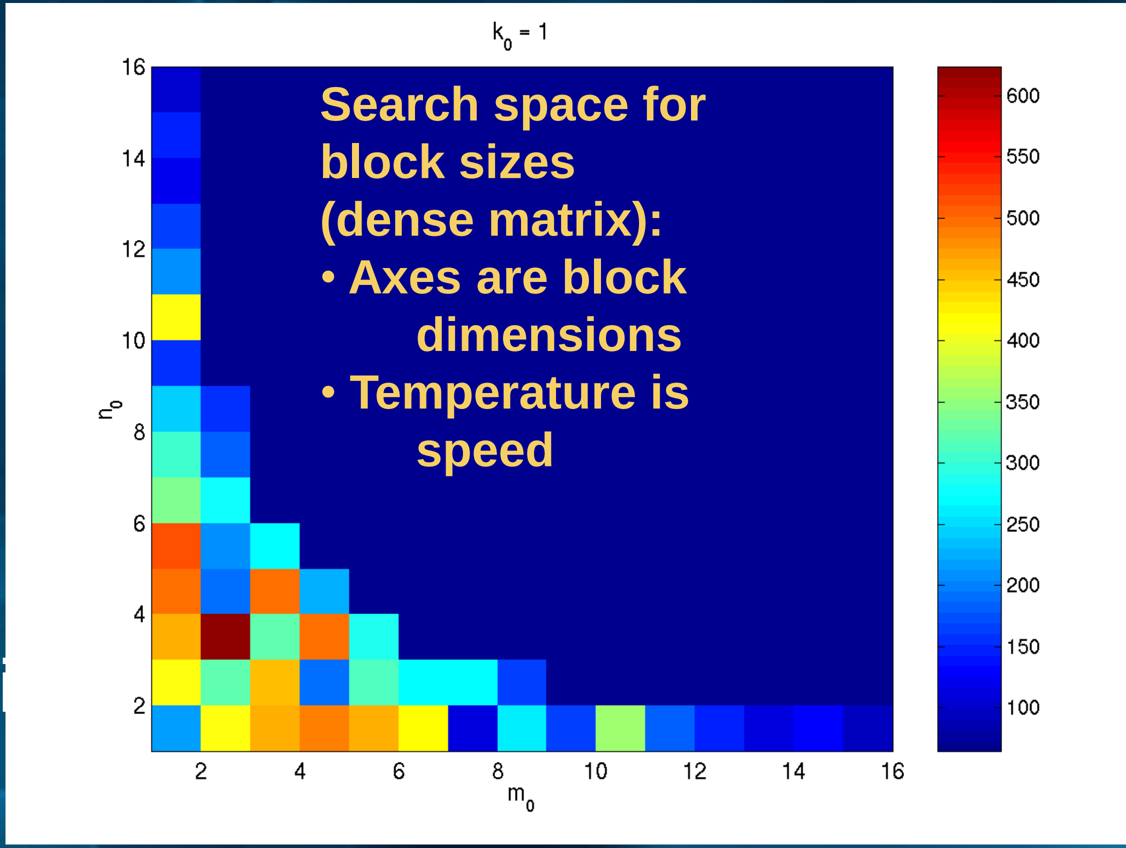
- Problem: generating optimal code like searching for needle in haystack
- Manycore even more diverse
- New approach: “Auto-tuners”
  - 1st generate program variations of combinations of optimizations (blocking, prefetching, …) and data structures
  - Then compile and run to heuristically search for best code for *that* computer
- Examples: PHiPAC (BLAS), Atlas (BLAS), Spiral (DSP), FFT-W (FFT)



