Chapel: Status and Future Directions

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The Chapel Team

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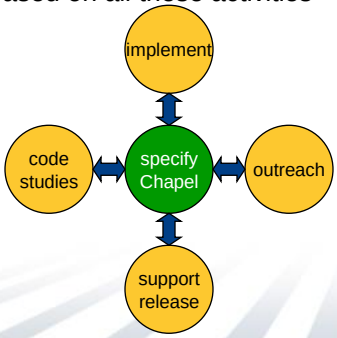
- Steve Deitz 
- Samuel Figueroa 
- David Iten 
- Lee Prokowich 

- Interns
  - Robert Bocchino (`06 – UIUC)
  - James Dinan (`07 – Ohio State)
  - Mackale Joyner (`05 – Rice)
  - Andy Stone (`08 – Colorado St)
- Alumni
  - David Callahan
  - Roxana Diaconescu
  - Shannon Hoffswell
  - Mary Beth Hribar
  - Mark James
  - John Plevyak
  - Wayne Wong
  - Hans Zima

Chapel Work

- Chapel Team's Focus:
  - specify Chapel syntax and semantics
  - implement open-source prototype compiler for Chapel
  - perform code studies of benchmarks, apps, and libraries in Chapel
  - do community outreach to inform and learn from users/researchers
  - support users of code releases
  - refine language based on all these activities



Outline

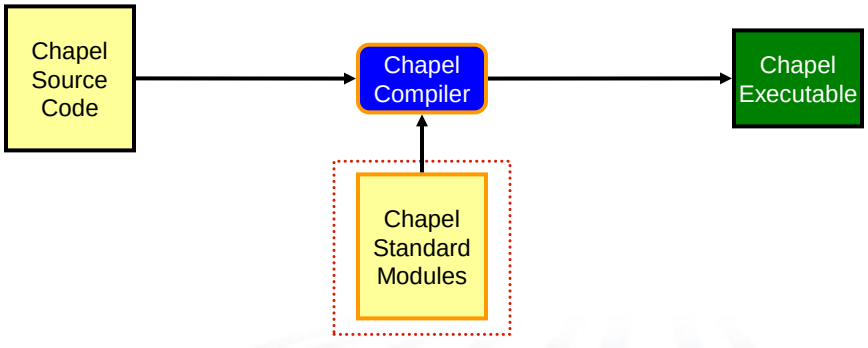
- Who we are and what we do
- Chapel prototype compiler
  - compiler architecture
  - implementation status
- Chapel and the broader community
- Wrap-up

Prototype Compiler Development

- Development Strategy:
  - start by developing and nurturing within Cray under HPCS
  - initial releases to small sets of "friendly" users for the past few years
    - ~90 users at ~30 sites (academic, government, industry)
  - first public release made available November 2008
    - ~220 downloads as of February 1st
  - turn over to community when it's ready to stand on its own

- Compilation approach:
  - source-to-source compiler for portability (Chapel-to-C)
  - link against runtime libraries to hide machine details
    - threading layer currently implemented using pthreads
    - communication currently implemented using Berkeley's GASNet

Compiling Chapel



Chapel Standard Modules

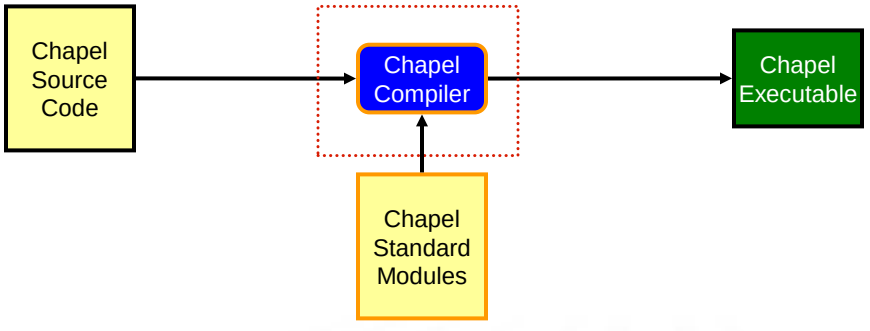
Standard Modules: implement standard library support

