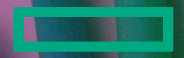

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Chapel 1.33 / 2.0 Release Notes: Compiler and Tool Updates

Chapel Team

December 14, 2023 / March 21, 2024

Outline

- Separate and Incremental Compilation
  - Separate Compilation
  - Incremental Compilation
- Editor Tooling
- Debugging Chapel Programs
- Other Compiler and Tool Updates

Separate and Incremental Compilation

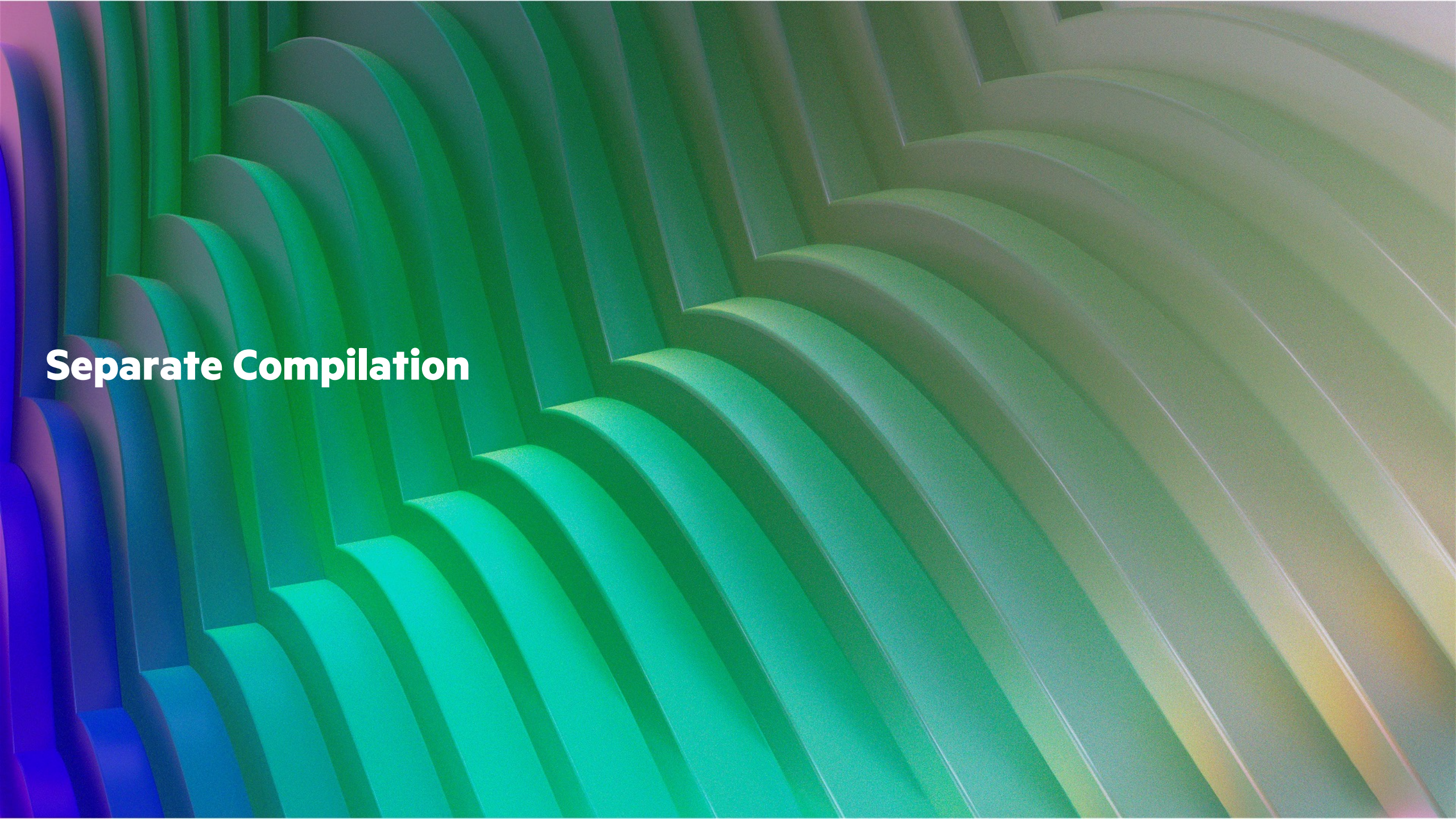
Separate and Incremental Compilation

- Separate Compilation
- Incremental Compilation

Separate and Incremental Compilation: Background

- We have been working towards significantly improving compile times in the *Dyno* effort
- We are also working towards supporting separate compilation and incremental compilation
