Chapel:
An Emerging Parallel Programming Language

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Emerging Technologies, SC13

November 20th, 2013

A Call To Arms

Q: Why doesn't HPC have languages as enjoyable and productive as Python / Java / Matlab / __(your favorite language here)__?

A: We believe it's due not to any particular technical challenge, but rather to a lack of sufficient…

…long-term efforts

…resources

…community will

…co-design between developers and users

…patience

Let's change this!

What is Chapel?

- **An emerging parallel programming language**
  - Design and development led by Cray Inc.
    - in collaboration with academia, labs, industry
  - Initiated under the DARPA HPCS program

- **A work-in-progress**

- **Chapel's overall goal: Improve programmer productivity**
  - Improve the programmability of parallel computers
  - Match or beat the performance of current programming models
  - Support better portability than current programming models
  - Improve the robustness of parallel codes

Chapel's Implementation

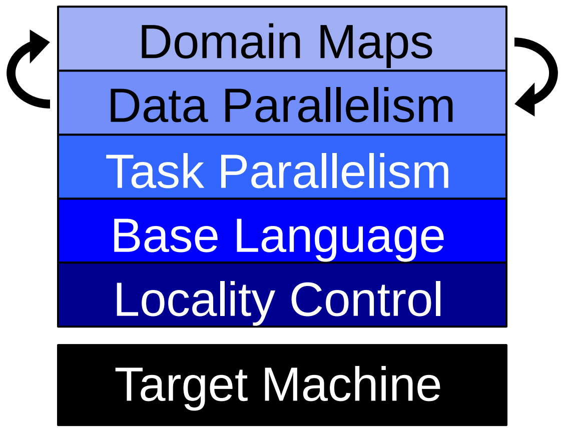
- **Being developed as open source at SourceForge**
- **Licensed as BSD software**
- **A Community Effort**
  - version 1.8 saw 19 developers from 8 organizations and 5 countries
- **Target Architectures:**
  - multicore desktops and laptops
  - commodity clusters and the cloud
  - HPC systems from Cray and other vendors
  - *in-progress:* CPU+accelerator hybrids, manycore, …

Multiresolution Design

Multiresolution Design: **Support multiple tiers of features**

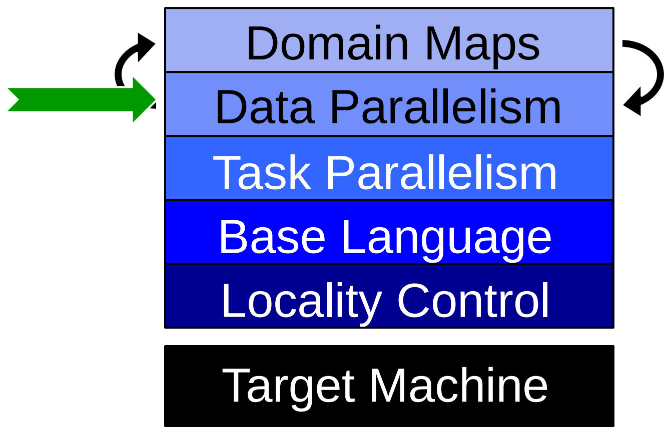
- higher levels for programmability, productivity
- lower levels for greater degrees of control

Chapel language concepts



- build the higher-level concepts in terms of the lower
- permit the user to intermix layers arbitrarily

Data Parallel Features

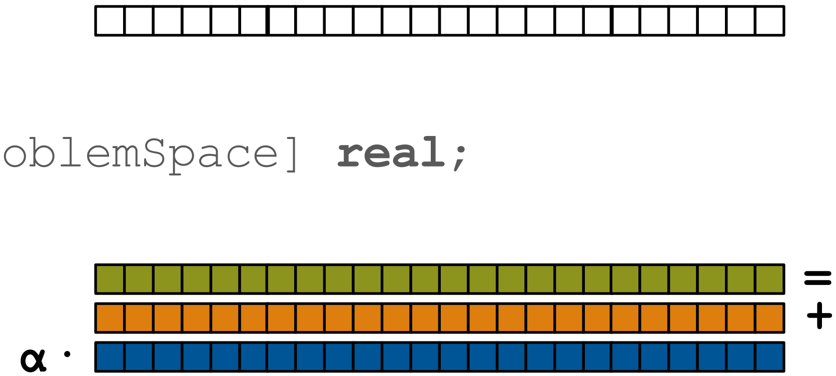


STREAM Triad in Chapel

domains
(first-class index sets)

```
const ProblemSpace = {1..m};
```

```
var A, B, C: [ProblemSpace] real;
```