- explicitly imported by user code:

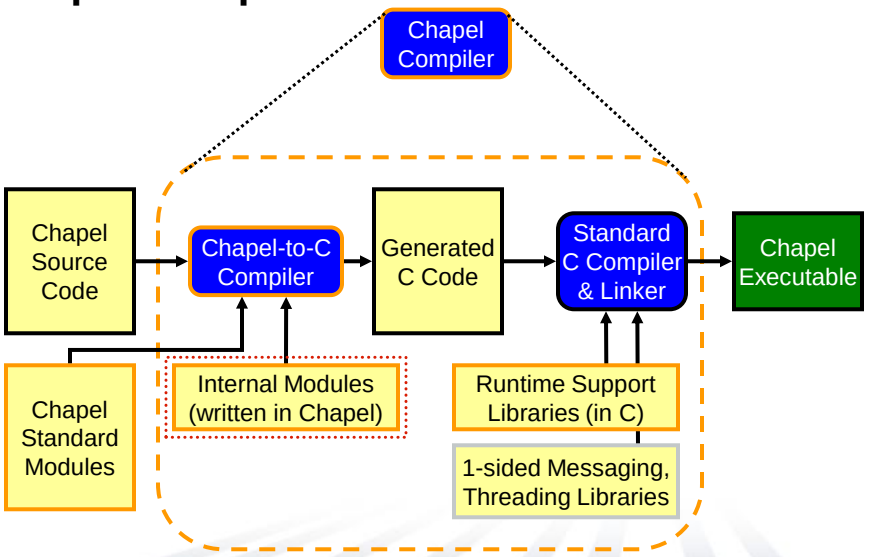
```
use Random;
use Time;
```

- current release contains rough sketch of anticipated support:
  - machine resource queries
  - timer and time-of-day support
  - random number generators
  - advanced bit operations
  - more to come…

Compiling Chapel



Chapel Compiler Architecture



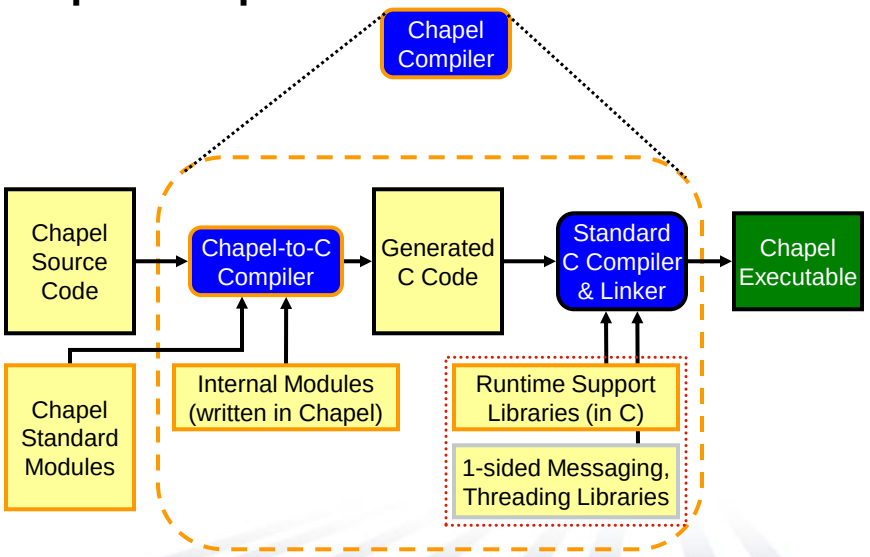
Chapel Internal Modules

Internal Modules: Chapel code to help implement Chapel

- either by…
  …using lower-level Chapel concepts
  …wrapping C runtime support routines
- unseen by typical users
- current internal modules implement:
  - standard operators (arithmetic, bitwise, logical)
  - standard math routines (sin(), abs(), …)
  - user-level I/O routines and concepts
  - user-level assertions and halt routines
  - tuples, domains, & arrays
  - synchronization variables