- Both strategies may reduce the amount of time needed to compile a program
- The two strategies are related but not the same
- This presentation will discuss both and describe their status

Separate Compilation



What is Separate Compilation?

- In separate compilation, *library files* record information for use across multiple compilations
  - a *compiler* takes some unit of source code and generates a *library file*
  - a *linker* combines library files to create an executable program

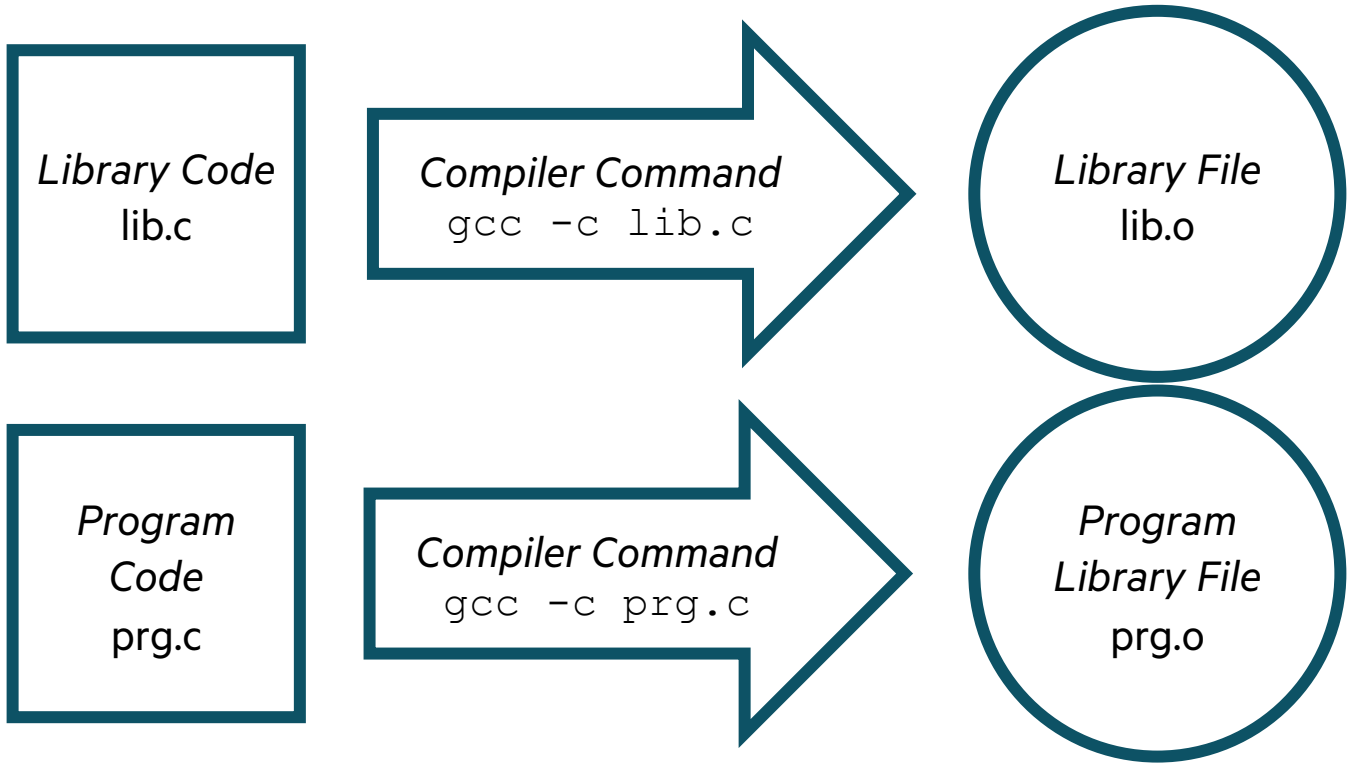
- The user could initiate this process by telling the compiler to create a *library file,* e.g.,

```
chpl -c lib.chpl    # This could produce 'lib.chlib'
```

