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Title:	Imperative, Declarative, Functional and Domain-Specific Programming… Oh My!
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Imperative, Declarative, Functional and Domain-Specific Programming… Oh My!

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Are we entering a new age of software development for HPC?

Yes… I hope so…. Would like to think so...

But we still have a ways to go...

The “Simple” set of Goals

- **Performance (fast)**
- **Portability (run everywhere)**
  - Fast… Standardized...
- **Productivity/Programmability**
  - Easily, everywhere, and high-performance
- **What we are typically asking for is sequential semantics with parallel execution…**

Is the key Cost Really Data Movement?

- ***"Data movement is expensive, compute is free."***
- ***But...***
  - ***Idle processors are not free***
  - **Trinity**: *If you dump data from memory to disk you spend 10X more power waiting on the data to move than to move the data!*
- ***So, no surprise, we really want to keep processors busy…***

Operation	Energy (pJ)
64-bit integer operation	1
64-bit floating-point operation	20
256 bit on-die SRAM access	50
256 bit bus transfer (short)	26
256 bit bus transfer (1/2 die)	256
Off-die link (efficient)	500
256 bit bus transfer (across die)	1,000
DRAM read/write (512 bits)	16,000
HDD read/write	$O(10^6)$

Courtesy Greg Asfaulk (HP) and Bill Dally (NVIDIA)

The Importance of Programming Abstractions

Imperative, explicit data movement:

- ***Focus on control flow, explicit parallelism and low-level data abstractions***

```
AsyncRecv(X);
DoWork(Y);
Sync();
F(X);
```

- *How much work should I do?*
- *Is this performance portable?*
- *When does forward progress really occur?*
- *What if I have more work and data movement happening in* `DoWork`*?*
  - *What resources are in use? Where is the data? Who is using it and how?*
- *Is this modular?*

Concept from: Mike Bauer's Thesis (Stanford),
Legion: Programming Distributed Heterogeneous Architectures with Logical Regions

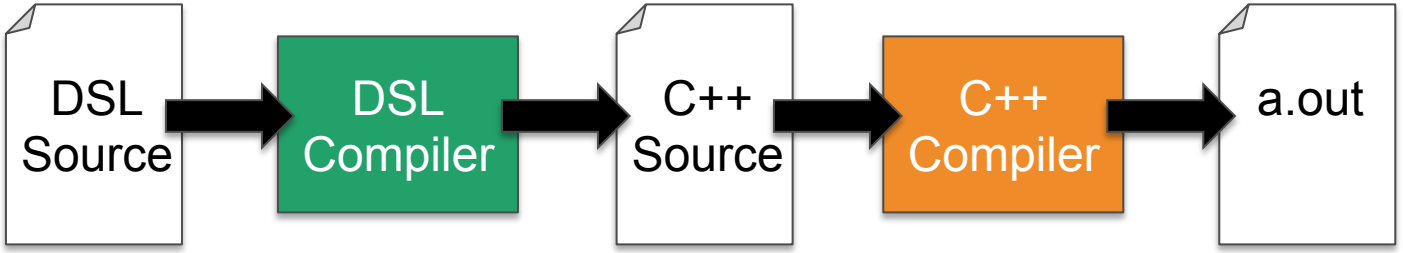
Simplifying the Challenge

"Domain-Specific" Languages

- **Why?**
  - Improved productivity, better maintainability, portability, validation, improved optimizations, thus improved reliability and performance
- **But…**
  - Risks in terms of costs associated with their design, implementation, adoption, maintenance/longevity, and education…

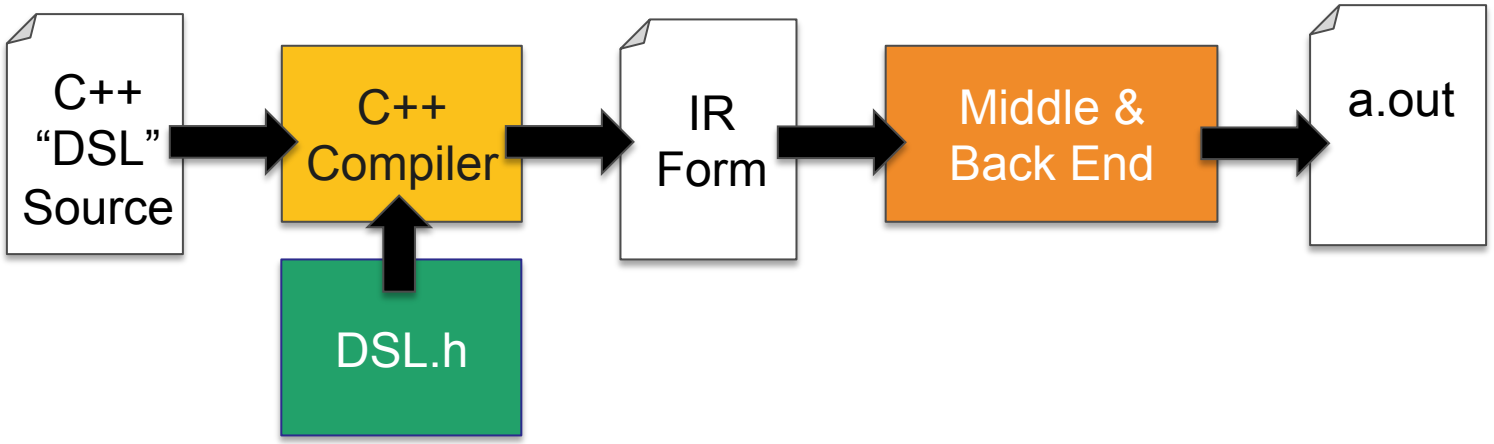
- **What can be done to reduce the risks/costs?**