Anatomy of a Par Lab Application

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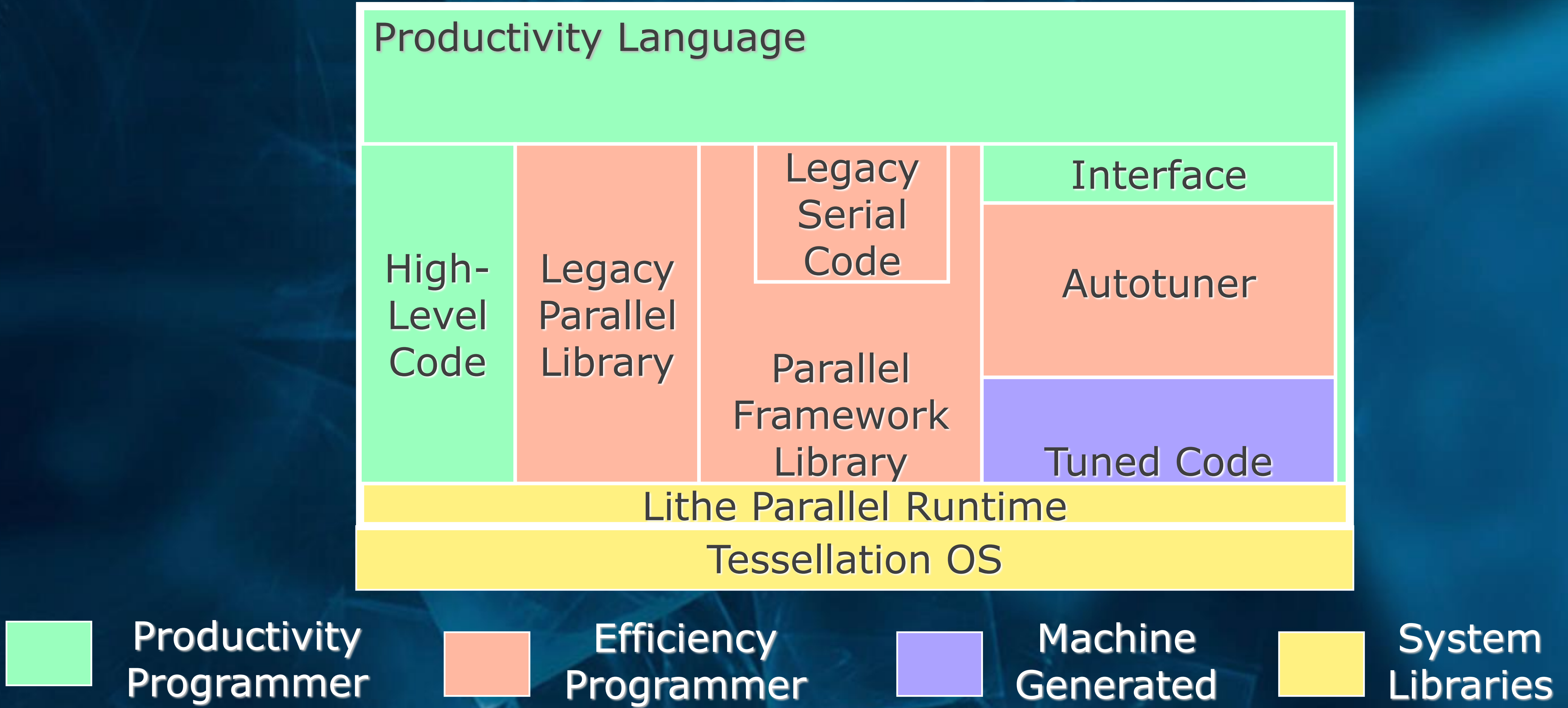