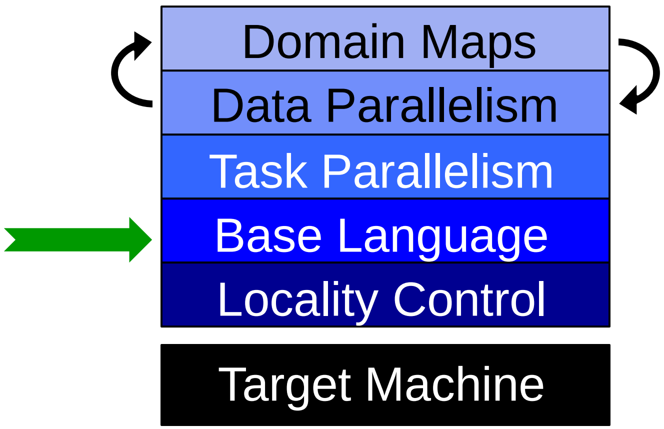



```
A = B + alpha * C;
```

promoted scalar operators

…and much more…

Base Language Features



Tiled Row-Major Order Iterator

CLU-style iterators

inferred types

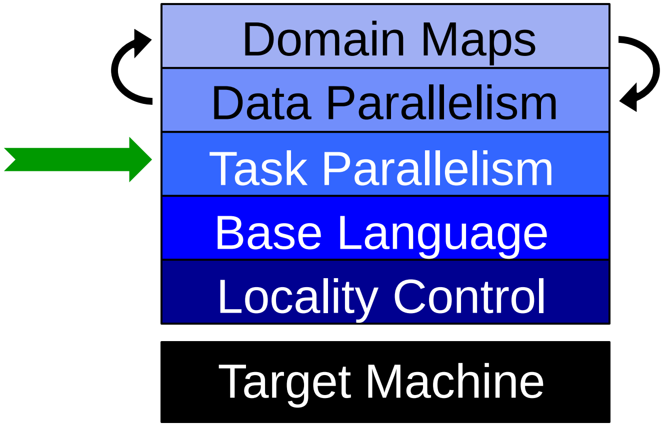
algebra on domains (index sets)

```
iter tiledRMO(D, tilesize) {
  const tile = {0..#tilesize, 0..#tilesize};

  for base in D by tilesize do
    for ij in D[tile + base] do
      yield ij;
}


for ij in tiledRMO({1..m, 1..n}, 2) do
  write(ij);
```

Prints:

```
(1,1)(1,2)(2,1)(2,2)(1,3)(1,4)(2,3)(2,4)…
(3,1)(3,2)(4,1)(4,2)(3,3)(3,4)(4,3)(4,4)…
```

Task Parallel Features



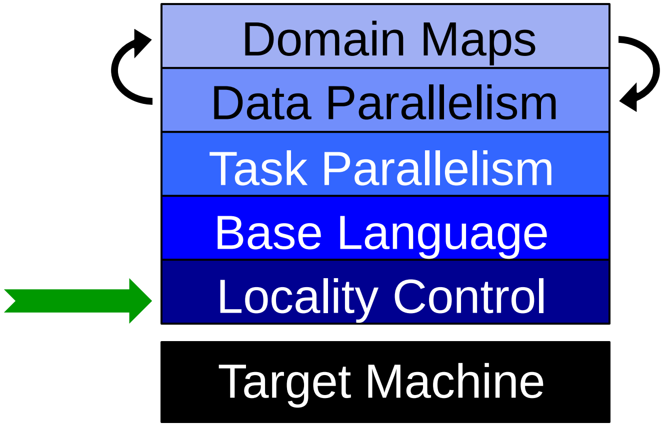
Coforall Loops

```
coforall t in 0..#numTasks {
  writeln("Hello from task ", t, " of ", numTasks);
} // implicit join of the numTasks tasks here

writeln("All tasks done");
```

Sample output:

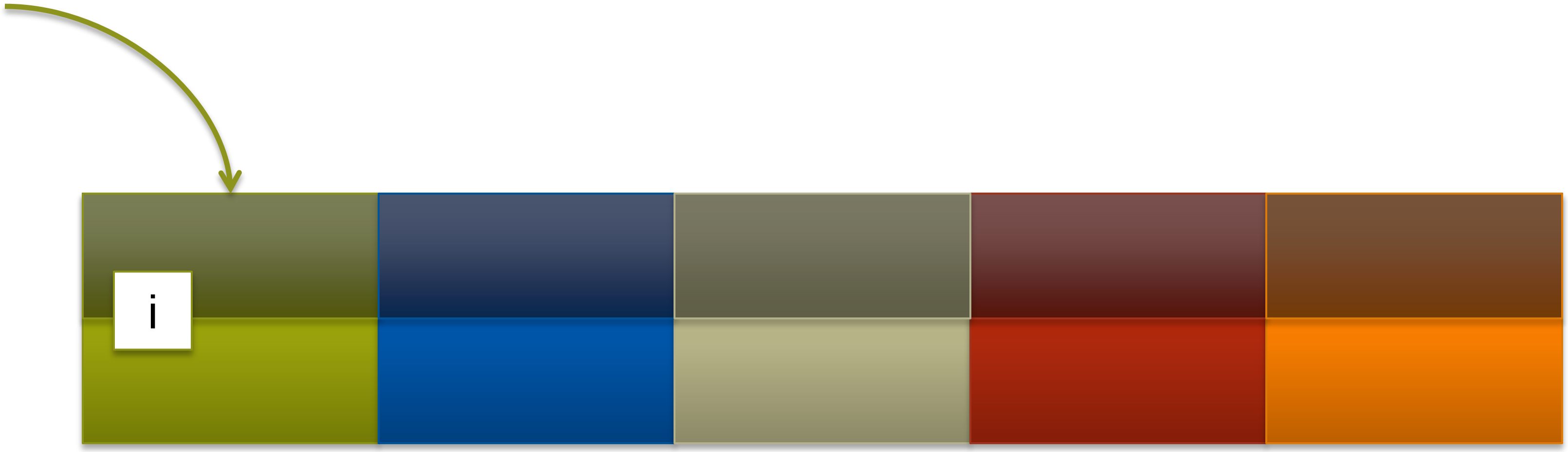
```
Hello from task 2 of 4
Hello from task 0 of 4
Hello from task 3 of 4
Hello from task 1 of 4
All tasks done
```

Locality Control Features



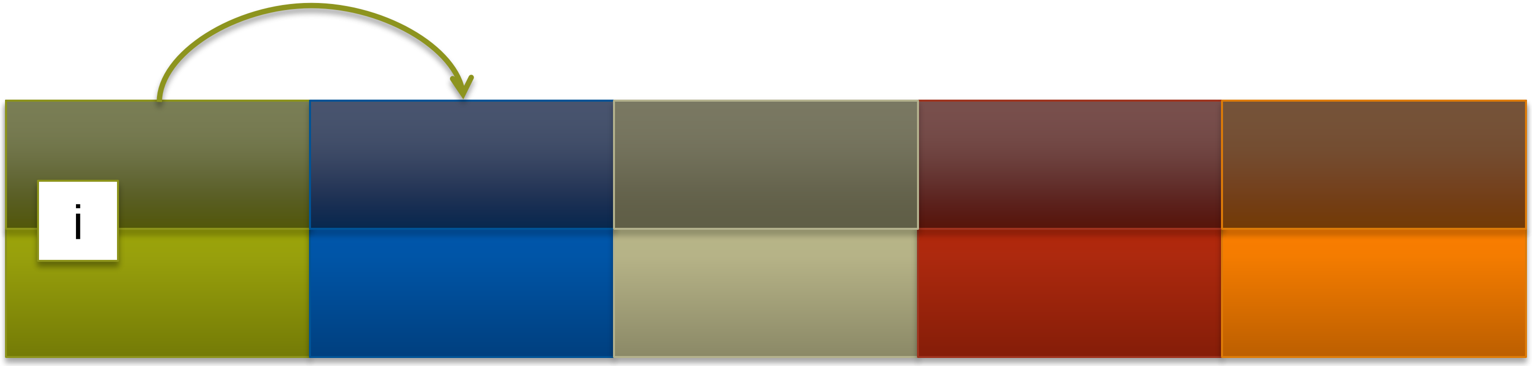
Chapel: Scoping and Locality

```
var i: int;
```