- These modules have been invaluable to our development
  - exercise the Chapel implementation
  - leverage Chapel's productivity features making us more productive

Chapel Compiler Architecture



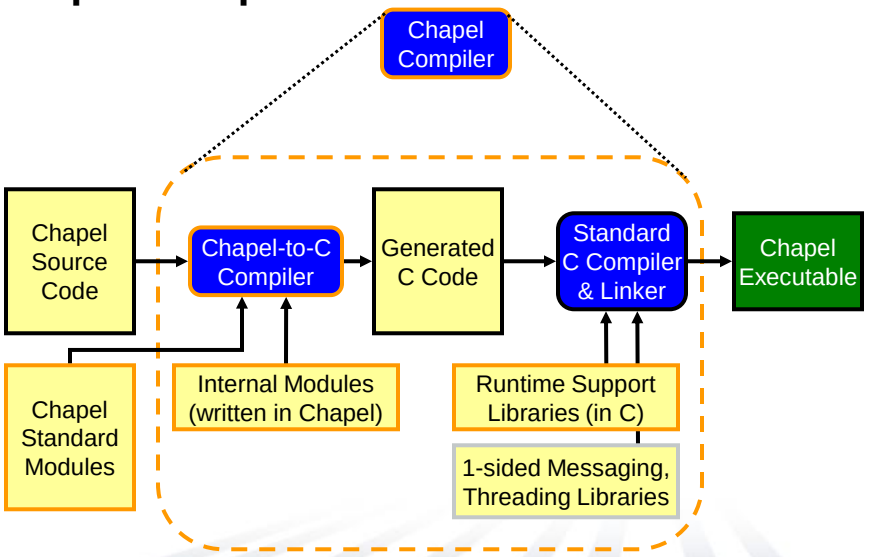
Chapel Runtime Support Libraries

Runtime Support Libraries: C code to help implement Chapel

- for features that are too low-level to implement in Chapel
- can be thought of as helping bootstrap the language
- current support libraries implement:
  - command-line argument parsing
  - console and file I/O primitives
  - error handling
  - memory management and tracking
  - timing/time-of-day primitives
  - type conversions
  - thread creation and management
  - inter-process communication and coordination

- As Chapel matures, functionality tends to migrate from the C runtime support libraries to the Chapel internal modules

Chapel Compiler Architecture

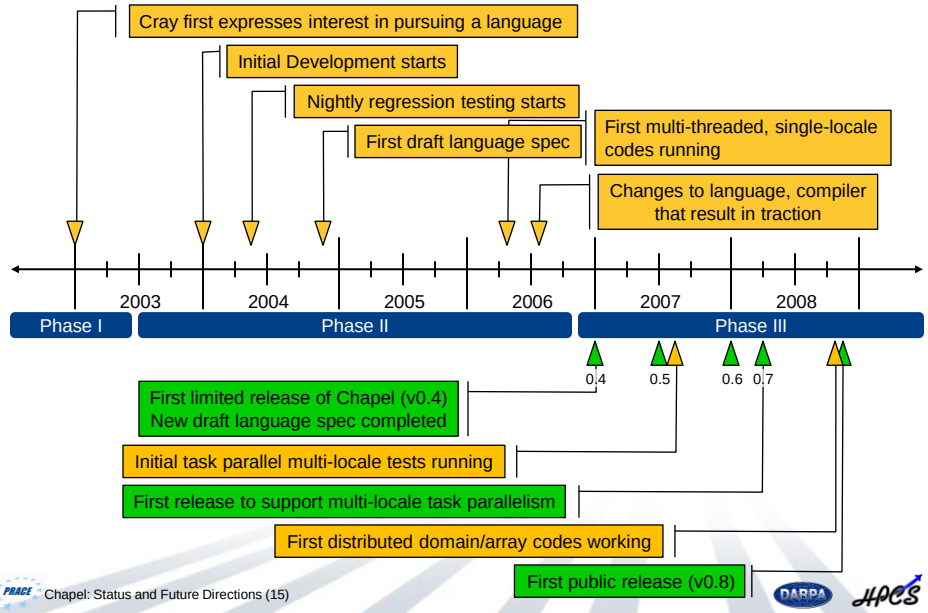


Implementation Status

- **Base language:** stable (a few gaps and bugs remain)
- **Task parallel:** stable, multithreaded
- **Data parallel:**
  - stable serial reference implementation
  - initial support for multi-threaded implementation
- **Locality:**
  - stable locale types and arrays
  - stable task parallelism across multiple locales
  - initial support for distributed arrays across multiple locales
- **Performance:**
  - has received much attention in designing the language
  - yet very little implementation effort thus far

