CHIUW 2017: Welcome and State of the Project

Brad Chamberlain
Chapel Team, Cray Inc.
June 2, 2017
This presentation may contain forward-looking statements that are based on our current expectations. Forward looking statements may include statements about our financial guidance and expected operating results, our opportunities and future potential, our product development and new product introduction plans, our ability to expand and penetrate our addressable markets and other statements that are not historical facts. These statements are only predictions and actual results may materially vary from those projected. Please refer to Cray's documents filed with the SEC from time to time concerning factors that could affect the Company and these forward-looking statements.
Chapel, briefly
What is Chapel?

**Chapel:** A productive parallel programming language
- portable
- open-source
- a collaborative effort

**Goals:**
- Support general parallel programming
- Make parallel programming at scale far more productive
Motivation for Chapel

Q: Can a single language be…
   …as programmable as Python?
   …as fast as Fortran?
   …as portable as C?
   …as scalable as MPI?
   …as generic and meta- as C++? (but using simpler notation?)
   …as fun as <your favorite language here>?

A: We believe so.

Q: So why don’t we have such languages already?

A: Due to a lack of…
   …long-term efforts
   …resources
   …community will
   …developer/user co-design
   …patience

Chapel is our attempt to change this
A Year in the Life of Chapel

● **Two major releases per year** (April / October)
  ● ~a month later: detailed release notes
  ● latest release: Chapel 1.15, released April 6th 2017

● **CHIUW**: Chapel Implementers and Users Workshop (~June)

● **SC** (November)
  ● tutorials, panels, BoFs, posters, educator sessions, exhibits, …
  ● annual CHUG (Chapel Users Group) happy hour

● **Talks, tutorials, research visits, blog posts, …** (year-round)
A Year in the Life of Chapel

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Welcome to CHIUW 2017!

the 4th annual Chapel Implementers and Users Workshop
Chapel’s Home in the Landscape of New Scientific Computing Languages
(and what it can learn from the neighbours)
Jonathan Dursi
*The Hospital for Sick Children, Toronto*
HPC is dying, and MPI is killing it

Jonathan Dursi

Toronto

Pictured: The HPC community bravely holds off the incoming tide of new technologies and applications. Via the BBC.

This should be a golden age for High Performance Computing.

For decades, the work of developing algorithms and implementations for tackling simulation and data analysis problems at the largest possible scales was obscure if important work. Then, suddenly, in the mid-2000s, two problems — analyzing internet-scale data, and interpreting an incoming flood of genomics data — arrived on the scene with data volumes and performance requirements which seemed quite familiar to HPCers, but with a size of audience unlike anything that had come before.

Suddenly discussions of topics of scalability, accuracy, large-scale data storage, and distributed matrix arithmetic all became mainstream and urgent. The number of projects and workshops addressing these topics exploded, and new energy went into implementing solutions problems faced in these domains.

In that environment, one might expect that programmers with HPC experience — who have dealt routinely with terabytes and now petabytes of data, and have years or decades of experience with designing and optimizing distributed memory algorithms — would be in high demand.
CHIUW 2017: Keynote (“Why do I know that name…?”)

Pictured: The HPC community bravely holds off the incoming tide of new technologies and applications. Via the BBC
CHIUW 2017: Research Papers

Identifying Use-After-Free Variables in Fire-and-Forget Tasks
Jyothi Krishna V S (IIT Madras) and Vassily Litvinov (Cray Inc.)

Towards a GraphBLAS Library in Chapel
Ariful Azad and Aydin Buluc (LBNL)

Comparative Performance and Optimization of Chapel in Modern Manycore Architectures
Engin Kayraklıoğlu, Wo Chang, and Tarek El-Ghazawi (The George Washington University)
CHIUW 2017: Technical Talks

Improving Chapel and Array Memory Management
Michael Ferguson, Vassily Litvinov, and Brad Chamberlain (Cray Inc.)