“Standalone” Source-to-Source Compilation



- **Simplified compiler – heavy lifting done by “real” compiler**
  - Great way to prototype…
- **But… Custom language maintenance issues**
- **Domain knowledge/semantics lost in code generation…**
  - DSL compiler optimizations can be undone by C++ compiler
  - Developer ends up with C++ tools...

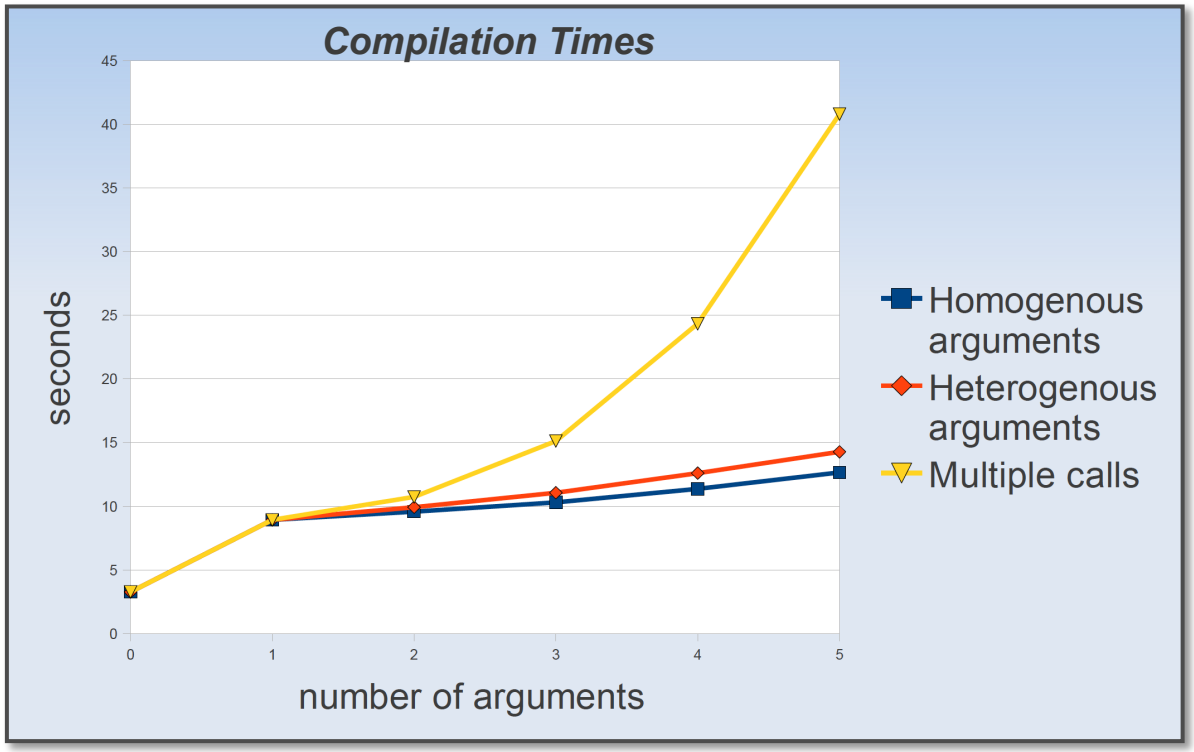
C++ Embedded DSLs



- **Meta-programmed code generation - standardized "goodness"**
- **Underlying infrastructure can be complex and difficult (and often not as opaque as we might like). Stuck w/ C++ semantics and syntax…**
- **Once again, domain knowledge/semantics lost in code generation (after template expansion)…**
  - Can be hard to optimze, match semantic goals due to host language restrictions
  - Developer (and optimizer) ends up with expanded "goop"