- The following slides show how library files are created with the ‘gcc’ C compiler
  - Note the ‘gcc’ commands because they demonstrate a user interface

What is Separate Compilation?

Separately Compiling in C



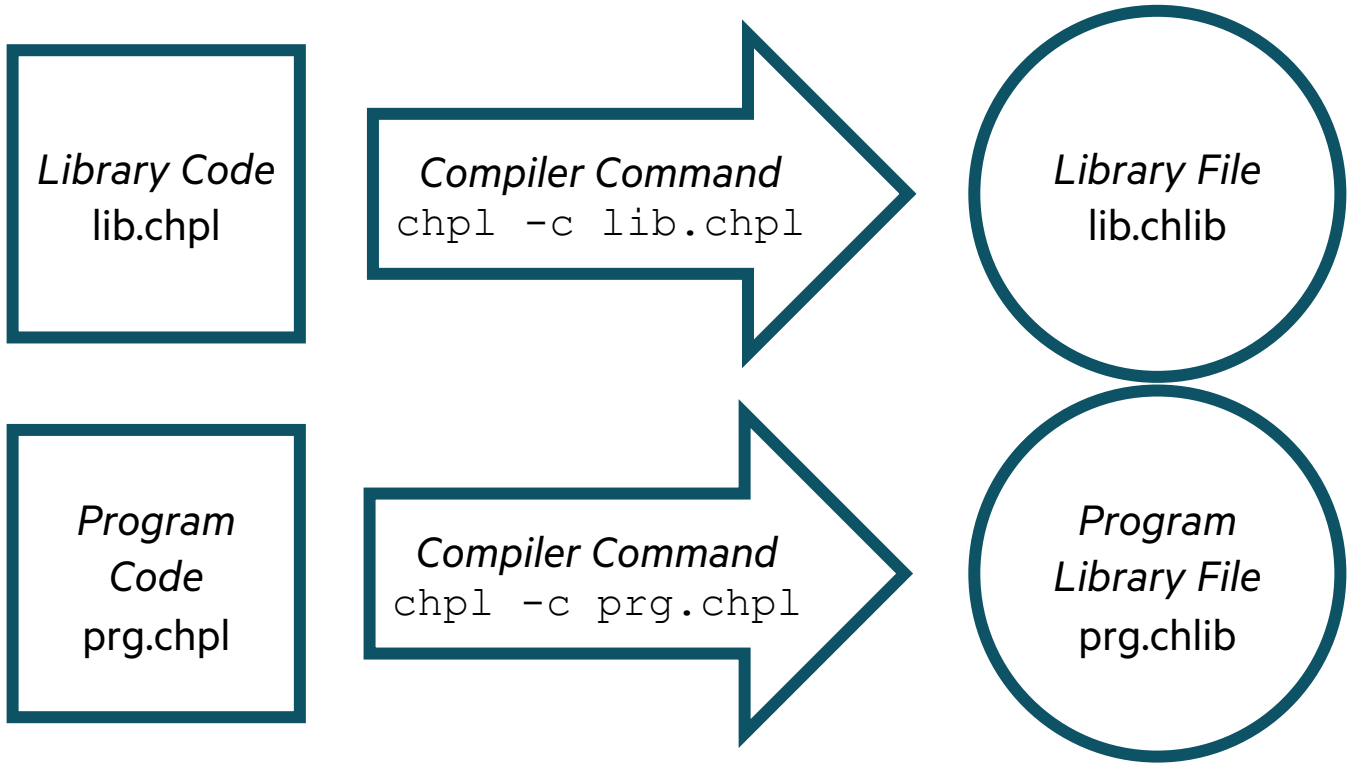
Header files are involved in this process, but are not illustrated here

What is Separate Compilation?

