Hewlett Packard
Enterprise

CHAPEL 1.27.0/1.28.0 RELEASE NOTES: ONGOING EFFORTS—DYNO UPDATES

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DYNO UPDATES OUTLINE

- Introduction and Motivation
- Separate Compilation
- Parsing to uAST
- Scope Resolution
- Resolving Types and Calls
- Dyno-chpldoc
- Performance
- Goals

INTRODUCTION AND MOTIVATION

COMPILER REWORK EFFORT

- *dyno* is an ongoing effort to address problems with the Chapel compiler
- Focused on improving:
  - Speed
  - Error messages
  - Compiler structure and program representation
  - Compiler development

- Recent work has focused on:
  - Creating a documented compiler library suitable for use in the compiler and other tools
  - Rewriting ‘chpldoc’ to use this new compiler library
  - Replacing the early compilation passes with incremental versions
  - Adding features to the incremental resolver

PROBLEMS FACED BY THE CHAPEL COMPILER

Speed:

- The current compiler is generally slow, and extremely so for large programs (~7s to 15 minutes)
- Large programs require complete recompilation whenever a change is made

Errors:

- For incorrect programs, the compiler frequently displays only some of the errors at a time
- Compilation errors can be hard for users to understand and address

Structure and Program Representation:

- The compiler is structured only for whole-program analysis, preventing separate/incremental compilation
- Unclear how to integrate an interpreter, provide IDE support, or ‘eval’ Chapel snippets
- Compilation passes are highly coupled

Development:

- The modularity of the compiler implementation needs improvement
- There is a steep learning curve to become familiar with the compiler implementation

COMPILER REWORK DELIVERABLES

Incremental Compilation Front-end

- Only re-parse and do type resolution on files that were edited
  - Could result in reducing compilation time
- Will still have the whole-program optimization and code-generation back-end

Separate Compilation

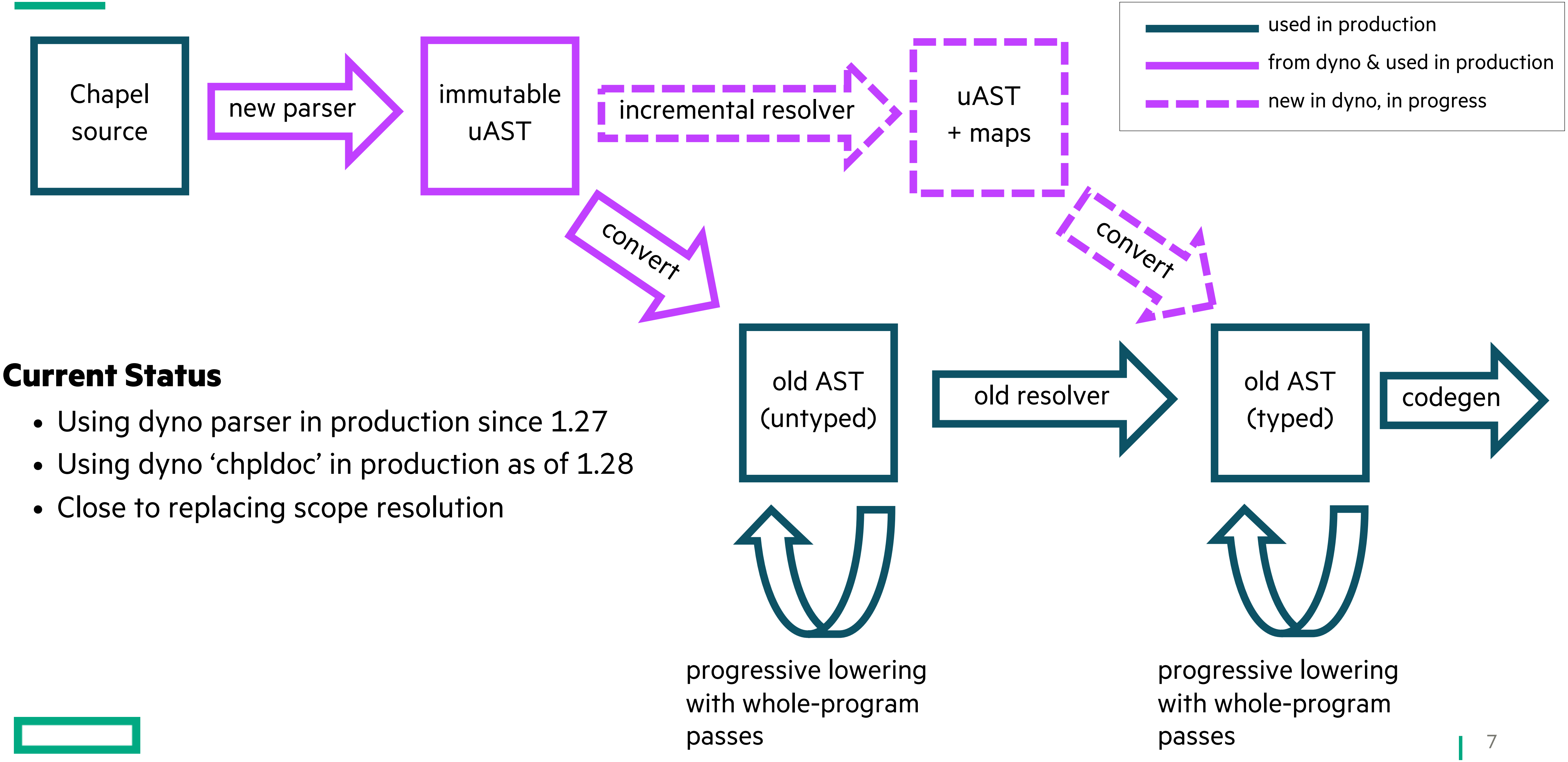
- Make most of the whole-program optimization happen per-file
- Will need a linking step for optimizations like function inlining that span files
- Should result in significantly faster compilation times