Try, Not Halt: An Error Handling Strategy for Chapel
Preston Sahabu, Michael Ferguson, Greg Titus, and Kyle Brady (Cray Inc.)

GPGPU support in Chapel with the Radeon Open Compute Platform
Michael Chu, Ashwin Aji, Daniel Lowell, and Khaled Hamidouche (AMD)

An OFI libfabric Communication Layer for the Chapel Runtime
Sung-Eun Choi (Cray Inc.)

Sketching Streams with Chapel
Christopher Taylor (DoD)

Entering the Fray: Chapel's Computer Language Benchmarks Game Entry
Brad Chamberlain, Ben Albrecht, Lydia Duncan, Ben Harshbarger, Elliot Ronaghan, Preston Sahabu, Michael Noakes (Cray Inc.), and Laura Delaney (Whitworth University)
CHIUW 2017: Planning Committee

General Chairs:
● Tom MacDonald, *Cray Inc.*
● Michael Ferguson, *Cray Inc.*

Program Committee:
● Brad Chamberlain (chair), *Cray Inc.*
● Nikhil Padmanabhan (co-chair), *Yale University*
● Richard Barrett, *Sandia National Laboratories*
● Mike Chu, *AMD*
● Mary Hall, *University of Utah*
● Jeff Hammond, *Intel*
● Jeff Hollingsworth, *University of Maryland*
● Cosmin Oancea, *University of Copenhagen*
● David Richards, *Lawrence Livermore National Laboratory*
● Michelle Strout, *University of Arizona*
● Kenjiro Taura, *University of Tokyo*
8:30: Chapel Boot Camp (optional)
9:00: Welcome, State of the Project
9:30: Break
10:00: Talks: Chapel Design and Implementation
11:10: Quick Break
11:20: Talks: Targeting New Architectures
12:00: Lunch
1:30: Keynote Talk: Jonathan Dursi
2:30: Talks: Uses of Chapel
3:20: Break
3:50: Talks: Benchmarking and Performance
4:40: Lightning Talks and Flash Discussions
5:30: Wrap-up / Head to Dinner
CHIUW 2017: Lightning Talks & Flash Discussions

- New this year!
- Last session of the day!
- Goal: high-energy hot topics for low attention spans!
- Format: Short talks, Q&A, war stories, …whatever!
- Sign up for a slot!
CHIUW 2017: Lightning Talks & Flash Discussions

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CHIUIW 2017: Code Camp (Half) Day

- **Tomorrow morning: 8:30-noon (room: Tangerine 5)**

- **Proposed topics (so far):**
  - write a user-defined domain map
  - Chapel on AWS
  - work on GPU support
  - introduction to Chapel code generation & optimizations
  - network atomics in Chapel’s runtime libraries
  - re-architect launcher scripts
  - unified communication diagnostics hooks
  - storage technologies
  - beef up Linear Algebra module
  - port gravitational n-body code to Chapel
  - pyChapel improvements
  - ...
SWAG and Surveys

● We have a few giveaways today:
  ● Chapel stickers
  ● Chapel microfiber wipes for screens / glasses

● We also have a CHIUW survey
  ● available in paper or online form—please fill one out
State of the Chapel Project 2017
Releases since CHUW 2016

- Since last year, two new major versions of Chapel:
  - 1.14: October 6, 2016
  - 1.15: April 6, 2017  ➔ our most significant release ever!