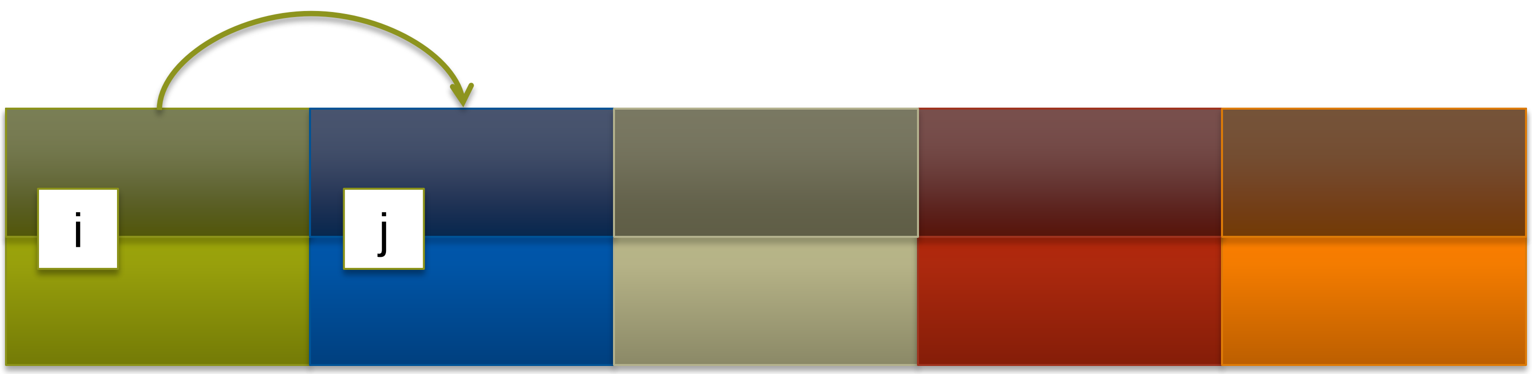
Chapel: Scoping and Locality

```
var i: int;
on Locales[1] {
```



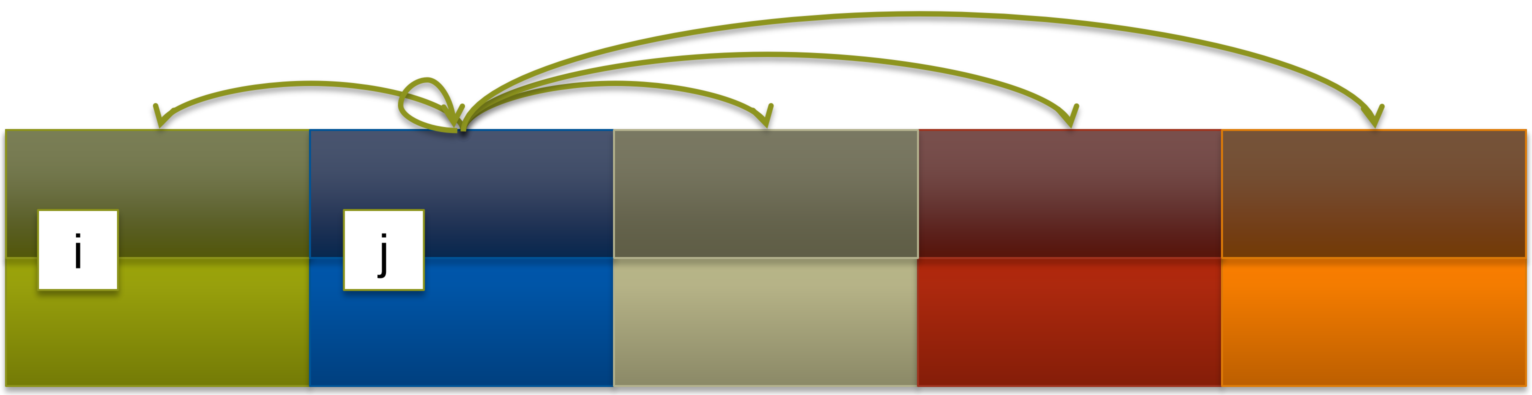
Chapel: Scoping and Locality

```
var i: int;
on Locales[1] {
  var j: int;
```