Dynamic Compilation and Evaluation

- Enable Chapel code snippets to be written and run interactively
  - e.g., in Jupyter notebooks

Throughout the effort, working towards improving the learning curve and error messages.

COMPILER REWORK STATUS



Chapel source

new parser

immutable uAST

incremental resolver

uAST + maps

convert

convert

old AST (untyped)

old resolver

old AST (typed)

codegen

progressive lowering with whole-program passes

progressive lowering with whole-program passes

▬	used in production
▬	from dyno & used in production
╍	new in dyno, in progress

Current Status

- Using dyno parser in production since 1.27
- Using dyno ‘chpldoc’ in production as of 1.28
- Close to replacing scope resolution

SEPARATE COMPILATION

SEPARATE COMPILATION: BACKGROUND

- We would like to support separate compilation
  - Challenging because there are generic functions and no equivalent to C++ header files
  - Compiled libraries will store AST or source code for generic functions in case new instantiations are needed
- In a separate compilation scenario, both *compile* and *link* steps need a more flexible pass structure
  - *compile*: need to be able to compile a library without also re-compiling all dependencies
  - *link*: do not want to go through entire compilation process
    - rather, *link* should be limited to:
      - instantiating generics as necessary
      - connecting invocations of concrete functions to their implementations
- Neither of these are possible with the current rigid whole-program pass structure
  - Each pass is run in turn on the entire AST
  - Passes make whole-program assumptions and modify global variables

SEPARATE COMPILATION: NEXT STEPS

- Develop a prototype file format for a Chapel library
  - Requires serialized uAST to instantiate new calls
  - Need to discuss a suitable file extension