Linking Separately Compiled Files in C

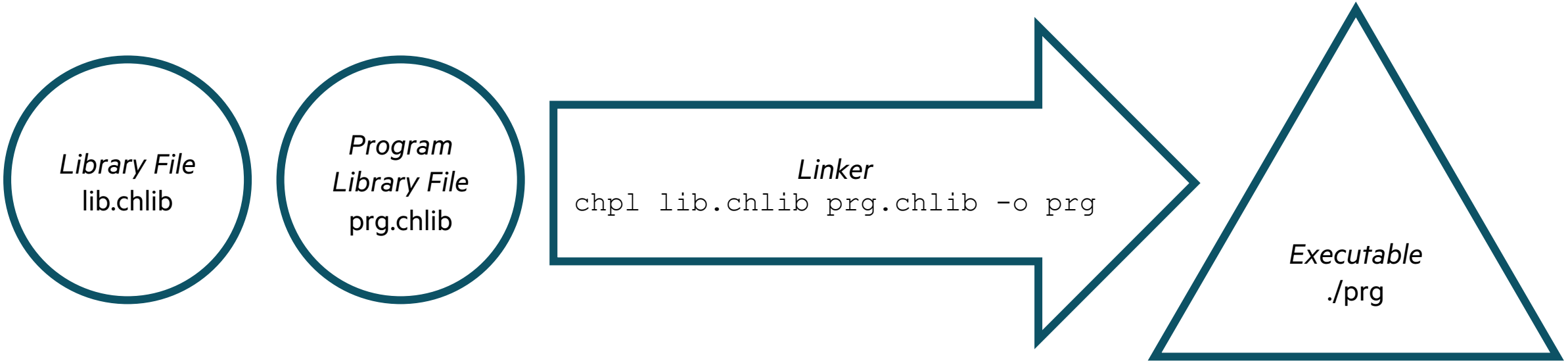
What is Separate Compilation?

Separately Compiling in Chapel can be Similar (planned, exact details TBD)



What is Separate Compilation?

Linking Separately Compiled Files in Chapel can be Similar (planned, details TBD)



Challenges to Separate Compilation for Chapel

- Chapel doesn't have an equivalent to C header files
  - The Chapel compiler *could* generate a header file from source code if necessary
  - However, library files themselves can store details needed to support separate compilation
  - Some details work like a precompiled header file (.pch) does for C compilers

- Generic functions are a challenge
  - Instantiation details for a generic function might not be known until link-time
    - So, we need the ability to instantiate at link-time

- The current whole-program compiler must be adjusted to support separate compilation
  - Adjustments are planned on a case-by-case basis for passes in the production compiler
  - Several approaches can be considered for each pass:
    - Compute the information the pass needs during link-time
    - Or compute it during separate compilation, storing it in the library file for use at link-time
    - Sometimes the pass can be rewritten so it is not whole-program

