Visibility Control:

Use and Import Statement Improvements

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Outline

- Introduction
- Transitivity
- Correctness and Compilation Speed
- Renaming
- Qualified Access and ‘import’
- What’s Next?

Introduction

Introduction

- The Chapel team at Cray/HPE is working towards Chapel 2.0
    - This means determining which language features are likely to be stable

- ‘use’ statements have been part of the language for a long time
    - Enable symbols in one module to be visible in another module
        - Either with *unqualified* access (no module prefix)…

          … or *qualified* access (with the module prefix)

```
use M;
writeln(x);     // prints the value of M.x
writeln(M.y);   // prints the value of M.y
```

Introduction

- Chapel 1.12 / 1.13 improved support for privacy and namespace control, e.g.
  - Added ‘public’ and ‘private’ designators for symbols
  - Added ‘only’ and ‘except’ clauses to ‘use’ statements
    - These limit the symbols brought in for unqualified access
  - These changes were presented at CHUIW 2016

- But we also had several extensions and changes planned that weren’t done
  - Some of these changes would break backwards compatibility

- This talk will cover recent changes, as well as some forward-looking features

Transitivity

Transitivity

- To motivate some of these changes to ‘use’, we need to talk about transitivity
  - Prior to Chapel 1.20, ‘use’ statements were always ‘public’
  - This meant that symbols brought in were made more broadly available

```
module B { use A; … }
module C {
  …
  proc bar() {
    use B;
    writeln(x); // ‘x’ is defined by module ‘A’, but ‘C’ didn’t ‘use A’ itself
  }
}
```

Transitivity

- This was a problem
  - Required increased care when naming symbols…

```
module B { use A; … }
module C {
  var x = 3;
  proc bar(){
    use B;
    writeln(x); // ‘x’ is defined by module ‘A’, so this won’t necessarily print 3!
  }
}
```

Transitivity

- This was a problem
  - Could lead to hijacking if a library you rely on changed its underlying definition
    - Or what modules it relied upon…
    - Or even if modules it relied upon changed!

  - Could also lead to compilation errors when the symbols would conflict

  - Meant that users might rely on implementation details
    - Good language design should give library writers control over what is seen

Transitivity

- Could work around this by limiting the scope of the ‘use’ statement
  - E.g. by putting the ‘use’ inside a function body:

```
module B {
  proc foo() {
    use A;
  }
}
```

  - But this wasn’t always feasible
    - If module is integral to your program, will dramatically increase # of ‘use’s
    - If you need the module due to an argument type, you are out of luck

Transitivity

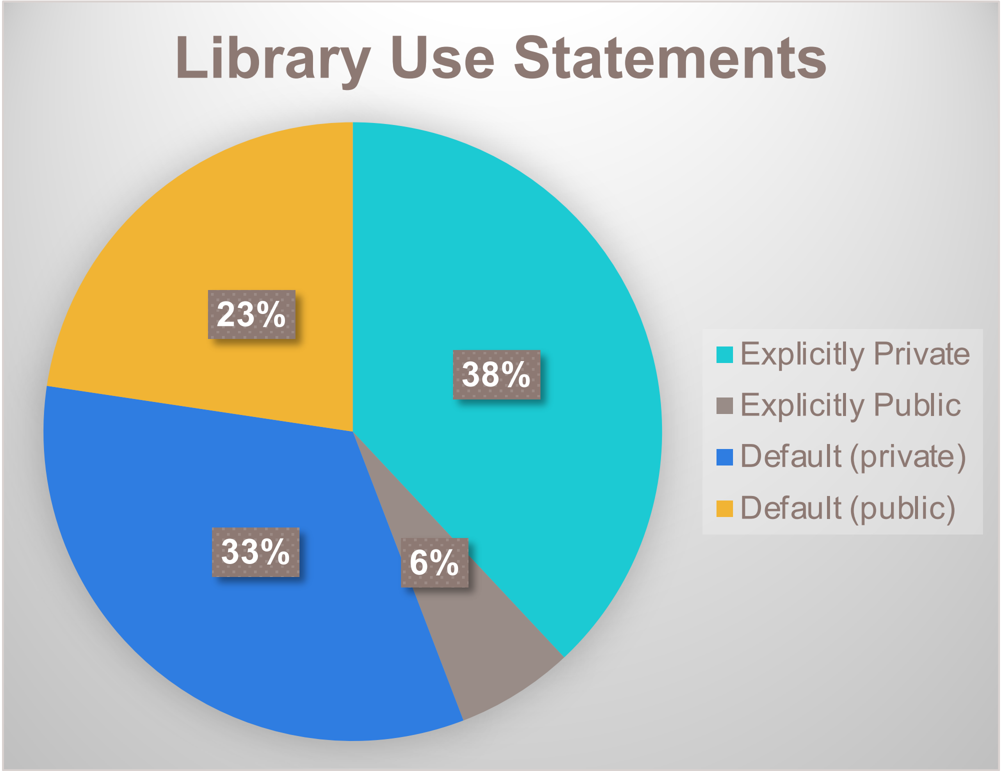
- We added ‘public’ and ‘private’ specifiers to ‘use’ statements

```
private use A;
```

