Hewlett Packard Enterprise

CHAPEL 1.29.0/1.30.0 RELEASE NOTES: COMPILER, PERFORMANCE, AND PACKAGING

Chapel Team

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OUTLINE

- Generated Assembly
- Reducing Compilation Time
- Array Creation Optimizations
- Parallel Array Deinitialization
- Docker Changes
- LLVM Status
- Portability and Prerequisites
- Documentation Improvements

SHOWING THE GENERATED ASSEMBLY

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Background: Performance-minded users have requested a way to view a procedure's generated assembly

- Useful for checking compiler optimizations and for evaluating different ways to write something in Chapel

This Effort: Enabled showing an assembly dump for a specific function

- For example, we might like to know if the procedure below uses a vectorized 'sqrt( )'
- The command on the right can be used to answer this question

```
config const n = 16;
var A: [1..n] real(32);

proc foo() {
  foreach i in 1..n {
    A[i] = sqrt(i:real(32));
  }
}
foo();
```

```
$ chpl program.chpl --fast \
                    --llvm-print-ir foo \
                    --llvm-print-ir-stage asm

# Disassembling symbol foo_chpl

... output showing vsqrtss instruction ...
```

Status: The new flag currently only works when using the LLVM backend

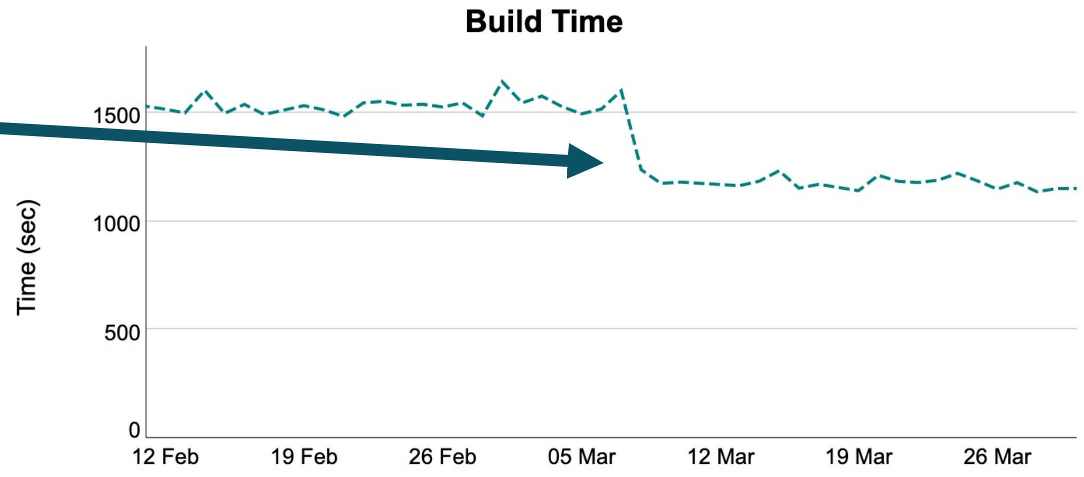
REDUCING COMPILATION TIME

REDUCING COMPILATION TIME
Reduced Polynomial Overhead in Compiler

Background: Chapel users and developers are understandably annoyed by slow compilation times
- Long-term, 'dyno' is being designed and engineered to help reduce compilation times
- In the meantime, large applications like Arkouda are suffering

This Effort: Eliminated one source of polynomial overhead in the compiler
- For each routine returning 'true'/'false'/'void', the compiler looked at all occurrences of that value in the program
  – This included a huge number of occurrences internal to the compiler

Impact: 20% reduction in Arkouda build time



Next Steps: Continue speeding up the compiler
- Look for similar sources of overhead in production
- Continue improving 'dyno's resolution capabilities
  - Goal: make it the production resolver