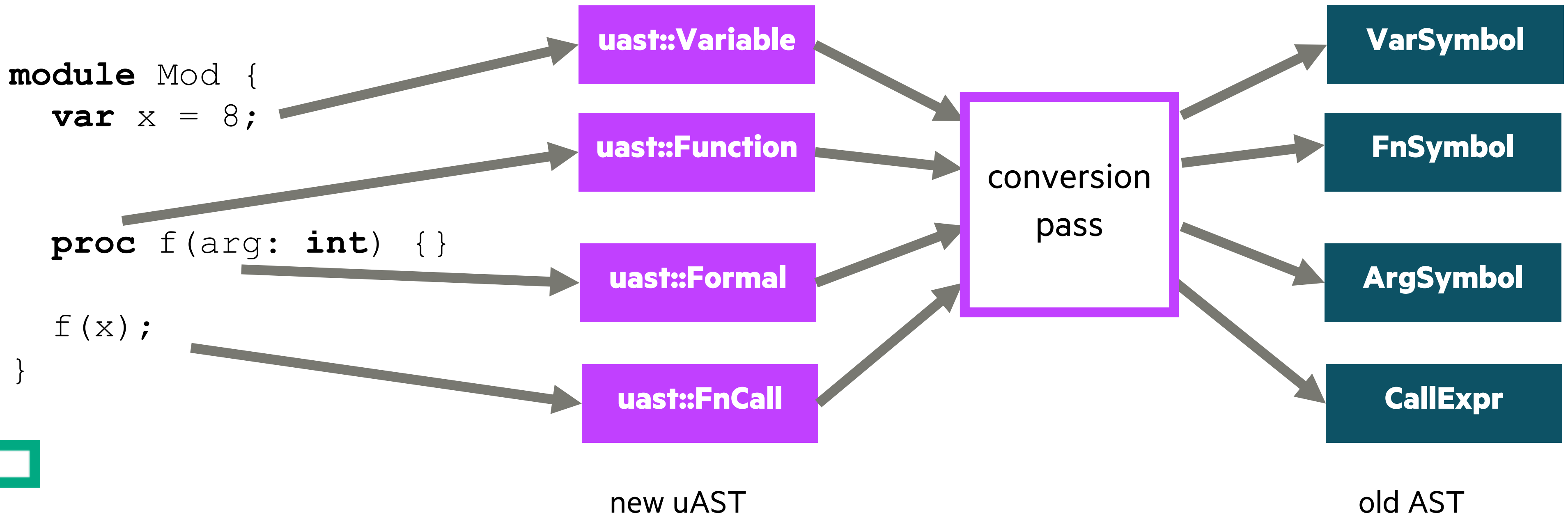
- Update ‘chpl’ to produce this new file format as a library file
  - Initially, produce a very simple table of symbols and uAST
  - Eventually, begin to cache information in this file, such as resolved functions and types

- Update ‘chpl’ to read this new file format
  - Initially, substitute a Chapel library file for a ‘.chpl’ file to skip the parsing stage
    - In this way, early prototypes will provide support similar to precompiled headers in C/C++
  - Then, begin exploring how to leverage cached information to skip steps of compilation

PARSING TO UAST

PARSING

- *Parsing* is the process of reading source code and generating an abstract syntax tree (AST)
- Since 1.27, 'chpl' uses the new dyno parser that generates uAST from source code
  - uAST (untyped AST) is more faithful to the source code than the old AST
- A new pass in the compiler translates uAST to the old AST
- The old parser has been removed in 1.28 to reduce maintenance



```
module Mod {
  var x = 8;


  proc f(arg: int) {}

  f(x);
}
```