From OS to User-Level Scheduling

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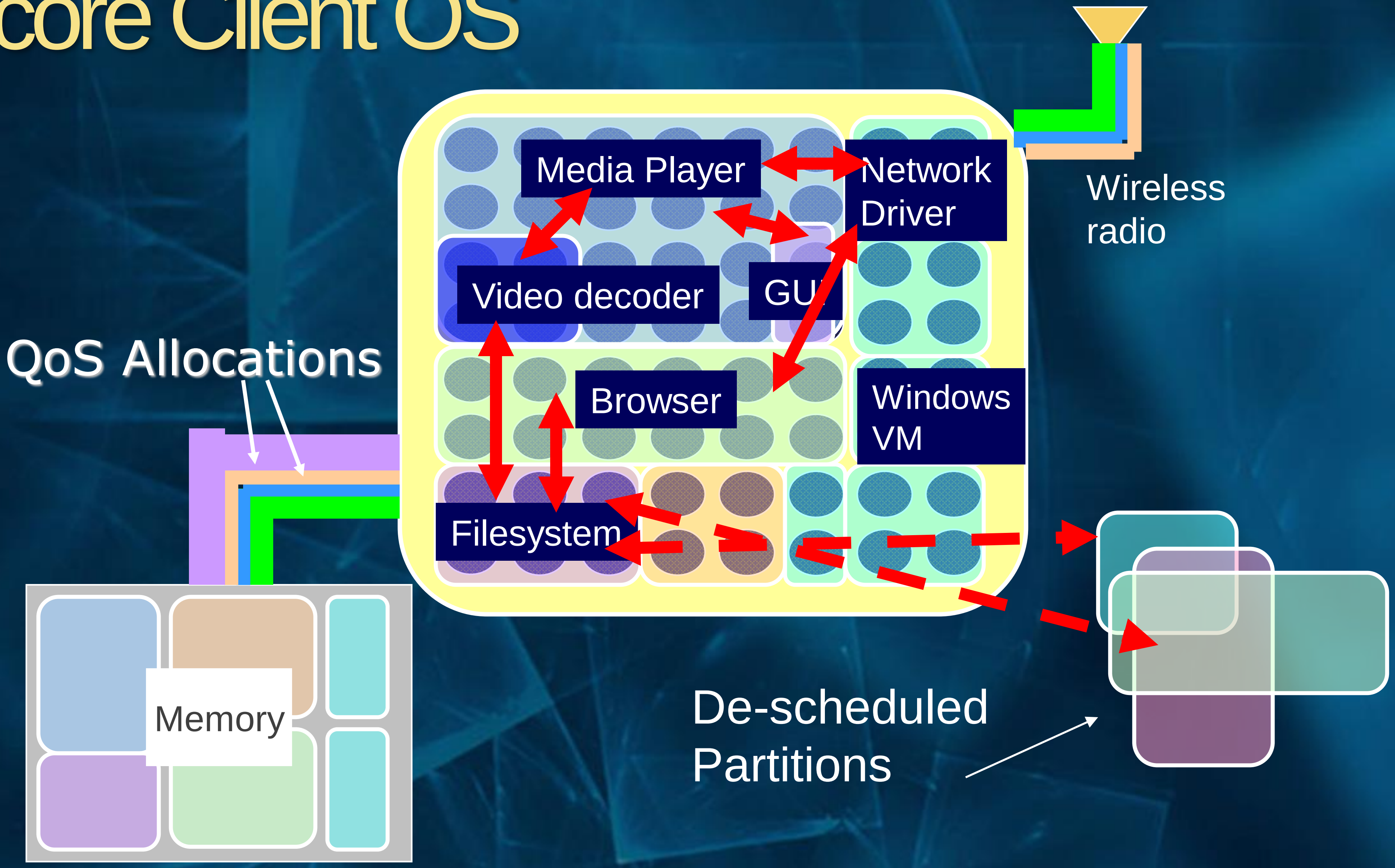
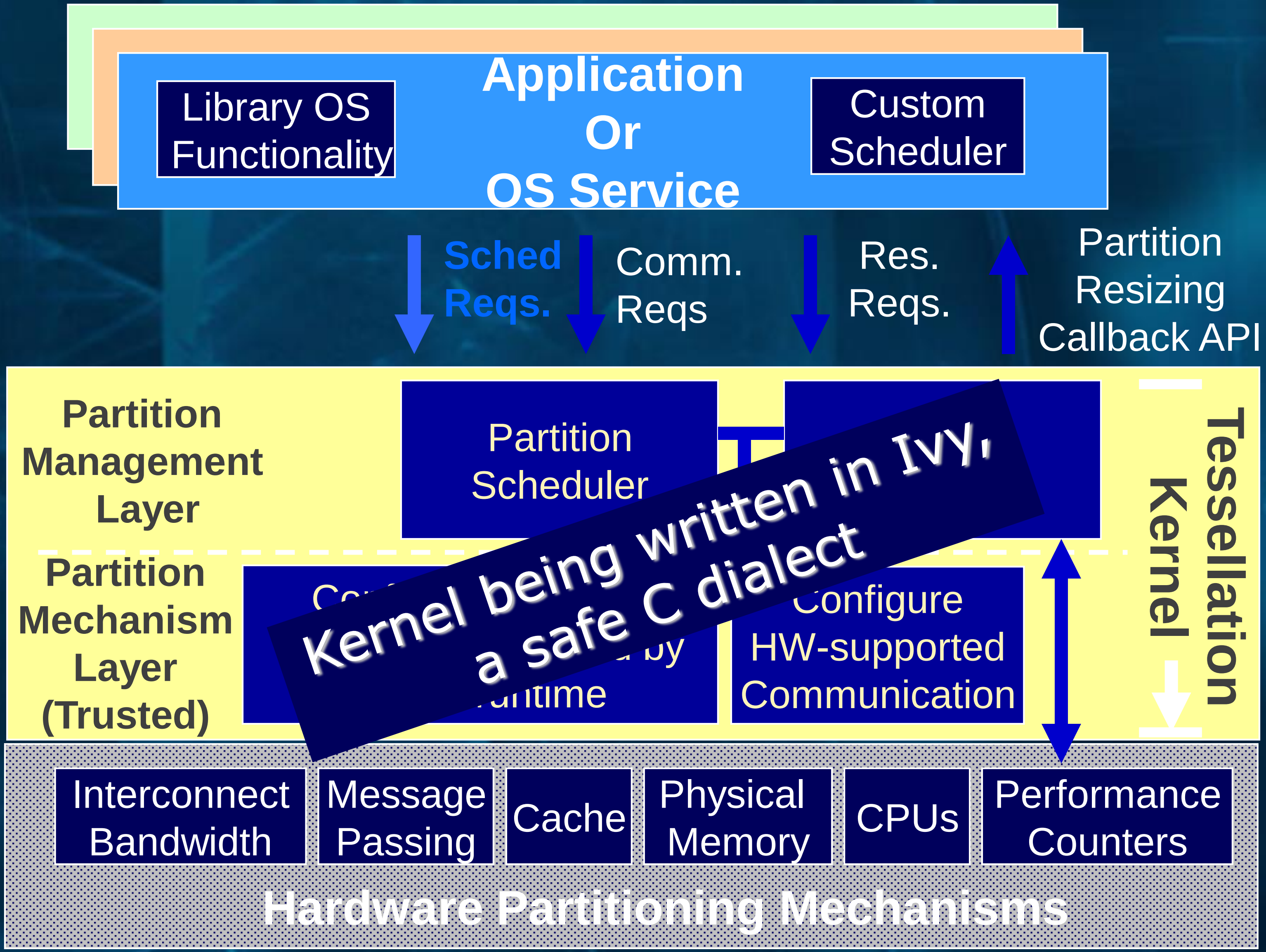
- Tessellation OS allocates hardware resources (e.g., cores) at coarse-grain, and user software shares hardware threads co-operatively using Lithe ABI
- Lithe provides performance composability for multiple concurrent and nested parallel libraries
  - Already supports linking of parallel OpenMP code with parallel TBB code, without changing legacy OpenMP/TBB code and without measurable overhead