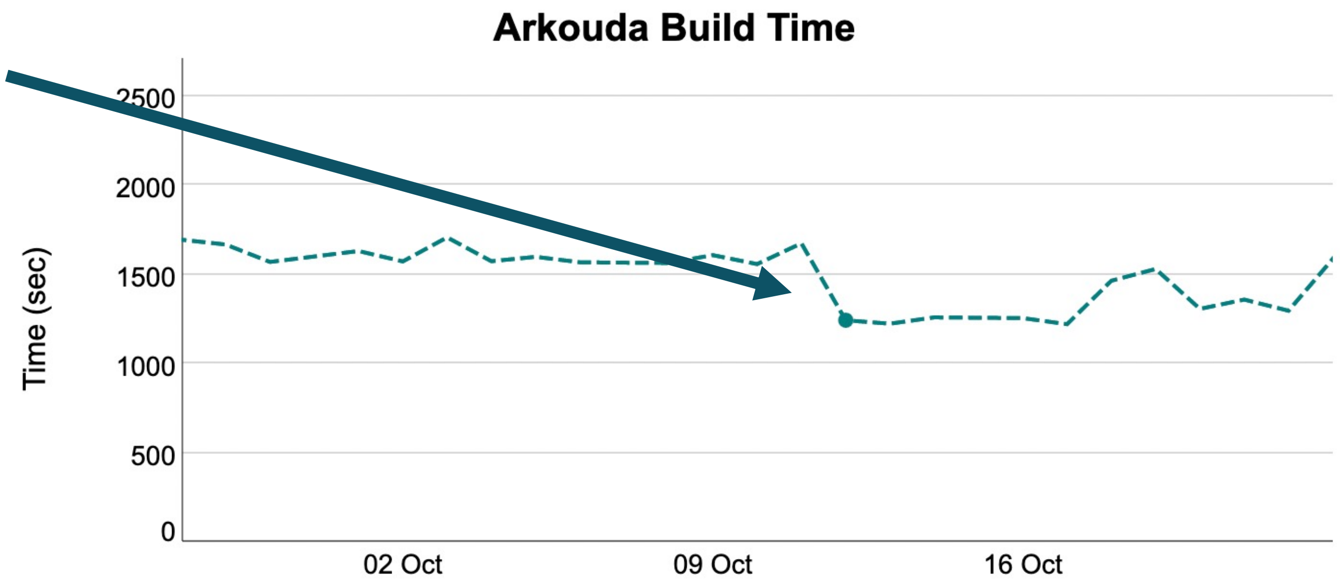
REDUCING COMPILATION TIME
Building Compiler with ‘jemalloc’

Background: The compiler allocates many objects

- ~7 million allocations for ‘chpl examples/hello.chpl’
- Previous releases added the option to build the compiler with ‘jemalloc’, which improves allocation performance
- Users had to opt-in to using ‘jemalloc’ to benefit from improvements

This Effort: Made ‘jemalloc’ the default for building the compiler whenever possible

Impact: 25% reduction in Arkouda build time



ARRAY CREATION OPTIMIZATIONS

ARRAY CREATION OPTIMIZATIONS

Background and This Effort

Background: Chapel uses *privatization* to replicate distributed domain and array metadata to all locales