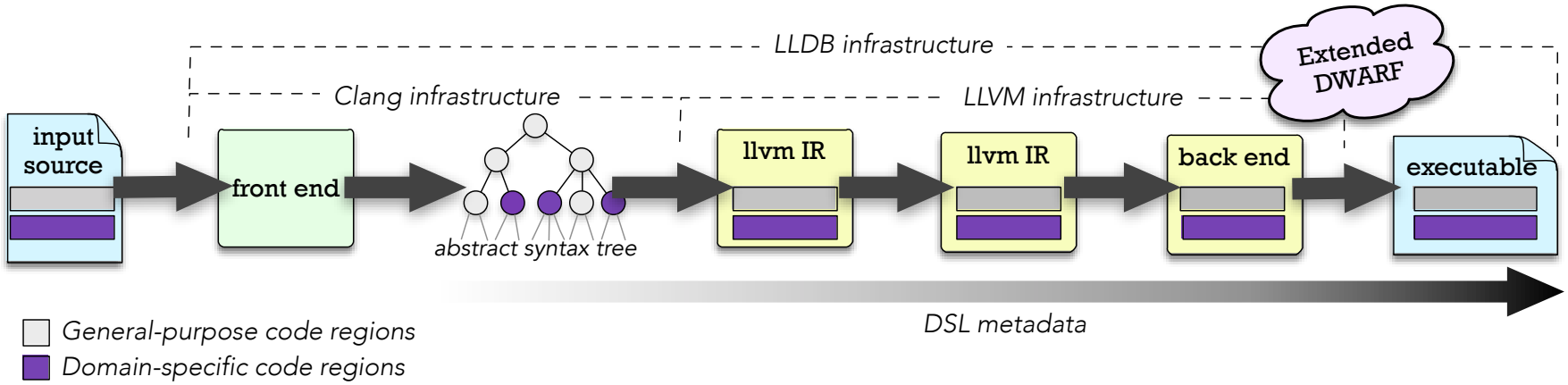
Can you Spare a Minute? More C++ EDSL worries…

```
safe::printf<_S("Hello %s!")>(”World!");
```



“Domain-specific Language Integration with Compile-time Parser Generator Library”, Zoltan Porkolab and Abel Sinkovics, Proceeding GPCE '10 the ninth international conference on Generative Programming and Component Engineering.

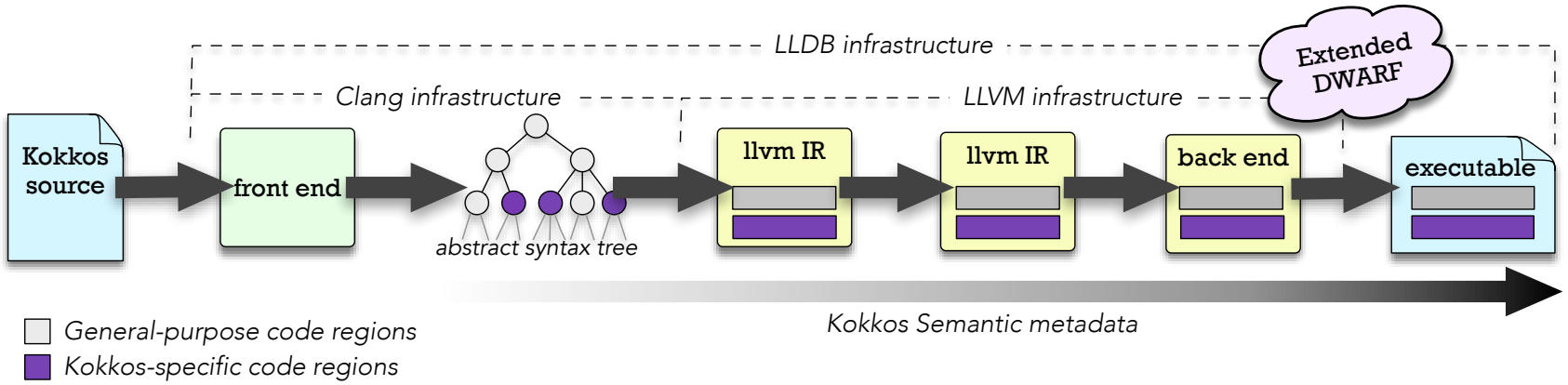
Domain-Aware Toolchains



- **We really want a fully supported toolchain – not just a set of "front end" semantics and abstractions…**
  - Allow the developer (and the compiler) to reason in terms of the original abstractions (not the "goop")

- **OpenMP implementations do/can have similar issues…**

Kokkos-Aware Clang



- **Code generation phase of Clang intercepts Kokkos constructs prior to template expansion and implements semantics-aware code generation**
  - SC15 tutorial code:
    - Compile time is approx. 4.5 times faster
    - Code generation: parallel-for about 5% faster (GPUs), reductions need to be optimized (about 2-3x slower at present)

Due to Complexity we Often Only Look at one Piece of the Puzzle…

- **How do we?**
  - Interoperate across different models/abstractions, languages and legacy code bases?
  - Build a set of useful and flexible tools for understanding details in terms of the abstractions we're developing with?
  - Get applications to adopt new approaches for programming?