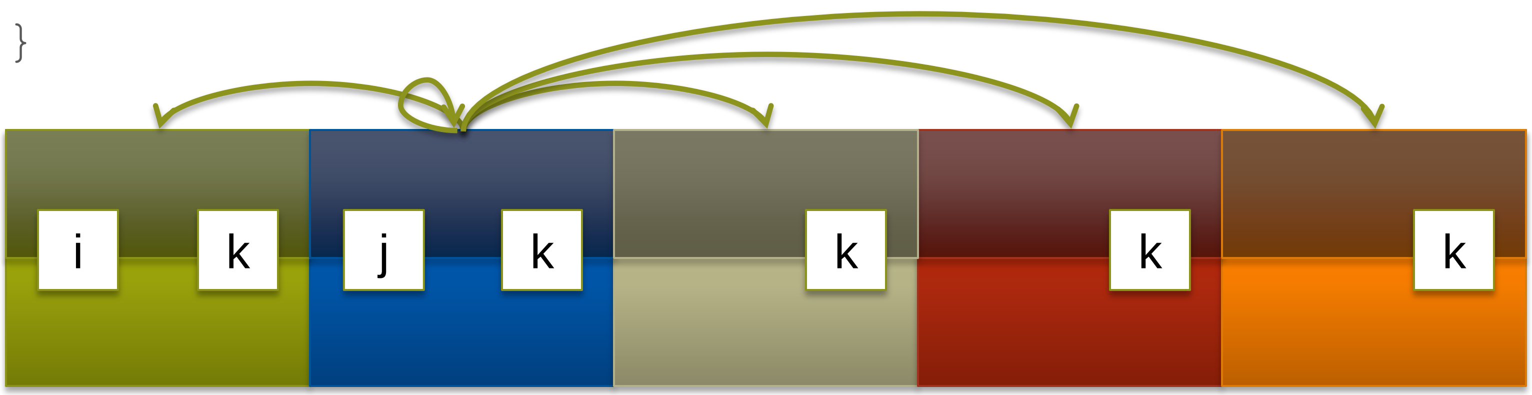
Chapel: Scoping and Locality

```
var i: int;
on Locales[1] {
  var j: int;
  coforall loc in Locales {
    on loc {
```

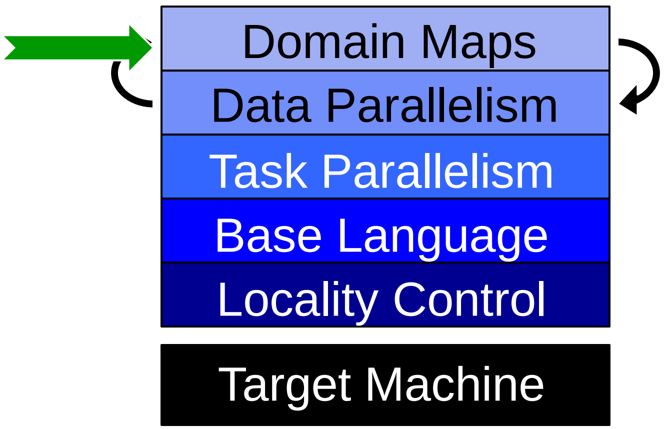


Chapel: Scoping and Locality

```
var i: int;
on Locales[1] {
  var j: int;
  coforall loc in Locales {
    on loc {
      var k: int;

      // within this scope, i,j,k can be referenced;
      // the implementation manages the communication
    }
  }
}
```