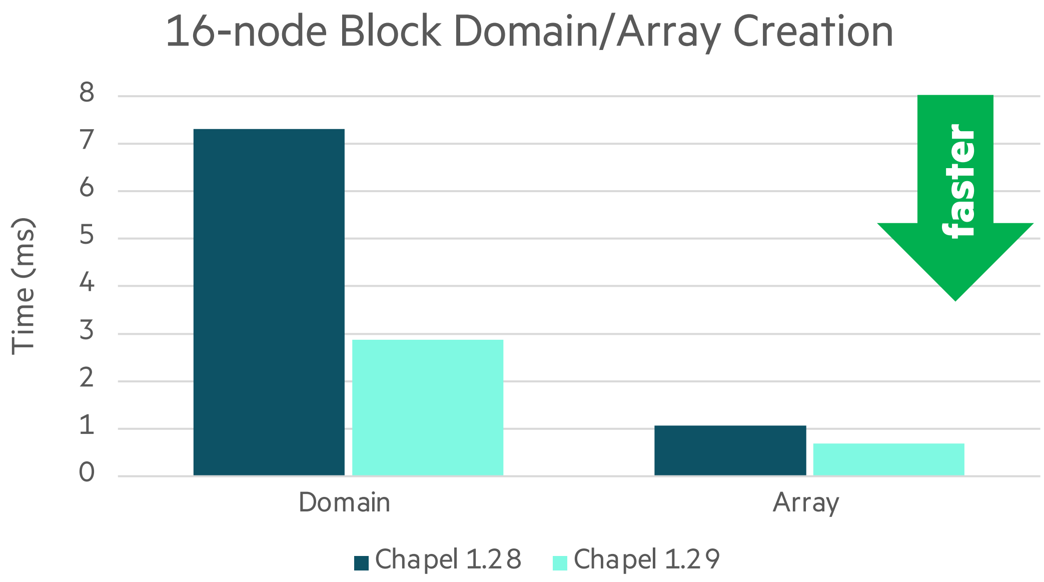
- Privatization increases creation time, but speeds up later uses
- Creation time is not a bottleneck for many codes
  - Tends to be outside timed kernels for most benchmarks
  - HPC applications tend to create arrays once and heavily reuse them
- Unlike most HPC codes, Arkouda frequently creates new arrays
  - A recent operation to display a summary of a DataFrame (DF) creates dozens of small arrays
  - This motivated trying to improve array creation speed

This Effort: Optimized distributed domain and array privatization

- Improved communication strategy used to broadcast metadata
- Eliminated re-privatization when creating rectangular domains

ARRAY CREATION OPTIMIZATIONS
Impact

- Improved performance for distributed domain and array creation
  - Non-trivial speedup for many Arkouda operations, especially when combined with ‘SymEntry’ optimizations



16-node Arkouda

Benchmark	Before	After	Speedup
DF Display	0.8 s	0.4 s	2x
Stream	465 GiB/s	600 GiB/s	1.3x
Scan	580 GiB/s	1010 GiB/s	1.7x

ARRAY CREATION OPTIMIZATIONS
Next Steps

- Further optimize domain and array creation
  - Implement minor communication and allocation reductions for ‘BlockDist’
  - Reset task placement to improve cache reuse between domain and array creation
  - Explore replacing eager privatization with on-demand forwarding

PARALLEL ARRAY DEINITIALIZATION

PARALLEL ARRAY DEINITIALIZATION
Background and This Effort

Background: Array elements are initialized in parallel, but were historically deinitialized serially

- Parallel init is important for first-touch and speeding up memory fault-in for all types
- Many types do not require deinit
  - Only complex types like domains/arrays and records/classes with ‘deinit( )’ methods
- Historically, trying to parallelize deinit resulted in large regressions for array-of-arrays
  - Caused by contention on a lock used to implement domain reference counting and array tracking
  - These overheads have been reduced in recent releases, but not eliminated
- Recently-added Arkouda ‘bigint’ arrays were impacted by slow serial deinitialization
  - Motivated revisiting parallel deinitialization

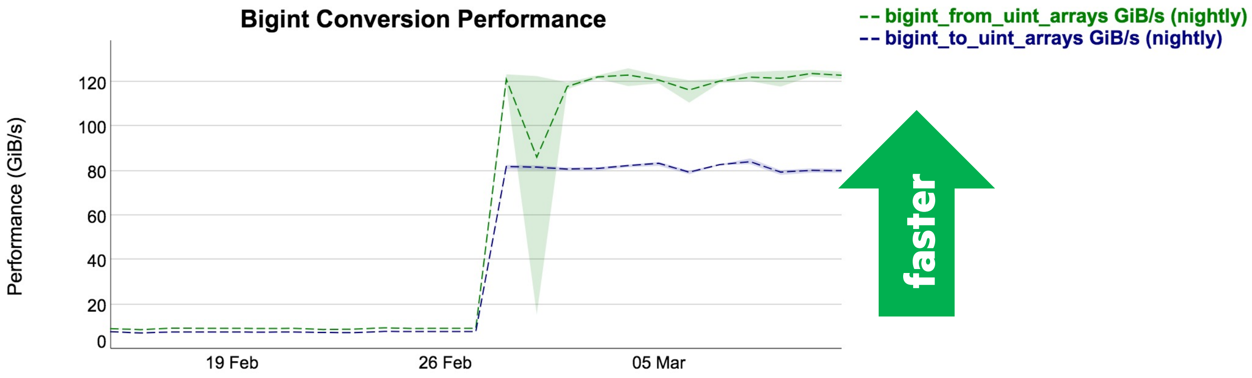
This Effort: Parallelized array deinitialization for all types