  - This allows library writers to intentionally choose which ‘use’s are visible
  - We also switched the default to ‘private’
    - This could result in some broken code, but the fixes should be simple
    - And default code will be safer going forward

Transitivity: Impact on Libraries

- All default ‘use’ statements in the standard and package libraries are now ‘private’
- All default ‘use’ statements in the internal libraries are still ‘public’
  - Want to make some of these ‘private’, too, but it’s not trivial
- Many ‘use’ statements are now either explicitly ‘public’ or ‘private’



Transitivity: Impact on Libraries

- As a result, some modules are no longer available by default to user programs
  - RangeChunk, SysCTypes, CommDiagnostics now require an explicit ‘use’
    - Some of these were accidentally included before (e.g. CommDiagnostics)
    - Others we knew had been getting included, but didn’t want to still do so
  - These modules were not used in the common case
    - So not including them by default makes sense

Transitivity: Impact on Libraries

- And default-included symbols no longer take precedence over outer-scoped
  - Here’s an example of when that was a problem:

```
var e = 17;
{
  use Mod;
  // Used to print Math.e because of the default ‘public use’ of Math by Mod
  // Now, the default ‘use’ is ‘private’, so it prints ‘17’
  writeln(e);
}
```

Transitivity

- Transitive ‘use’ statements are powerful, but often have broad consequences
- Giving users control over the transitivity of their ‘use’ statements is valuable
  - Users have better knowledge of what is appropriate for their code

- Changing the default transitivity makes code safer
  - Users must actively choose to make a ‘use’ transitive
  - Therefore, they are more likely to understand what doing so means

- And limiting the transitivity of library ‘use’s improves the user experience
  - It reduces the potential for namespace confusion

Correctness and Compilation Speed

Or:
Why Is My Compilation Slower? An Apology

Correctness and Compilation Speed

- Function resolution in the compiler had an “optimization”, standardModuleSet
  - Had been in the compiler since the Dawn of Time*
  - Basically, treated every module used by default as though it was in one scope
  - This made it easy to resolve default symbols
    - Too easy…

*The compiler has not been around since the Dawn of Time

Correctness and Compilation Speed

- This “optimization” assumed everything was visible everywhere
  - As a result, some internal modules were accessing modules they didn’t use
    - And that weren’t transitively available to them, either:

```
module ChapelBase {
  // needed ‘private use ChapelEnv;’ to access ‘CHPL_NETWORK_ATOMICS’
  …
  config param useAtomicTaskCnt =
                CHPL_NETWORK_ATOMICS != "none";
}
```