Separate Compilation for Chapel: Status and Next Steps

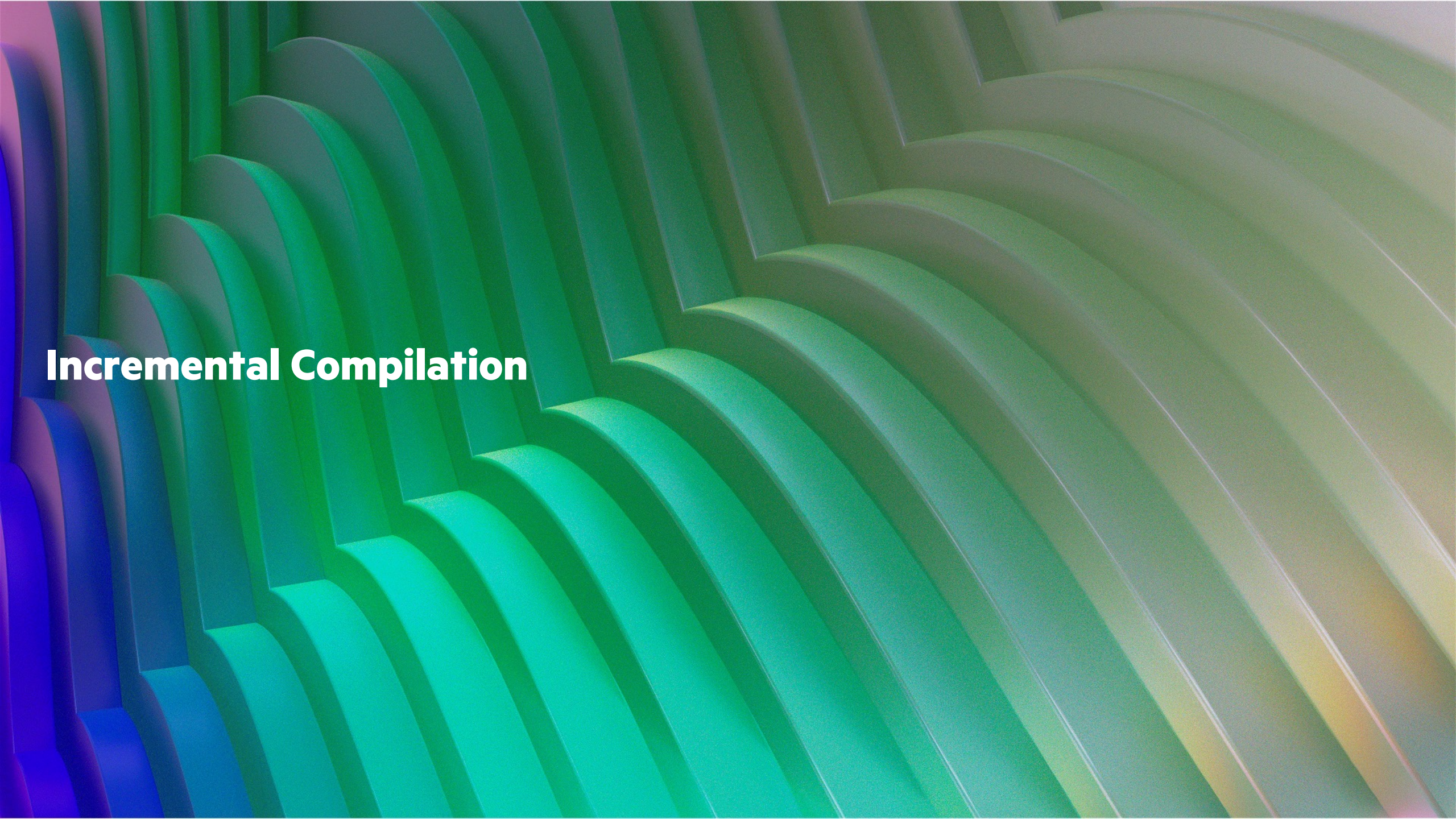
Status:

- Can generate a library file with a prototype flag:
  ```
  chpl --dyno-gen-lib lib.dyno lib.chpl
  ```
- Resulting 'lib.dyno' contains:
  - Serialized uAST, which provides capabilities like a precompiled header in C
  - LLVM IR for some non-generic functions

- Library files can be used when compiling a program:
  ```
  chpl lib.dyno prog.chpl
  ```
- The compiler will skip parsing 'lib.chpl' and use the uAST stored in 'lib.dyno' instead
  - Provides a modest speed improvement (around 0.1 seconds for the standard library)
- The compiler can skip code-generation for non-generic library functions
  - Saves time spent code-generating
  - However, resolution (the most expensive compilation phase) still occurs

Next Steps: Store more information in library files and identify more potentially redundant work

Incremental Compilation



What is Incremental Compilation?