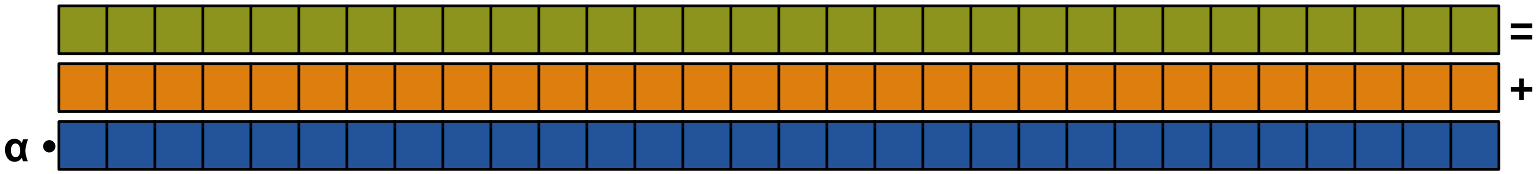


Domain Map Features



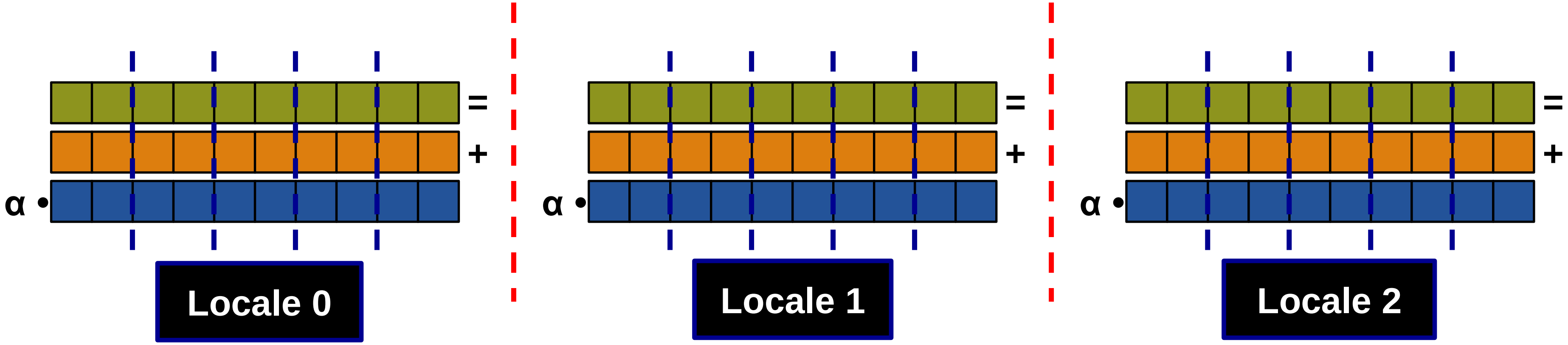
Domain Maps

Domain maps are “recipes” that instruct the compiler how to map the global view of a computation…



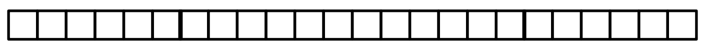

```
A = B + alpha * C;
```

…to the target locales’ memory and processors:

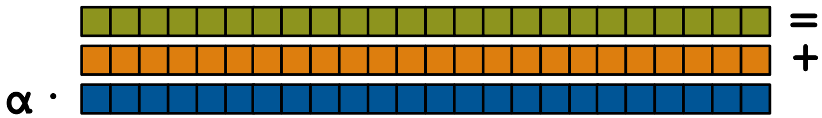


STREAM Triad: Chapel

```
const ProblemSpace = {1..m};
```



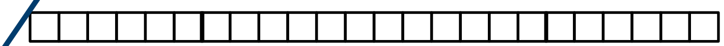
```
var A, B, C: [ProblemSpace] real;
```




```
A = B + alpha * C;
```

STREAM Triad: Chapel (multicore)

```
const ProblemSpace = {1..m};
```



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var A, B, C: [ProblemSpace] real;
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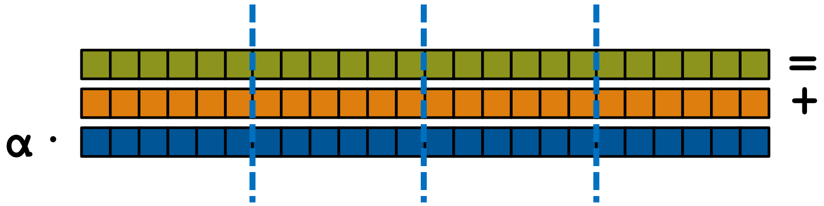
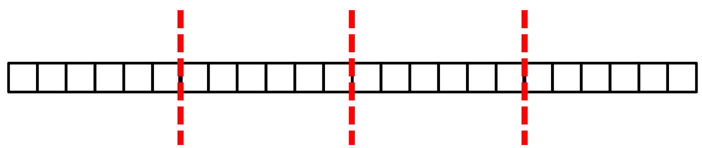



```
A = B + alpha * C;
```