  - There were many other examples of bad behavior enabled by it

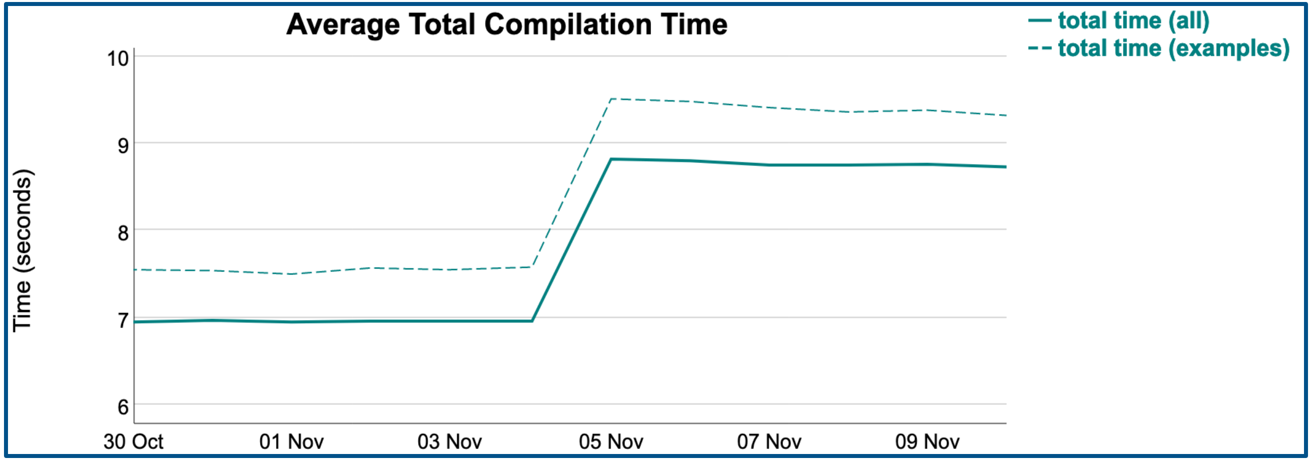
Correctness and Compilation Speed

- There wasn’t a way to reconcile this “optimization” and ‘private’ at all
  - ‘private’ depends on the module hierarchy being maintained
    - Both for ‘private use’ and ‘private’ symbols
  - standardModuleSet removes that hierarchy entirely

- It enabled a lot of bugs
- And made the internal modules harder to maintain as a result

Correctness and Compilation Speed

- So we removed the standardModuleSet …

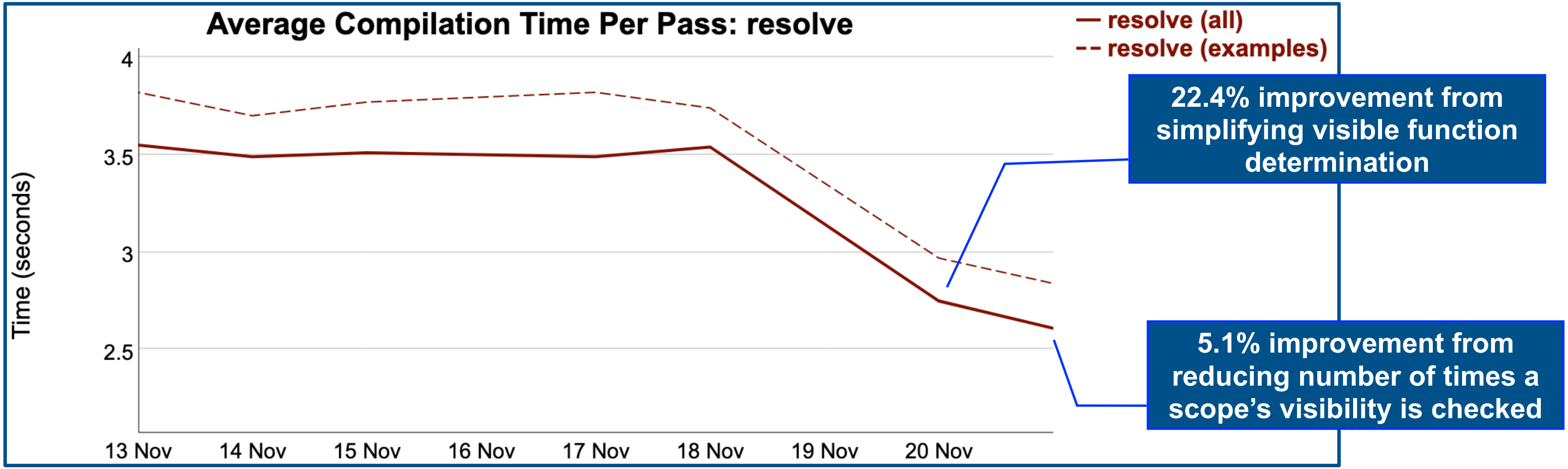


… resulting in an average slowdown of 26.7% for our testing suite as a whole …

… and roughly 37% for arkouda!

Correctness and Compilation Speed

- Still, removing the “optimization” was the right thing to do
- So we set about looking at ways to mitigate this impact
  - Mostly by improving parts of function resolution



22.4% improvement from simplifying visible function determination

5.1% improvement from reducing number of times a scope’s visibility is checked

Correctness and Compilation Speed

- Ultimately, compilation is still slower than it was
  - But most of the impact from this change has been recovered
  - We're hoping to work more on compilation in this release cycle
- The default libraries are more accurate and less tangled than they were before
  - Though work still needs to be done to disentangle them further

Renaming

Renaming

- ‘use’ statements can limit the symbols brought in to ‘only’ specific symbols

```
use Mod only veryLongName;
```

- When ‘only’ lists were added, they also enabled symbol renaming

```
use Mod only veryLongName as vln;
writeln(vln);  // Prints value of ‘Mod.veryLongName’
```

- This allowed users to avoid:
  - conflicts with symbols brought in from other modules,
  - shadowing symbols at outer scopes that share the same name,
  - and having to type long descriptive names repeatedly.