- In incremental compilation, the compiler transparently reuses information to save time
  - The user doesn’t need to be aware of the process
- The compiler detects source code changes and can recompile only newly changed portions
  - Recompilation can be finer-grained than e.g., 'gcc', which handles one source file at a time
- Some existing tools that leverage incremental compilation:
  - Many implementations of the Language Server Protocol (LSP)
  - The ‘ccache’ program
  - The Rust compiler
- Incremental compilation information can be stored:
  - Only in memory (typical for LSP implementations)
  - In the filesystem ('ccache')

Planned Directions for Incremental Compilation in Chapel

- The Chapel compiler launches a long-lived 'chpl' server that stores incremental compilation state

```
chpl program.chpl      # The first compiler invocation launches a compilation server and feeds it information

<edit program.chpl>

chpl program.chpl      # The second invocation uses info from the server to speed up compilation
```

- The Chapel language server runs continually and updates its state for live results
  - The server provides end-to-end commands such as "compile and run"
  - The updates are incremental to maximize responsiveness

Incremental Compilation for Chapel: Status and Impact

- A fully incremental type and call resolver is available for a growing subset of Chapel

- Incremental resolution is up to 25x faster than initial resolution
  - With a simple 'proc trace' experiment program containing one function and calling it:
    - Initial type and call resolution = 0.5 s
    - After changing the input = 0.02 s

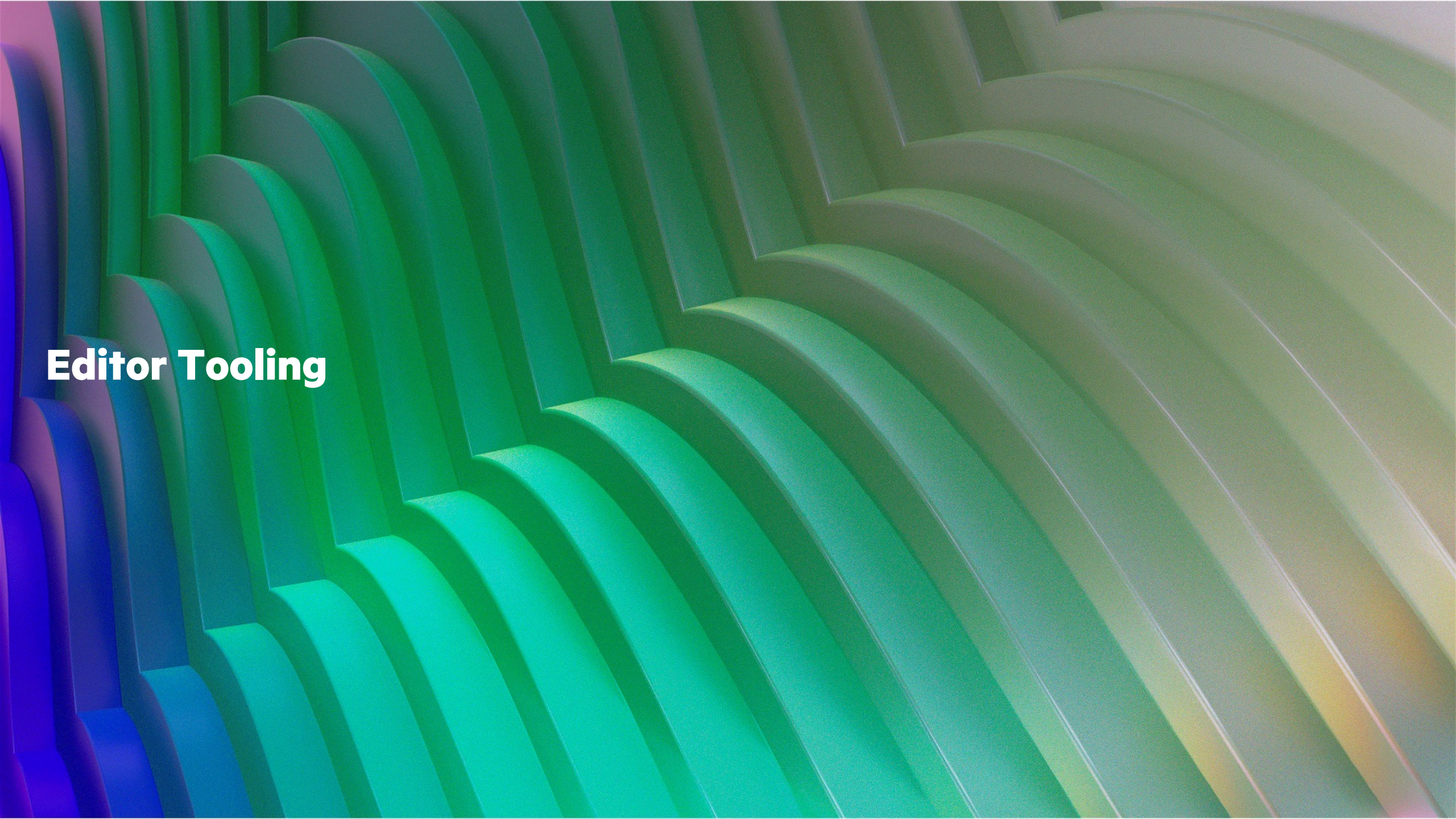
- The Chapel language server currently leverages incremental compilation
  - Allows for type and call resolution at interactive speeds:
    - Notice that the type of 'result' is updated in real time as the right-hand side is edited

```
3 proc trace(x) {
4   writeln("The value of x is: ", x);
5   return x;
6 }
7 var result: int(64) = trace(x = 1);
```