- Uses the same size heuristics as parallel initialization

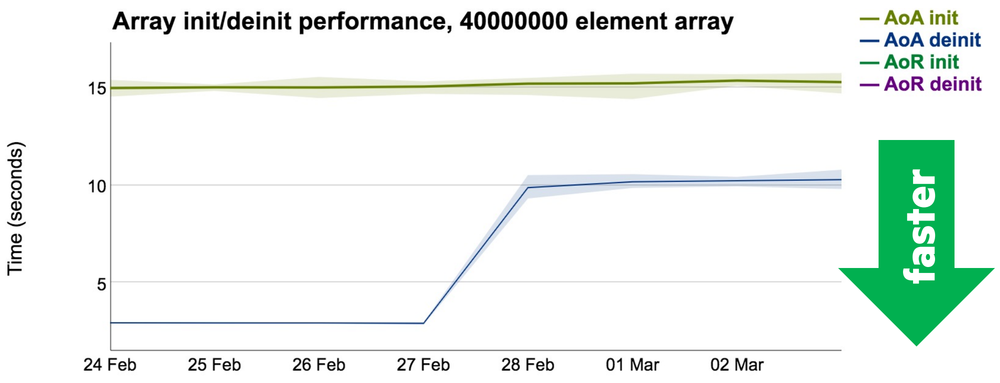
PARALLEL ARRAY DEINITIALIZATION

Impact

- Faster array deinitialization for many types that require deallocation, including Arkouda 'bigint' arrays



- Slower array-of-arrays deinitialization, though still faster than initialization



PARALLEL ARRAY DEINITIALIZATION

Next Steps

- Reduce overheads for initializing and deinitializing array-of-arrays
  - Reduce need for locking by using atomic counter for reference counting
  - Do bulk reference counting for array-of-arrays
  - Explore eliding reference counting if compiler can prove lifetimes

DOCKER CHANGES

DOCKER CHANGES

Background:

- Previous Dockerfile fetched latest release's source tarball from GitHub and built that release's image
  - Only provided pre-built LLVM backend

This Effort:

- Modified Dockerfile to build from its containing Chapel source tree and build the C backend as well

Impact:

- Enabled building and using Chapel Docker images from any version of Chapel source code
  - Can build images from specific commits
  - More in line with general practice for Dockerfiles
  - Removes the necessity of fetching the latest release
  - Allows creation of a CI job to test building Docker image from latest source
- C backend can be used to reduce time or memory overheads when compiling Chapel programs

LLVM STATUS

LLVM STATUS

Background:

- LLVM is Chapel's recommended backend
  - Versions 11–14 are supported and tested nightly
  - Version 15 removed support for typed pointers, which the Chapel compiler has relied upon

This Effort:

- Started adjusting the LLVM backend to stop using typed pointers
  - Manually tracking types for LLVM pointers where needed

Status:

- More work remains before Chapel can support LLVM 15

Next Steps:

- Make LLVM 15 the default
  - Continue adjusting the backend to use opaque pointers

PORTABILITY AND PREREQUISITES

PORTABILITY

Background: Have been gradually improving portability of Chapel on a variety of Unix systems

This Effort: Performed ad hoc testing with many current operating systems

Status: Verified portability to 12 OS distributions and 32 versions:

- ‘make’ and ‘make check’ work with or without the system LLVM package on the following systems:
  - Alma Linux 8, 9.0, 9.1
  - Alpine Linux 3.15, 3.17
  - Amazon Linux 2
  - Arch linux (March 2023 version)
  - CentOS Stream 8, 9
  - Debian 10, 11, 12
  - Fedora 34, 35, 36
  - FreeBSD 12.2, 12.4, 13.1
  - Mac OS X (with Homebrew)
  - OpenSuse Leap 15.3, 15.4
  - Rocky Linux 8, 9.0, 9.1
  - Ubuntu 20.04, 22.04, 22.10
  - Ubuntu 22.04 with Homebrew
- ‘make’ and ‘make check’ work with ‘quickstart’, but the system LLVM package cannot be used
  - Amazon Linux 2023
  - CentOS 7 with Devtoolset 11
  - Fedora 37, 38

Next Steps: Automate this portability testing to run it more frequently

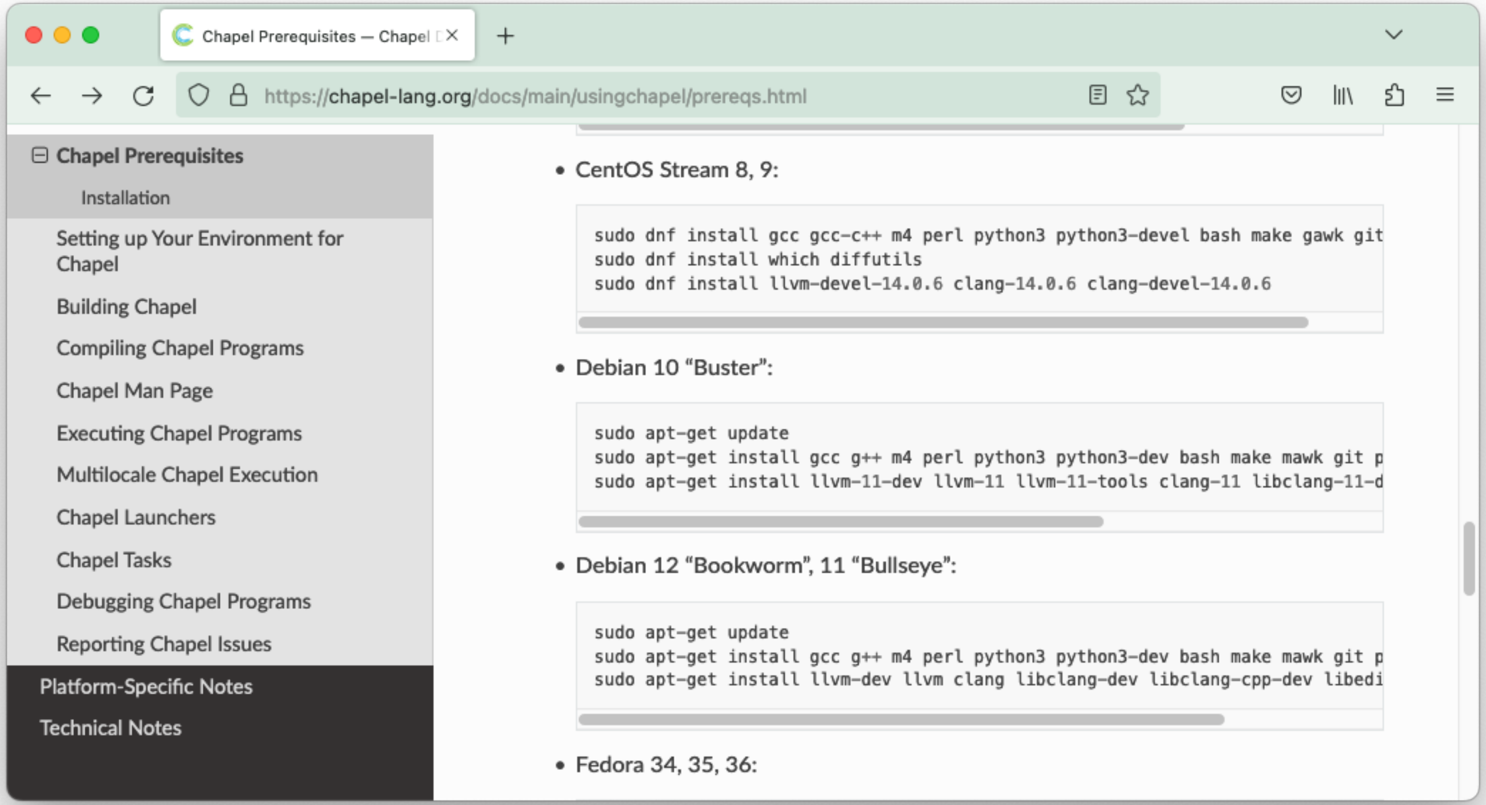
PREREQUISITES DOCUMENTATION

Background: Chapel requires some tools to be pre-installed in order to build correctly

This Effort: Wrote scripts to automatically generate platform-specific prerequisite docs

- lists commands for installing required packages based on portability testing results