Renaming

- As a side effect, we could rename submodules when using their parent module

```
        use Mod only InnerMod as IM;
```

- We decided to extend this to enable renaming when the module itself is used…

```
        use Mod.InnerMod as IM;
```

… which allowed top-level modules to be renamed for the first time

```
        use Mod as M;
```

Qualified Access and ‘import’

Import Statements

- ‘use’ statements have been imprecise
  - Default behavior brought every visible symbol into scope
    - However, could limit the symbols brought in with ‘except’ and ‘only’ lists
  - Design focused on “programming in the small” scenarios

- Users desired a feature for more precise access of module symbols
  - One better suited for maintaining large-scale software
  - Ideally, without breaking current code

Import Statements: This Effort

- We designed and implemented the ‘import’ statement as an alternative to ‘use’
  - Simplest form enables qualified access to the symbols in a module:

```
import MyModule;
writeln(MyModule.sym1); // Enabled by the ‘import’
writeln(sym1);          // Not enabled, won’t work
```

  - This was previously only achievable with “empty” ‘use’ statements, e.g.

```
use MyModule only;
use MyModule except *;
```

Import Statements: Accessing Module Contents

- Can also enable unqualified access to a single symbol within a module:

```
import MyModule.sym1;
writeln(sym1);             // Enabled by the 'import'
writeln(MyModule.sym1);    // Not enabled by the 'import'
```

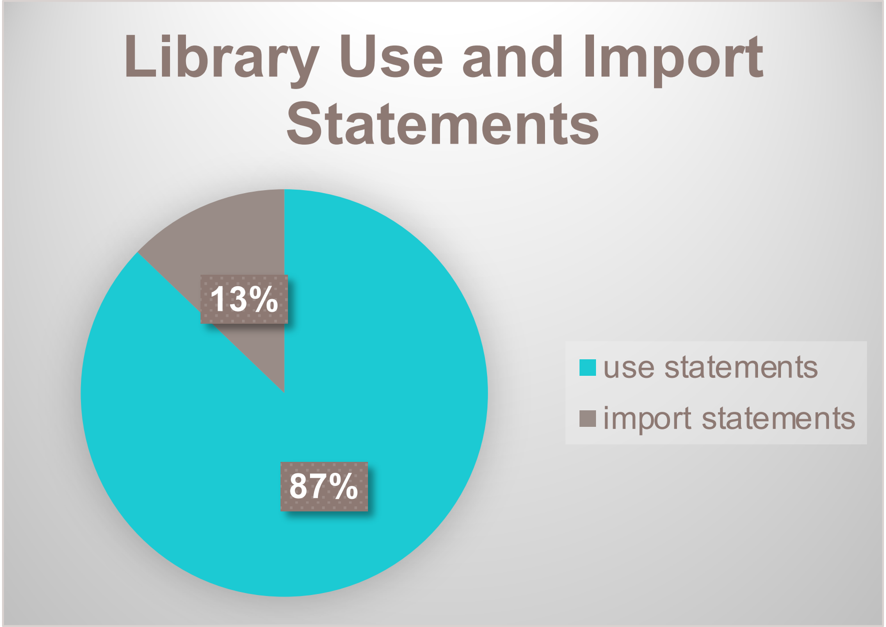
- Or multiple symbols within a module:

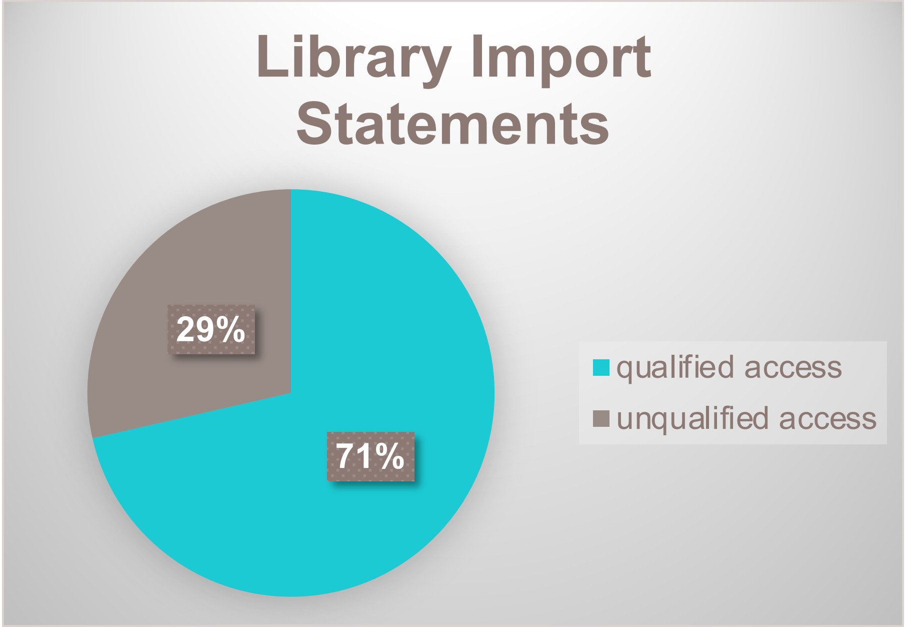
```
import MyModule.{sym1, sym2, sym3};
```