Incremental Compilation for Chapel: Next Steps

- The *Dyno* team will complete the incremental type and call resolver

- After that, investigate end-to-end incremental compilation
  - Adjust passes that rely on whole-program info, similarly to incremental compilation
  - Gauge interest in a 'chpl' server or end-to-end compilation support via the language server


Editor Tooling

Editor Tooling: chpl-language-server and chplcheck

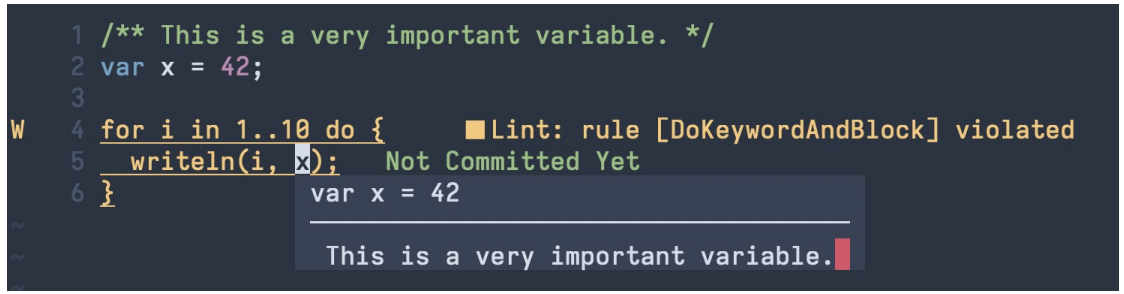
Background and This Effort

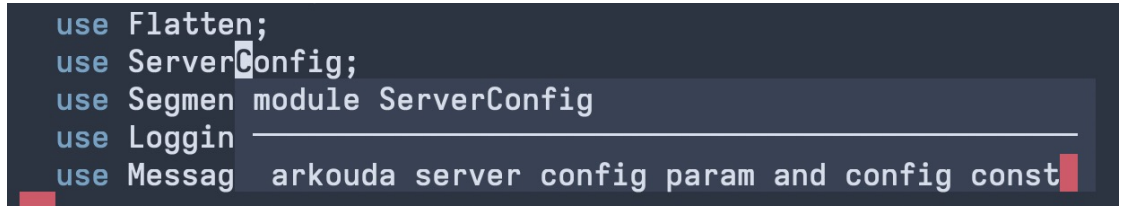
Background:

- the Language Server Protocol is an editor-agnostic way of adding code intelligence for programming languages
- language authors (or community) provide a server for a language, editors use the server for code intelligence

This Effort: provide two tools based on LSP

- **chpl-language-server**
  - go-to-definition, renaming, hover information
  - advanced features: type inference, param inlays, call graphs
  - more!
- **chplcheck**
  - detection of common errors that aren't disallowed per se
  - report unconventional capitalization for records, classes, etc.
  - unused variables
  - extraneous 'do' blocks
  - more!