Impact: Users with tested distributions can easily find commands to install prerequisites



DOCUMENTATION IMPROVEMENTS

DOCUMENTATION IMPROVEMENTS

Background and This Effort

Background:

- For 2.0, beyond keeping documentation up-to-date, we've also been improving descriptions of existing features
- Recent releases have particularly focused on the "Built-in Types and Functions" section of the docs
  - These were topics that were technically part of the language, yet whose documentation was generated by 'chpldoc'

This Effort:

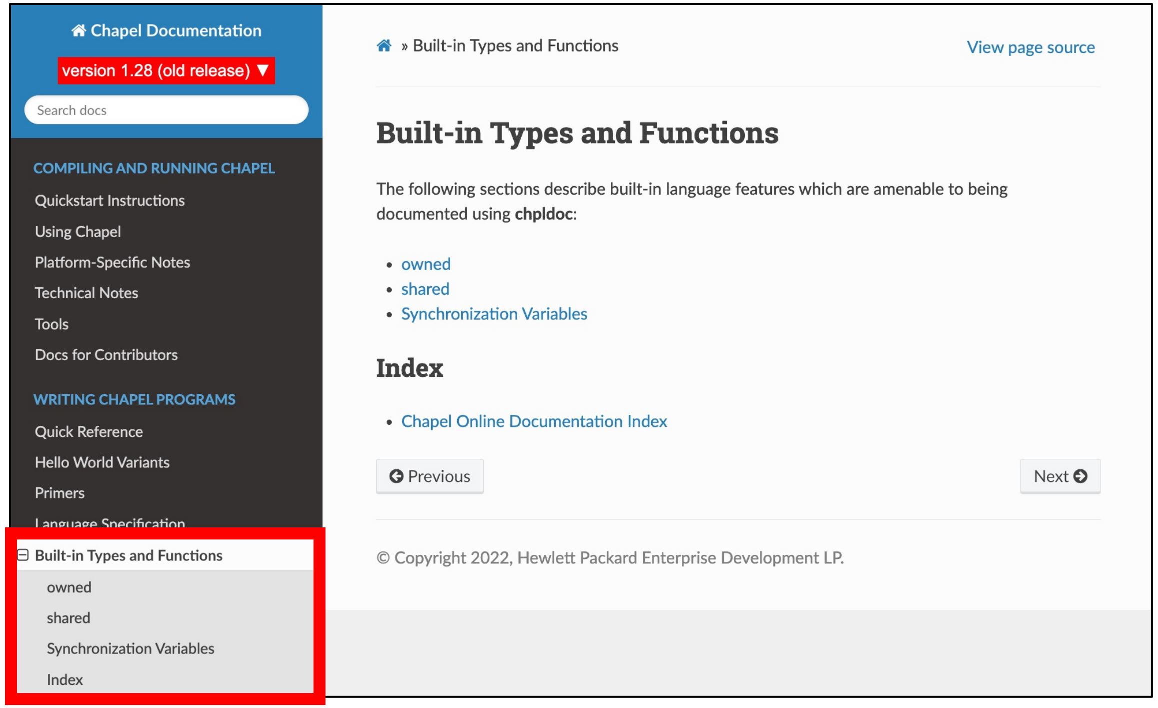
- Folded the remaining "Built-in Types and Functions" topics from Chapel 1.28 into the language specification
- Clarified the language specification with respect to several features:
  - abstract argument intents
  - storage of records with array fields
  - 'out' arguments and split initialization
  - 'yield' semantics
  - re-exporting symbols
  - non-promoted arguments in promoted expressions
  - definitions of subroutine bodies
- Also improved documentation for several standard modules