SCOPE RESOLUTION

SCOPE RESOLUTION: BACKGROUND

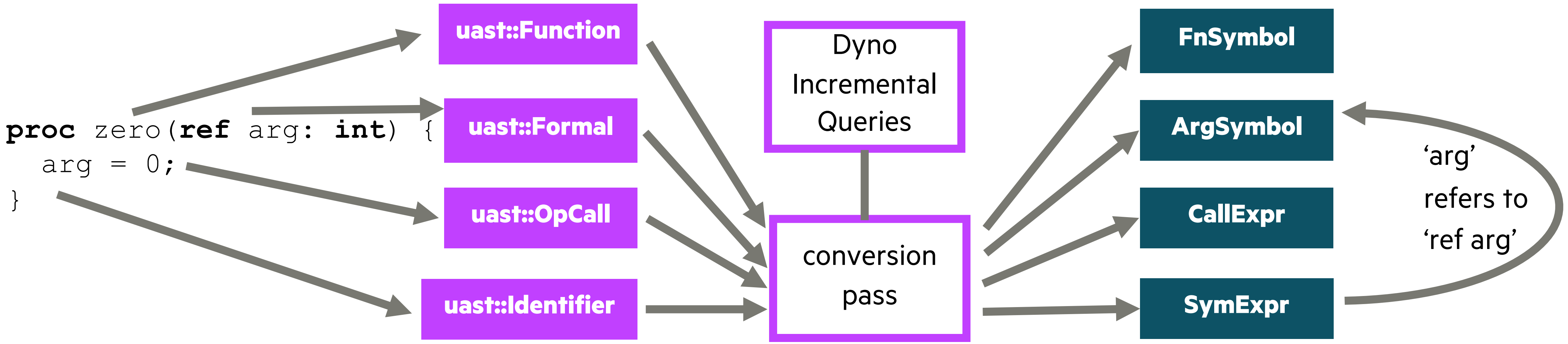
- *Scope resolution* is the process of matching identifiers with declared symbols
  - That is, the process of recognizing that, in ‘arg = 0’ below, ‘arg’ refers to ‘ref arg: int’

```
proc zero(ref arg: int) {
  arg = 0;
}
```

- In 1.26, dyno scope resolution support was:
  - inextricable from type resolution
    - Ultimately the model we will pursue long-term, but not ideal for incremental progress
    - No way to use scope resolution results elsewhere, like the old compiler
  - minimal
    - Basic functionality for simple variables and use-statements
    - Other essential features missing, e.g., could not scope-resolve fields from inside methods

SCOPE RESOLUTION: THIS EFFORT

- Added support for scope resolution API queries to dyno library
  - Allows for some coarse-grained queries, like scope-resolving a function body
- Improved support for various features
  - fields, ‘include’ statements, task intents, catch statements, and more
- ‘--dyno’ flag now activates new scope resolution queries
  - A pass at the beginning of the old compiler invokes these queries when translating uAST to old AST



```
proc zero(ref arg: int) {
  arg = 0;
}
```

SCOPE RESOLUTION: IMPACT AND NEXT STEPS

Impact:

- Dyno scope resolution can now be used with ‘--dyno’
- Significantly improved the implementation and implemented missing pieces
- Can begin to run test suite with ‘--dyno’ to measure progress

Next Steps:

- Expand ‘--dyno’ support for test suite
  - current status: 13,626/14,020 tests pass (97%)
  - Note: ‘--dyno’ still leans on old compiler for some unhandled cases, so true progress is difficult to quantify
- Begin to disable parts of old compiler as new functionality becomes stable
- Improve support for language features
  - E.g., ‘except’/’only’ lists, transitive properties of use/import statements
- Preserve error detection and messages
  - E.g., use-before-definition errors

RESOLVING TYPES AND CALLS

RESOLVING TYPES AND CALLS: BACKGROUND

- *Resolving* includes resolving types and resolving calls

- Resolving types is the process of assigning types to symbols

```
var x = "hello";    // ‘x’ has the type ‘string’
var y = 1;          // ‘y’ has the type ‘int’
type t = x.type;    // ‘t’ refers to the type ‘string’
```

- Resolving calls is the process of determining which function a call refers to
  - Instantiations are determined if the function is generic
  - If there are multiple overloads, determines which overload is called

```
proc f(arg) {}          // #1
proc f(arg: numeric) {} // #2
proc f(arg: int) {}     // #3
f(1);                   // Calls ‘f’ #3
f("hello");             // Calls ‘f’ #1 with ‘arg’ instantiated with type ‘string’
f(2.0);                 // Calls ‘f’ #2 with ‘arg’ instantiated with type ‘real’
```

RESOLVING TYPES AND CALLS: STATUS

- In 1.26, the resolver was improved to support many language features
  - Tuples, recursive types, type queries, function disambiguation, and more