- Significant progress in all areas of the release
  - performance, memory leaks, libraries, documentation, portability, …

- Achieving 1500+ downloads per release
Contributors to the Past Year’s Releases

Contributors to 1.14 / 1.15:

- Ben Albrecht, Cray Inc.
- Matthew Baker, ORNL
- Paul Cassella, Cray Inc.
- Brad Chamberlain, Cray Inc.
- Sung-Eun Choi, Cray Inc.
- Marcos Cleison Silva Santana, individual contributor
- Laura Delaney, Whitworth University / Cray
- Lydia Duncan, Cray Inc.
- Michael Ferguson, Cray Inc.
- Ben Harshbarger, Cray Inc.
- Andrea Francesco Iuorio, Università degli Studi di Milano / GSoC
- David Iten, Cray Inc.
- David Keaton, Cray Inc.
- Engin Kayraklioglu, George Washington University / Cray Inc.
- Sagar Khatri, individual contributor
- Przemysław Leśniak, individual contributor
- Vassily Litvinov, Cray Inc.
- Tom MacDonald, Cray Inc.
- Deepak Majeti, individual contributor
- Phil Nelson, Western Washington University / Cray
- Michael Noakes, Cray Inc.
- Nikhil Padmanabhan, Yale University
- Nicholas Park, DOD
- Sriraj Paul, Rice University
- Kumar Prasun, individual contributor
- Elliot Ronaghan, Cray Inc.
- Preston Sahabu, Cray Inc.
- Kushal Singh, Int'l Institute of Information Technology, Hyderabad / GSoC
- Kenjiro Taura, University of Tokyo
- Chris Taylor, DOD
- Greg Titus, Cray Inc.
- Rob Upcraft, individual contributor
- Tony Wallace, Cray Inc.
- Hui Zhang, [University of Maryland]

This year saw a record number of contributors to the releases.
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- Hui Zhang, [University of Maryland]

17 Cray employees, 3 Cray summer interns/contractors, 15 external contributors
The Chapel Team at Cray (May 2017)

14 full-time employees + 2 summer interns
Chapel R&D Organizations

Heriot Watt University
AMD
The George Washington University
Western Washington University

東京大学
The University of Tokyo
Colorado State University
Rice University
University of Maryland

Lawrence Berkeley National Laboratory
Lawrence Livermore National Laboratory
Sandia National Laboratories

Department of Defense
Yale

(and several others…)

http://chapel.cray.com/collaborations.html
Single-Locale Performance
Single-Locale Performance: the past year

- Overall, single-locale performance improved dramatically
LCALS: Serial Timings, Chapel 1.13.0

Normalized time – serial reference is 1.0

Serial Chapel vs g++

Normalized Time

Long problem size
(Similar results for medium and short problem sizes)

chpl --fast
--no-ieee-float

g++ -Ofast -fopenmp
LCALS: Serial Timings, Chapel 1.14.0

Long problem size
(Similar results for medium and short problem sizes)

Serial Chapel vs g++
Normalized time – serial reference is 1.0

Normalized Time

<table>
<thead>
<tr>
<th>Function</th>
<th>g++ serial</th>
<th>Chapel serial</th>
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<tbody>
<tr>
<td>PRESSURE_CALC</td>
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<td>HYDRO_FIRST_MIN</td>
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</table>

Long problem size: better

chpl --fast
--no-ieee-float

Better performance:
g++ -Ofast -fopenmp
Parallel variants still lagged behind the reference in 1.14
- between 1.5X and 8X slower for long problem size
LCALS: Parallel Timings, Chapel 1.15.0

- Chapel 1.15 closed the gap significantly
  - ~3-4x speedup: on par or very close to reference for most kernels

Parallel Chapel vs g++/OMP

Normalized time – parallel reference is 1.0

- Chapel 1.15 closed the gap significantly
- ~3-4x speedup: on par or very close to reference for most kernels
The Computer Language Benchmarks Game

64-bit quad core data set
Will your toy benchmark program be faster if you write it in a different programming language? It depends how you write it!

Which programs are fast?
Which are succinct? Which are efficient?