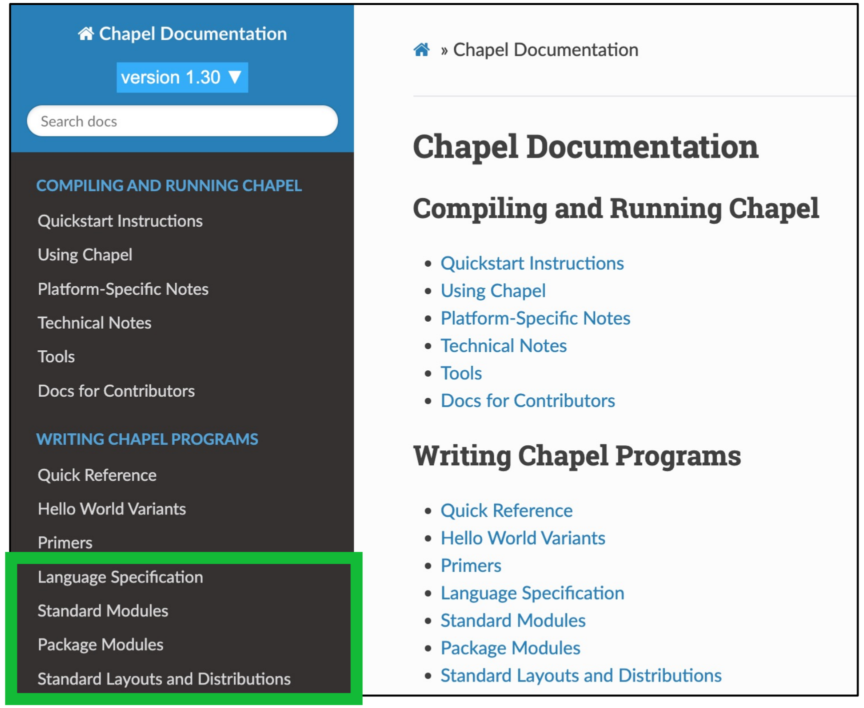
DOCUMENTATION IMPROVEMENTS

Impact and Next Steps

Impact:

- The “Built-in Types and Functions” section of the sidebar no longer exists:





- Chapel’s documentation continues to reflect the language better and more accurately going into Chapel 2.0

Next Steps: Continue improving docs as we approach Chapel 2.0

OTHER IMPLEMENTATION / PACKAGING IMPROVEMENTS

OTHER IMPLEMENTATION / PACKAGING IMPROVEMENTS

For a more complete list of implementation and packaging changes and improvements in the 1.29.0 and 1.30.0 releases, refer to the following sections in the CHANGES.md file:

- ‘Configuration / Build / Packaging Changes’
- ‘Tool Improvements’
- Compilation-Time / Generated Code Improvements’
- ‘Performance Optimizations / Improvements’
- ‘Language Specification Improvements’ and ‘Other Documentation Improvements’
- ‘Portability / Platform-specific Improvements’
- ‘Compiler Improvements’ and ‘Compiler Flags’
- ‘Error Messages / Semantic Checks’
- ‘Bug Fixes’
- ‘Third-Party Software Changes’
- ‘Developer-oriented changes: …’

THANK YOU

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