- In 1.28, the resolver also supports:
  - Ranges, if-expressions, ‘enum’s
  - Vararg functions
  - Loop index variables and ‘param’ for-loops
  - Improved function return type inference
  - Better inference for generic-with-defaults records and classes
  - Rejecting invalid calls to dependently typed functions

RESOLVING TYPES AND CALLS: STATUS

Areas of progress since April 2022 are in **bold**

Done	In Progress	To Do
• generic instantiation	• scope resolution	• initializers set types
• param folding	• resolve method calls	• check initializers
• implicit conversions	• function disambiguation	• split init
• read a file on use/import	• resolve ‘new’ to initializers	• copy init & copy elision
• resolve tuple types	• resolve ‘?t’ in formals	• deinit
• type construction	• caching of instantiations	• forwarding
• **varargs functions**	• default functions	• const checking
• **resolve loop index variables**	• **casts and other operators**	• try/catch
• **param loops**	• **arrays & domains**	• task/loop intents
• **resolve enums**	• **resolve fields**	• reflection
	• **resolve parenless methods**	• reductions

RESOLVING TYPES AND CALLS: IMPACT

- Ranges can now be resolved
- Some of the recent work was motivated by resolving ranges
- Ranges use some tricky language features as shown below

```
record range
{
  type idxType = int; // element type
  param boundedType: BoundedRangeType = BoundedRangeType.bounded; // bounded or not
  // …
  var _low : chpl__idxTypeToIntIdxType(idxType);   // lower bound
  // …
}

proc range.init(type idxType, low: idxType, high: idxType)
```

‘range’ is generic with defaults

‘range’ uses param enums

initializer is a dependently-typed function

RESOLVING TYPES AND CALLS: NEXT STEPS

- Complete the implementation of large language features missing from the resolver
  - Arrays and domains
  - Initialization and split initialization
  - Copy initialization and copy elision
  - Reflection

DYNO-CHPLDOC

DYNO-CHPLDOC

- As of 1.28, ‘chpldoc’ has been replaced by a dyno-based implementation

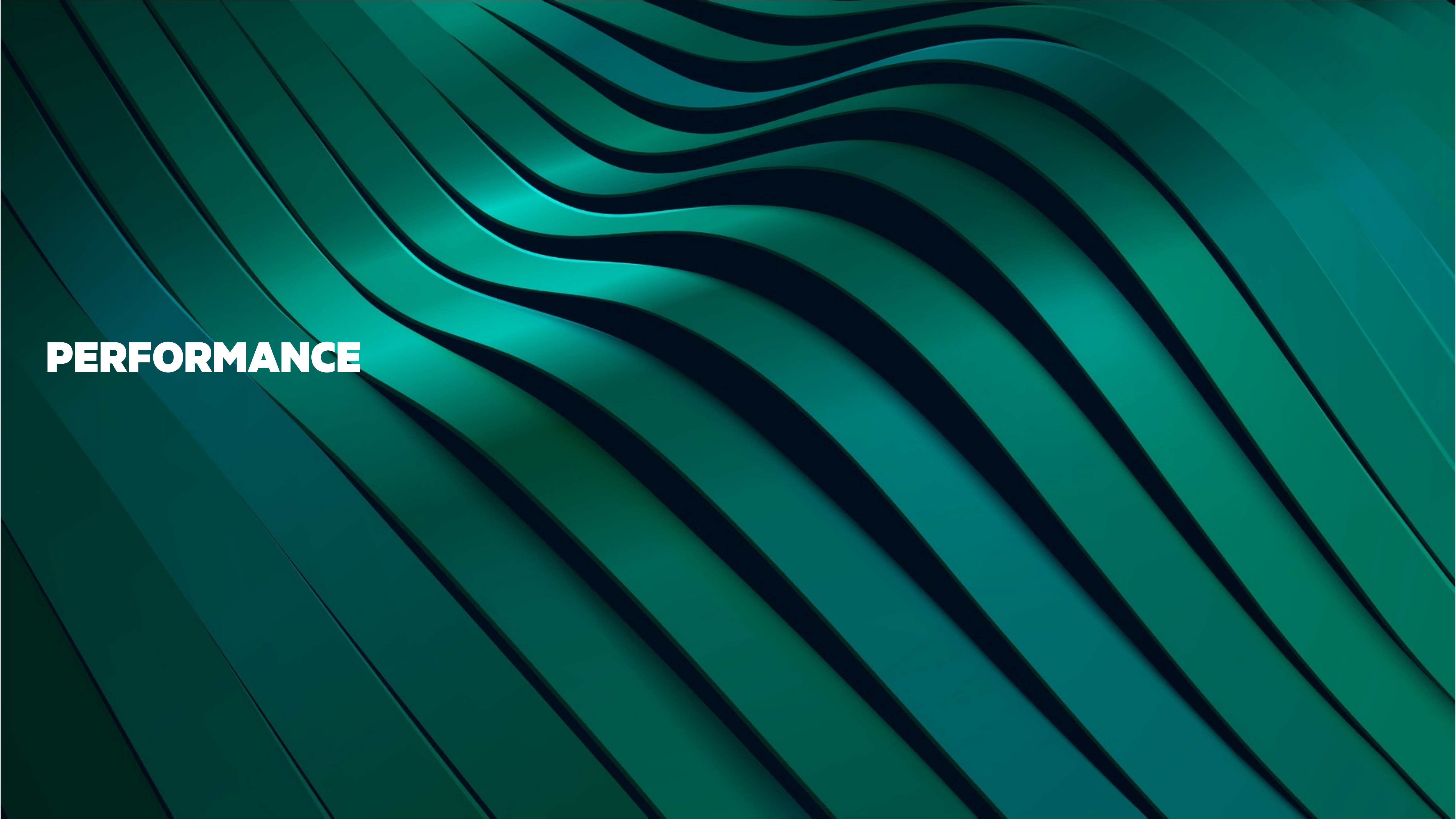
- ‘chpldoc’ now demonstrates a tool using the dyno library
  - Previous versions of ‘chpldoc’ were a pass within the compiler