Tessellation: Space-Time Partitioning for Manycore Client OS



Tessellation Kernel Structure



Par Lab Architecture

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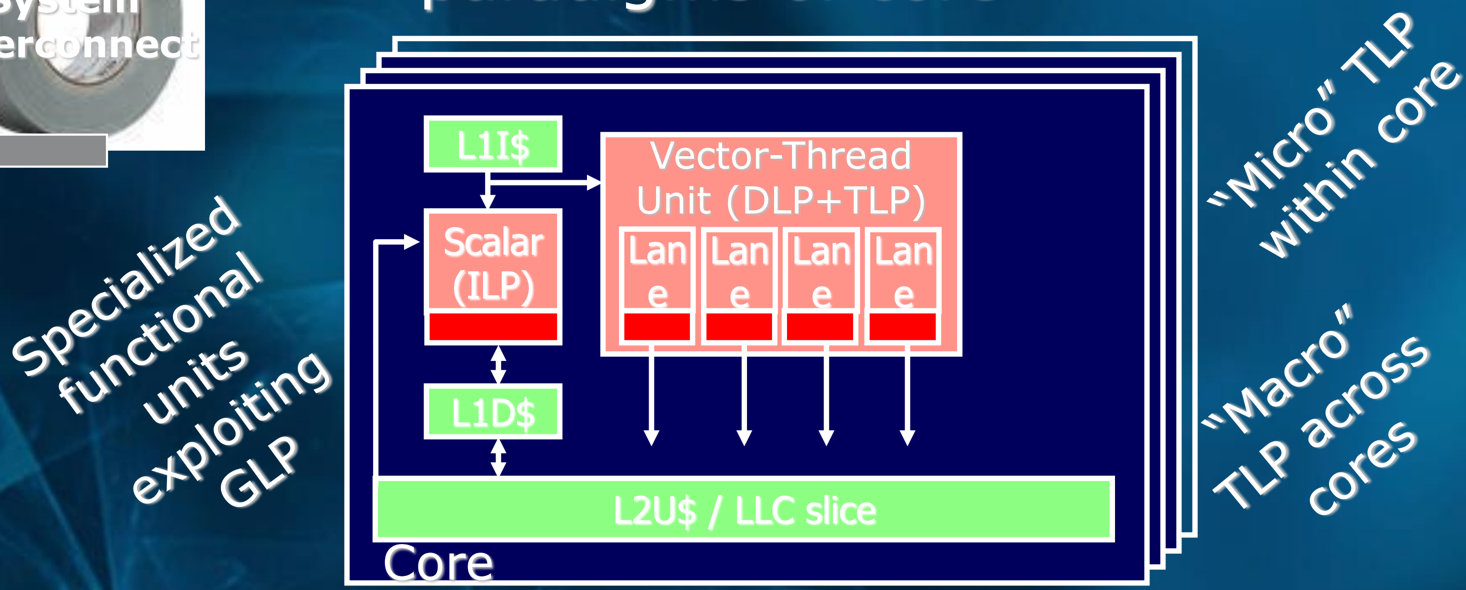
- Architect a long-lived horizontal software platform for independent software vendors (ISVs)
  - ISVs won't rewrite code for each chip or system
  - Customer buys application from ISV 8 years from now, wants to run on machine bought 13 years from now (and see improvements)

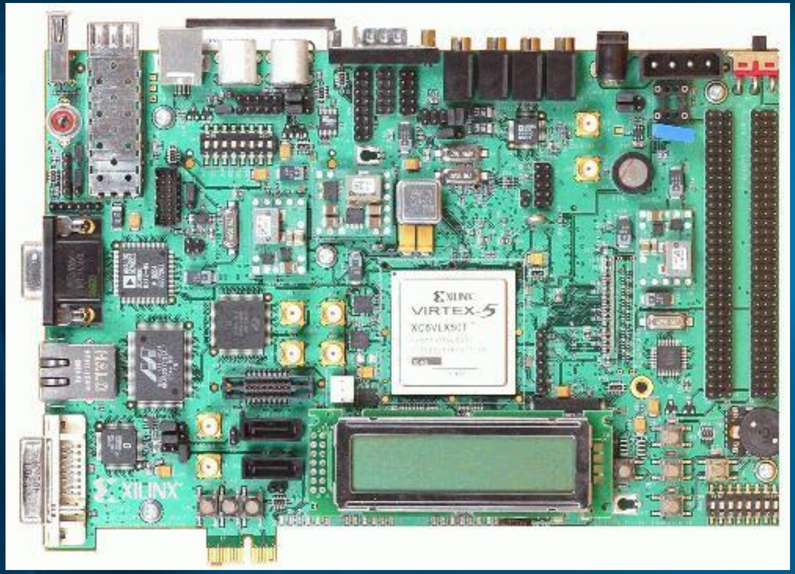
Not multiple paradigms of core



…instead, one type of multi-paradigm core

RAMP Gold

- Rapid accurate simulation of manycore architectural ideas using FPGAs
- Initial version models 64 cores of SPARC v8 with shared memory system on $750 board



Software Simulator	$2,000	0.1 - 1	1
RAMP Gold	$2,000 + $750	50 - 100	100

Par Lab's original research "bets"

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- To learn more: http://parlab.eecs.berekeley.edu

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