(See individual presentations for details)

Selected Chapel Timeline



Outline

- Who we are and what we do
- Chapel prototype compiler
- Chapel and the broader community
  - research challenges
  - collaborations
- Wrap-up

Chapel and Research

- Chapel contains a number of research challenges
  - the broadest: “solve the parallel programming problem”
- We intentionally bit off more than an academic project would
  - due to our emphasis on general parallel programming
  - due to the belief that adoption requires a broad feature set
  - to create a platform for broad community involvement
- Most Chapel features are taken from previous work
  - though we mix and match heavily, which brings new challenges
- Others represent research of interest to us/the community

Some Research Challenges

- Near-term:
  - user-defined distributions
  - zippered parallel iteration
  - index/subdomain optimizations
  - heterogeneous locale types
  - language interoperability
- Medium-term:
  - memory management policies/mechanisms
  - task scheduling policies
  - performance tuning for multicore processors
  - unstructured/graph-based codes
  - compiling/optimizing atomic sections (STM)
  - parallel I/O abstractions
- Longer-term:
  - checkpoint/restart; resiliency mechanisms
  - mapping to accelerator technologies: GP-GPUs (via OpenCL?), FPGAs?
  - hierarchical locales; exposing architectural hierarchy/diversity within a locale

Chapel and the Community

- Our philosophy:
  - Help the parallel community understand what we are doing
  - Make our code available to the community
  - Encourage external collaborations
- Goals:
  - to get feedback that will help make the language more useful
  - to support collaborative research efforts
  - to accelerate the implementation
  - to aid with adoption

Current Collaborations

UND/ORNL (Peter Kogge, Srinivas Sridharan, Jeff Vetter): Asynchronous STM over distributed memory

ORNL (David Bernholdt *et al.*): Chapel code studies – Fock matrix computations, MADNESS, Sweep3D, … (HIPS `08)

PNNL (Jarek Nieplocha *et al.*): ARMCI port of comm. layer

EPCC (Michele Weiland, Thom Haddow, Tom Omitowoju): performance studies of task parallelism

UIUC (Vikram Adve and Rob Bocchino): Software Transactional Memory (STM) over distributed memory (PPoPP `08)

CMU (Franz Franchetti): Chapel as portable parallel back-end language for SPIRAL

(Your name here?)

Possible Collaboration Areas

- any of the previously-mentioned research topics…
- task parallel runtime work
  - implementation using alternate threading packages
  - work-stealing task implementation
- application/benchmark studies
- different compiler back-ends (LLVM? MS CLR?)
- visualizations, algorithm animations
- library support
- tools
  - correctness debugging
  - performance debugging
  - IDE support
- runtime compilation and optimization
- (your ideas here…)

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Next Steps

- Continue to improve performance
- Continue to add missing features
- Expand the set of codes that we are currently studying
- Expand the set of architectures that we are targeting
- Support the public release
- Continue to support collaborations and seek out new ones

Chapel

Chapel: a new parallel language being developed by Cray Inc.

Themes:

- **general parallel programming**
  - data-, task-, and nested parallelism
  - express general levels of software parallelism
  - target general levels of hardware parallelism
- ***global-view* abstractions**
- ***multiresolution* design**
- **control of locality**
- **reduce gap between mainstream & parallel languages**

For More Information

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Parallel Programmability and the Chapel Language; Chamberlain, Callahan, Zima; International Journal of High Performance Computing Applications, August 2007, 21(3):291-312.

Questions?