- Community development of linters or code formatting tools is now possible
  - ‘chpldoc’ can serve as an example

- Provides better formatting for syntax that is rendered in the documentation
  - Including range expressions, array expressions, nilable class types, and numeric literals
  - A result of the uAST more closely representing the source code than the legacy compiler’s AST

- See the ‘chpldoc’ section in the Compiler, Performance, and Tools deck for more information

PERFORMANCE



PERFORMANCE

Background: Efforts are underway to study and improve dyno performance

- Wall-clock performance (how long does the resolver run?)
- Query performance (how many queries are needed to first resolve something? re-resolve?)

This Effort: Substitute specialized data structures in key places

- The LLVM project provides such data structures (e.g., 'SmallPtrSet')
  - Can perform better when used appropriately

Impact: Use of LLVM data structures led to performance improvements

- Exact magnitude is unclear while dyno scope resolving is still under development
- Measured a 17% performance improvement with partial scope resolution

Next Steps: Continue tracking resolver performance

- Investigate overhead of query framework itself
- Identify functions to turn into queries

NEXT STEPS

NEXT STEPS

These are the planned ‘dyno’ goals for the 1.29 and 1.30 releases:

1. Work towards replacing the scope resolver in the production compiler
   - Goal: use the ‘dyno’ scope resolver in production by 1.29 or 1.30
2. Build more components of the dyno resolver to reach feature-completeness
   - Goal: have initial implementations of remaining major components of the new resolver by 1.30
3. Design and implement file formats and commands for separate compilation
   - Goal: implement uAST serialization/deserialization by 1.29
   - Goal: implement draft library file format and demonstrate separate compilation commands by 1.30
4. Begin work on improving error messages
   - Goal: migrate errors from parsing and dyno scope resolution to a more user-friendly format by 1.29

OTHER DYNO IMPROVEMENTS

OTHER DYNO IMPROVEMENTS

For a more complete list of dyno changes and improvements in the 1.27.0 and 1.28.0 releases, refer to the following section in the CHANGES.md file:

- Developer-oriented changes: 'dyno' Compiler improvements/changes

THANK YOU

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