- Neither of these options was available previously
  - 'use' statements always enabled qualified access in addition to unqualified

Import Statements: Impact on Libraries

- We replaced all “empty” ‘use’ statements in the libraries with ‘import’ statements
- And are starting to use other variants, too





Import Statements: Renaming

- Modules that are imported can be renamed:

```
import MyModule as Foo;
writeln(Foo.sym1);         // Enabled by the ‘import’
writeln(sym1);             // Not enabled by the ‘import’
writeln(MyModule.sym1);    // Not enabled by the ‘import’
```

- As can symbols that are imported for unqualified access:

```
import MyModule.sym1 as x;  // or:
import MyModule.{sym1 as x, sym2 as y};
```

Import Statements: Nested Modules

- Nested modules must be named using their parent modules…

```
module OuterMod {
  import InnerMod;                // error: looks for top-level module 'InnerMod'
  import OuterMod.InnerMod;       // OK: names module starting from top-level
  writeln(InnerMod1.sym1);
  module InnerMod { var sym1 = …; }
}
```

- Unlike ‘use’ statements, ‘import’ statements can’t use relative naming
  - E.g. ‘OuterMod’ can’t just write ‘import InnerMod;’

Import Statements: Nested Modules

- Nested modules can be named directly in certain circumstances:
  - E.g. after being made available by another ‘import’ or ‘use’

```
use OuterMod;        // makes ‘OuterMod’s symbols available
import InnerMod;     // ‘InnerMod’ visible due to ‘use OuterMod’
```

- Both ‘use’ and ‘import’ can shorten the path with ‘this’ if within a parent module…

```
module OuterMod {
  module InnerMod { … }
  import this.InnerMod; // Enabled by being within ‘OuterMod’
}
```

Import Statements: Nested Modules

- Nested modules can also be imported using ‘super’ if within a sibling module
  - Like ‘this’, ‘super’ also works for ‘use’ statements

```
module OuterMod {
  module InnerMod { … }
  module SiblingMod {
    // Enabled by being within OuterMod.SiblingMod
    import super.InnerMod;
  }
}
```

Import Statements: Nested Modules

- Using ‘this’/‘super’ makes ‘use’ and ‘import’ safer than using relative names
  - Origin of relatively used modules is much more obvious to the reader

  - This style of ‘use’ makes code more robust to later changes
    - If dependency defines another module with same name, won’t conflict

Import Statements: Public / Private

- ‘import’ statements can be declared ‘public’ or ‘private’
  - Default is ‘private’
    - as with ‘use’, reduces unintentional leaking of names
  - ‘public’ means symbols brought in are *re-exported*

```
module Mod {
  public import OtherMod;
}
module ThirdMod {
  import Mod.OtherMod; // ‘OtherMod’ acts like a submodule of ‘Mod’
}
```

Import Statements: Impact

- The ‘import’ statement supports module access in a more precise manner
  - Its default behavior minimally extends the scope

- It also enables new functionality:
  - Can re-export symbols
  - Can bring symbols in for unqualified access without enabling qualified access

What’s Next?

What’s Next?

- Extend ‘import’ to support multiple expressions in a single statement

```
import Mod1.{a, b}, Mod2.{x, y}; // Should this be allowed?
```

  - See issue #14971 and #15583

- Enable re-exporting for ‘use’ statements
  - See issue #15282

- Implement ability to ‘use’ module and disable qualified access (issue #15457)

```
use Mod as _;
writeln(Mod.x); // Wouldn’t work, not enabled by this ‘use’
writeln(x);     // Would still work, enabled by this ‘use’
```

What’s Next?

- Design story for ‘private’ fields/methods and types
  - See issue #6067

- Continue reviewing the set of symbols made available by default

- Continue improving ‘use’ statements within internal modules

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