<table>
<thead>
<tr>
<th></th>
<th>Ada</th>
<th>C</th>
<th>Chapel</th>
<th>C#</th>
<th>C++</th>
<th>Dart</th>
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<td>Haskell</td>
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<td>JavaScript</td>
<td>Lisp</td>
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<td>OCaml</td>
<td>Pascal</td>
<td>Perl</td>
<td>PHP</td>
<td>Python</td>
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<td>Racket</td>
<td>Ruby</td>
<td>JRuby</td>
<td>Rust</td>
<td>Smalltalk</td>
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<td>Swift</td>
<td>TypeScript</td>
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{ for researchers } fast-faster-fastest stories

Since CHIUW 2016, Chapel entry completed and listed on site
CLBG: Fast-faster-fastest graph (Sep 2016)

Relative performance, sorted by geometric mean

How many times slower?

program time / fastest program time

benchmarks game

09 Sep 2016 u64q

better
CLBG: Fast-faster-fastest graph (May 2017)

Relative performance, sorted by geometric mean
CLBG: Fast-faster-fastest graph (May 2017)

Relative performance, sorted by geometric mean

For further details, see my talk this afternoon

How many times slower?

Better
Multi-Locale Performance
PGAS Applications Workshop

Monday, November 14th, 2016

Held in conjunction with SC16

In cooperation with:

sighpc
Optimizing PGAS overhead in a multi-locale Chapel implementation of CoMD

Riyaz Haque and David F. Richards
Performance is comparable to the reference implementation

- Code compiled using Chapel v1.13
  - The compiler itself was compiled with gcc-4.9.2, ibv on gasnet and qthreads as the threading framework
- Executed on 1-32 nodes of 64-bit Intel Xeon processors
  - 12 cores, 24 GB RAM, Infiniband high-speed interconnect

CoMD-Chapel vs. CoMD-Ref, 4x10^6 atoms

CoMD-Chapel performs to within 87% (8 locales) to 67% (32 locales) of the reference
Multi-locale Performance

- Significant multi-locale performance improvements
- No known regressions

Graphs showing improvements across different benchmarks:
- ISx (weakISO) --n=5592400
- miniMD --size 20 (sec)
- SSA2 Size 22, $2^4$ Vertices, Time
- DOE: Lulesh Dense Time (sec) sedov15 oct
Multi-locale Performance

- Significant multi-locale performance improvements
- no known regressions (qthreads now outperforms muxed even more)
ISx Execution Time: MPI, SHMEM

- 64 nodes on Cray XC

**ISx weakISO Total Time**

- SHMEM
- MPI

Better (x 36 cores per node)
ISx Execution Time: MPI, SHMEM, Chapel 1.14

- 64 nodes on Cray XC

ISx weakISO Total Time

- Time (seconds)
- Nodes (x 36 cores per node)

- Chapel 1.14
- SHMEM
- MPI

Copyright 2017 Cray Inc.
ISx Execution Time: MPI, SHMEM, Chapel

- 64 nodes on Cray XC

**ISx weakISO Total Time**

![Graph showing ISx Execution Time](image)
ISx Execution Time: MPI, SHMEM, Chapel 1.15

- 64 nodes on Cray XC

**Graph:**
- ISx weakISO Total Time
- Time (seconds)
- Nodes (x 36 cores per node)
- SHMEM
- MPI
- Chapel 1.15
- Better
RA Performance: Chapel vs. MPI

Performance of RA (atomics)

GUP/s

Locales (x 36 cores per locale)

ref MPI no-bucketing
ref MPI bucketing
1.15 u+q
1.15 u+q oversubscribed

better
Performance: Summary

Summary:
- Chapel has achieved dramatic performance improvements this year

Next steps:
- **Multi-locale:**
  - benchmark-driven performance and scalability improvements
    - particularly for stencils, PRKs, motivating applications
- **Single-locale:**
  - vectorization
Memory Improvements
Reduction in Memory Leaks

Summary:
- We’ve closed the last major source of compiler-introduced leaks:

Next Steps:
- Close user-introduced leaks in tests themselves
Reduction in Memory Leaks

Summary:
- We’ve closed the last major source of compiler-introduced leaks:

Next Steps:
- Close user-introduced leaks in tests themselves

For further details, see Michael Ferguson’s talk after the break
Library Improvements
Library Improvements in 1.14–1.15

**New Libraries:**
- Date / Time
- Owned / Shared for delete-free class objects
- Futures
- BLAS
- MPI
- ZeroMQ
- BigInteger
- MatrixMarket
- RangeChunk
- LinearAlgebra (first draft)

**Improved Libraries:**
- FFTW
- Sort/Search
Library Improvements in 1.14–1.15

New Libraries:
- Date / Time
- Owned / Shared for delete-free class objects
- Futures
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- LinearAlgebra (first draft)

Improved Libraries:
- FFTW
- Sort/Search

(contributed by non-Cray developers)
Summary: Chapel has an increasingly capable suite of libraries

Next Steps: Continue to grow this suite
Make it simpler for users to do so as well
Support a Chapel package manager
Interoperability Improvements

- Users can now pass Chapel function pointers to C
- Extern block support is far more robust
  - Sample import of GSL routines from C:

```c
extern {
    // Special functions
    #include "gsl/gsl_sf.h"
    // Constants
    #include "gsl/gsl_const.h"
    // Integration
    #include "gsl/gsl_integration.h"
    // Random numbers and distributions
    #include "gsl/gsl_rng.h"
    #include "gsl/gsl_randist.h"
    #include "gsl/gsl_cdf.h"
    // Interpolation
    #include "gsl/gsl_interp.h"
    #include "gsl/gsl_spline.h"
}
```

- Improvements to c2chapel script (see version on master)
Documentation Improvements
Documentation Improvements

- Significant Expansions / Improvements to online docs:
Pages of Online Docs across Releases

- Pages of online documentation
Portability / Packaging Improvements
Chapel can target KNL’s MCDRAM via on-clauses

```plaintext
on here.highBandwidthMemory() {
    x = new myClass();  // placed in MCDRAM
    ...
}

on here.defaultMemory() {
    y = new myClass();  // placed in DDR
    ...
}
}

on y.locale.highBandwidthMemory() {
    z = new myClass();  // same locale as y, but using MCDRAM
    ...
}
```
Other Portability / Packaging Improvements

- AWS EC2
- Windows 10 bash shell
- Docker package now available
- ARM64 support
- Support for Chapel configuration .dotfiles
- Improved portability across various *nix flavors

**in-progress:**
- Debian
- AMD
- OFI / libfabric
Other Portability / Packaging Improvements

- AWS EC2
- Windows 10 bash shell
- Docker package now available
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- Support for Chapel configuration .dotfiles
- Improved portability across various *nix flavors

in-progress:
- Debian
- AMD
- OFI / libfabric

For further details on the AMD and OFI / libfabric efforts, see the portability talks by Mike Chu and Sung-Eun Choi before lunch
Tool Improvements
chplvis: Chapel Execution Visualization Tool

Core Improvements
Language Improvements

● Improvements:
  ● improved array semantics
  ● improved support for generic objects
  ● first-class ‘void’ type
  ● module-level de-initializers
  ● forwarding fields in objects
  ● fixed where-clause support

● In-Progress:
  ● initializers (constructor replacement)
  ● error-handling

See Preston Sahabu’s talk this morning
Domain Map Improvements

New distributions:
- Stencil distribution
- Sparse Block distribution (needs further tuning)

Domain map improvements:
- Added locality queries to distributed domains/arrays
- Simplified domain map standard interface

See early block sparse results in Ariful Azad’s talk this afternoon
Misc Improvements

- Open-sourced ‘ugni’ communication layer
- Support for stack traces on program halt()s (GSoC project)
Meta Stuff
Google Summer of Code 2017

- **Google Summer of Code**
  - Google’s way of supporting the open source community
  - Chapel had 2 successful students in GSoC 2016