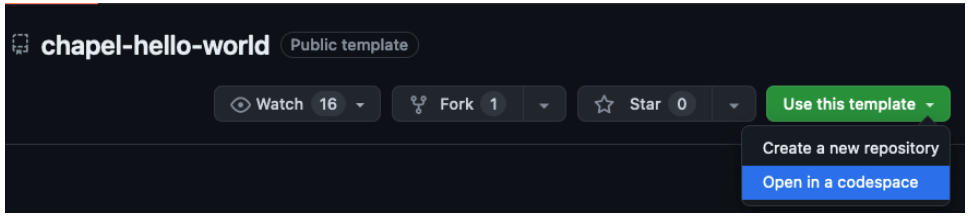
Editor Tooling: VSCode
Background and This Effort

Background:

- VSCode requires a full extension to support an LSP client

This Effort:

- Created a Chapel Language VSCode extension
  - supports chpl-language-server and chplcheck
  - improved syntax highlighting over previous community-contributed extensions
  - added other user improvements (e.g., GUI breakpoints, autofill code snippets)
- Used the extension to create a 2-click Chapel demo in the browser



Debugging Chapel Programs

Debugging Chapel Programs
Background

- Debugging Chapel programs has traditionally been fairly bare-bones
  - The main approach has been to use a typical C-style command-line debugger on the generated code / binary:

```
$ chpl --savec output -g myProg.chpl
$ ./myProg --lldb   # or --gdb
(lldb) b myProg.chpl:2
(lldb) run
* thread #2, stop reason = breakpoint 2.1
    frame #0: 0x100075d8c myProg`chpl__init_myProg (_ln..., _fn=...) at myProg.chpl:2
   1       for i in 1..10 {
-> 2         writeln("i is ", i);
   3       }
(lldb) p i
(long) $0 = 1
```

    - Ease-of-use can vary by program, depending on the degree to which the code was transformed during compilation
    - Additional flags and tips are available in https://chapel-lang.org/docs/usingchapel/debugging.html
  - For multi-locale runs, we have had some success running a gdb session per locale or using HPE's 'gdb4hpc' tool

Debugging Chapel Programs
This Effort, Status, and Next Steps

This Effort:

- As our team has grown, so has the desire to provide better debugging experiences
  - both for ourselves and for users
- During Chapel 1.33 and 2.0, we made some improvements:
  - added a new 'Debugger' module providing a 'breakpoint;' pseudo-statement (see "Library Improvements" release notes)
  - improved portability of debugging when using the LLVM back-end on Mac OS X
  - prototyped configuration files that enable debugging Chapel within VSCode, similar to the previous slide's example

Status: Debugging support has improved in modest ways as a result of these efforts

Next Steps: Continue improving support for debugging Chapel programs:

- Improve preservation of user identifiers and code structures during compilation
- Teach debuggers more about Chapel-specific types
- Continue improving support for debugging with IDEs and tools of interest to users and developers
- Extend debugging support to include evaluation of Chapel expressions (e.g., 'p [a in A] sqrt(a)')

Other Compiler and Tool Updates

Other Compiler and Tool Updates

For a more complete list of compiler and tool changes and improvements in the 1.33 and 2.0 releases, refer to the following sections in the CHANGES.md file:

- Improvements to Compilation Times / Generated Code
- Tool Improvements
- Compiler Improvements
- Compiler Flags
- Bug Fixes for Tools
- Developer-oriented changes: Compiler Flags
- Developer-oriented changes: Compiler improvements / changes
- Developer-oriented changes: 'dyno' Compiler improvements / changes
- Developer-oriented changes: Tool Improvements
- Developer-oriented changes: Utilities


Thank you
https://chapel-lang.org
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