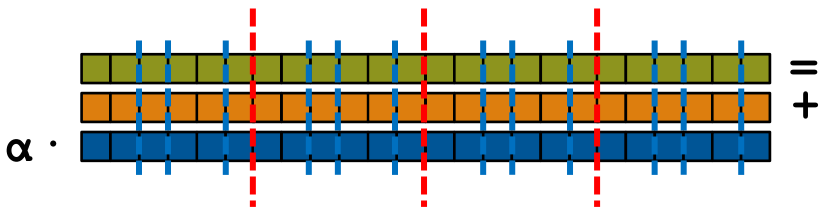
No domain map specified => use default layout
- current locale owns all indices and values
- computation will execute using local processors only

STREAM Triad: Chapel (multilocale, blocked)

```
const ProblemSpace = {1..m}
                     dmapped Block(boundingBox={1..m});
```



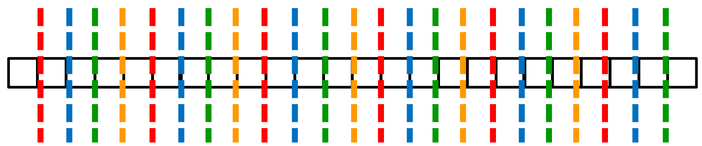
```
var A, B, C: [ProblemSpace] real;
```



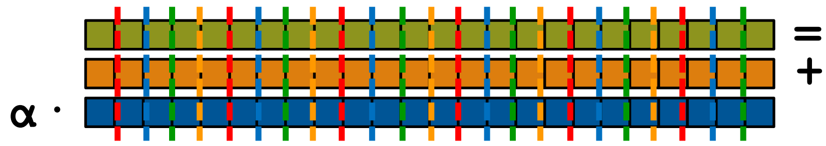

```
A = B + alpha * C;
```

STREAM Triad: Chapel (multilocale, cyclic)

```
const ProblemSpace = {1..m}
                        dmapped Cyclic(startIdx=1);
```



```
var A, B, C: [ProblemSpace] real;
```

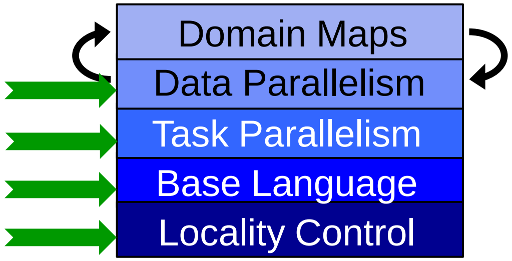



```
A = B + alpha * C;
```

Chapel's Domain Map Philosophy

1. **Chapel provides a library of standard domain maps**
   - to support common array implementations effortlessly

2. **Advanced users can write their own domain maps in Chapel**
   - to cope with shortcomings in our standard library



3. **Chapel's standard domain maps are written using the same end-user framework**
   - to avoid a performance cliff between "built-in" and user-defined cases

Implementation Status -- Version 1.8.0 (Oct 2013)

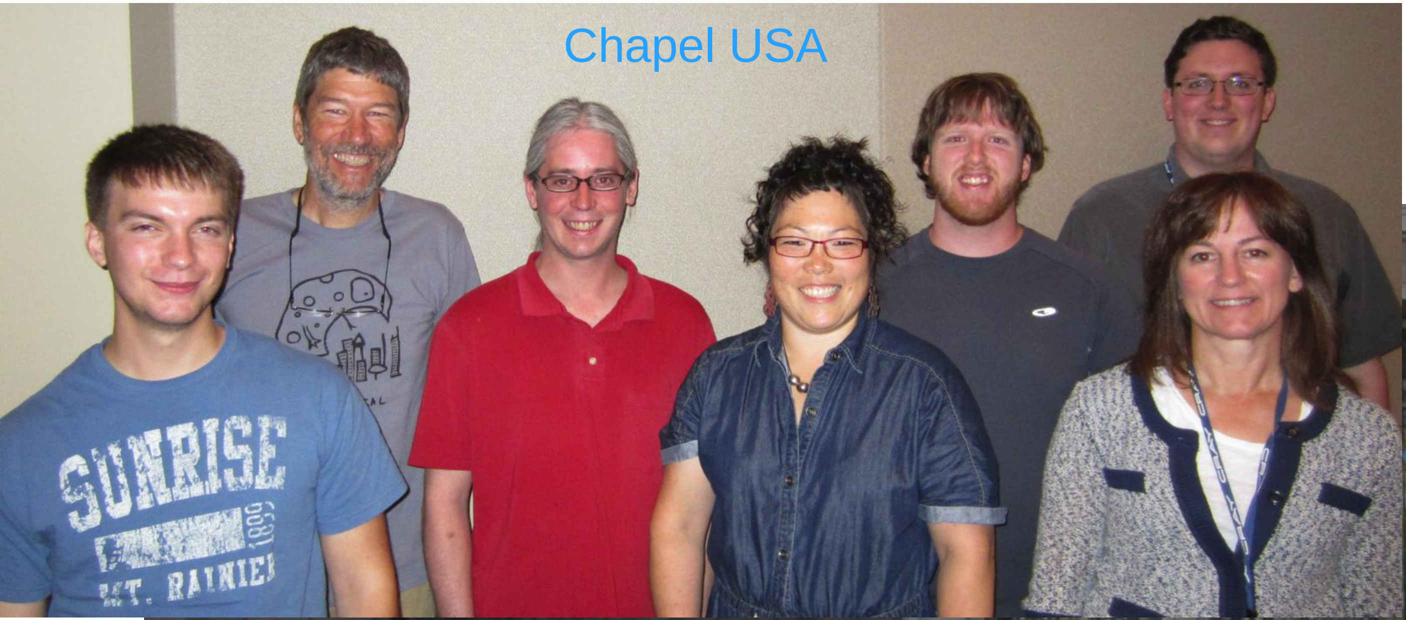
Overall Status:

- Most features work at a functional level
  - some features need to be improved or re-implemented (e.g., OOP)
- Many performance optimizations remain
  - particularly for distributed memory (multi-locale) execution

This is a good time to:

- Try out the language and compiler
- Use Chapel for non-performance-critical projects
- Give us feedback to improve Chapel
- Use Chapel for parallel programming education

The Cray Chapel Team (Summer 2013)



Chapel…

…is a collaborative effort — join us!

Chapel: the next five years

- **Harden Prototype to Production-grade**
  - Performance optimizations
  - Add/Improve features that are lacking
- **Target more complex/modern compute node types**
  - e.g., CPU+GPU, Intel MIC, …
- **Continue to grow the user and developer communities**
  - Including nontraditional circles: desktop parallelism, "big data"
  - Transition Chapel from Cray-controlled to community-governed
- **Grow the team at Cray**
  - we've just hired four new developers
  - we're currently hiring for a manager position

Chapel at SC13

- **Emerging Technologies Booth** (tomorrow)
  - Booth #3547: staffed by Chapel team members; poster and handouts
- **Poster** (Tues @ 5:15)**:** *Towards Co-Evolution of Auto-Tuning and Parallel Languages*
  - Posters Session: Ray Chen (University of Maryland)
- **Talk** (Tues @ 3:20): *Hierarchical Locales: Exposing the Node Architecture in Chapel*
  - KISTI booth (#3713): Sung-Eun Choi (Cray Inc.)
- **Chapel Lightning Talks BoF** (Wed @ 12:15)
  - 5-minute talks on education, MPI-3, Big Data, Autotuning, Futures, MiniMD
- ➢ **Talk** (Wed @ 4:30)**:** *Chapel, an Emerging Parallel Language*
  - HPC Impact Theatre (booth #3947): Brad Chamberlain (Cray Inc.)
- **Happy Hour** (Wed @ 5pm): *4th annual Chapel Users Group (CHUG) Happy Hour*
  - Pi Bar (just across the street at 1400 Welton St): open to public, dutch treat
- **HPC Education** (Thus @ 1:30pm): *High-Level Parallel Programming Using Chapel*
  - David Bunde (Knox College) and Kyle Burke (Colby College)

For More Information: Online Resources

Chapel project page: http://chapel.cray.com

- overview, papers, presentations, language spec, …

Chapel SourceForge page: https://sourceforge.net/projects/chapel/

- release downloads, public mailing lists, code repository, …

Mailing Aliases:

- chapel_info@cray.com: contact the team at Cray
- chapel-announce@lists.sourceforge.net: announcement list
- chapel-users@lists.sourceforge.net: user-oriented discussion list
- chapel-developers@lists.sourceforge.net: developer discussion
- chapel-education@lists.sourceforge.net: educator discussion
- chapel-bugs@lists.sourceforge.net: public bug forum

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