**Google Summer of Code 2017:**

- **Przemyslaw Lesniak – LLVM backend**
  - Mentor: Michael Ferguson

- **Sarthak Munshi – Cryptography module**
  - Mentor: Andrea Francesco Iurio

- **Louis Jenkins - Distributed data structures**
  - Mentor: Engin Kayraklioglu

- **Nikhil Mahendran - Chapel online**
  - Mentors: Ashish Chaudhary and Ben Albrecht
Chapel on Facebook and Twitter

As though it weren’t enough that we asked him to give a keynote talk for us at CHI-UW 2017 (at IPDPS) this week, Jonathan Dursi has written a new blog post comparing and evaluating Chapel and Julia:

https://www.dursi.ca/post/julia-vs-chapel.html

Should I use Chapel or Julia for my next project?
R&D computing at scale.

The Chapel sort:

```plaintext
coforall a in A {
    sleep(a);
    writeln(a);
}
```

The Julia sort:

```plaintext
$ cat sleepsort.stdin
5 2 9 6 8 1 4 10 3 7
$ ./sleepsort < sleepsort.stdin
1
2
3
4
5
6
```
Chapel YouTube Channel

The Audacity of Chapel: Scalable Parallel Programming Done Right - Brad Chamberlain [ACCU 2017]

ACCU Conference • 99 views • 1 day ago
Programming language designers have to date largely failed the large-scale parallel computing community, and arguably even parallel programmers targeting desktops or modest-scale clusters.

CHIUW 2016 keynote: "Chapel in the (Cosmological) Wild", Nikhil Padmanabhan

Chapel Parallel Programming Language • 279 views • 10 months ago
This is Nikhil Padmanabhan's keynote talk from CHIUW 2016: the 3rd Annual Chapel Implementers and Users workshop. The slides are available at: http://chapel.cray.com/CHIUW/2016/Padmanabhan-

Chapel Productive, Multiresolution Parallel Programming | Brad Chamberlain, Cray, Inc.

ANL Training • 671 views • 7 months ago
Presented at the Argonne Training Program on Extreme-Scale Computing, Summer 2016. Slides for this presentation are available here: http://extremecomputingtraining.ornl.gov/sessions/chapel-producti...

Pycon 2016: Fast Python! Don't Bother?

PyCon UK • 4.5K views • 7 months ago
Chapel StackOverflow and GitHub Issues
The starting files for your chosen language tests are always a function called `answer` that returns `6 * 9` and a test called `life`, the universe, and everything that expects `42`.

The starting files are *unrelated* to your chosen exercise. They are simply an example to start you off.

Tests must complete in 10 seconds.
What’s Next?
Top Chapel Priorities for version 1.16

● **Wrap up key language features:**
  ● initializers
  ● error-handling
  ● delete-free class idioms (Shared, Owned)

● **Package Manager**

● **Benchmark- / App-/ User-driven...**
  …performance tuning
  …library expansions
Our #1 Challenge

- How to grow the user and developer communities?
- How to encourage people to look at Chapel again?
  - overcome impressions made in our young, awkward years…

‘Scientific computing communities are very wary of new technologies (it took 10+ years for Python to start getting any traction), with the usual, self-fulfilling, fear being “what if it goes away?”’

- Jonathan Dursi, from Should I Use Chapel or Julia for my next project?
CHIUIW 2017: Agenda (chapel.cray.com/CHIUIW2017.html)

8:30: Chapel Boot Camp (optional)
9:00: Welcome, State of the Project
9:30: Break
10:00: Talks: Chapel Design and Implementation
11:10: Quick Break
11:20: Talks: Targeting New Architectures
12:00: Lunch
1:30: Keynote Talk: Jonathan Dursi
2:30: Talks: Uses of Chapel
3:20: Break
3:50: Talks: Benchmarking and Performance
4:40: Lightning Talks and Flash Discussions
5:30: Wrap-up / Head to Dinner
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