clang-scan-deps

Fast Dependency Scanning For Explicit Modules

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LLVM Developers' Meeting, Brussels, Belgium, April 2019

Clang Modules

Dependency Scanning

Fast Dependency Scanning

Dependency Extraction

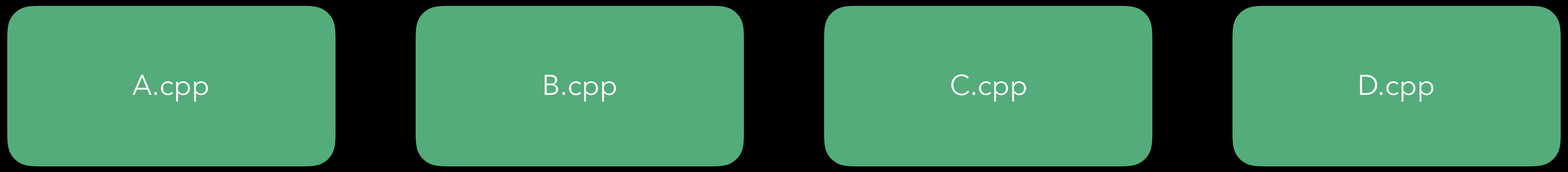
Future Work

Clang Modules

- Replace the textual preprocessor inclusions with an import of an AST
- Widely used in SDKs shipped with Xcode
  - Implicit modules: Clang builds modules as they’re included
  - Users don’t have to specify modular dependencies 🙂
  - Requires a build system in the compiler 😫

Implicit Modules

🔵 Compiler Discovered 🟢 Build System Known



A.cpp

B.cpp

C.cpp

D.cpp

Implicit Modules

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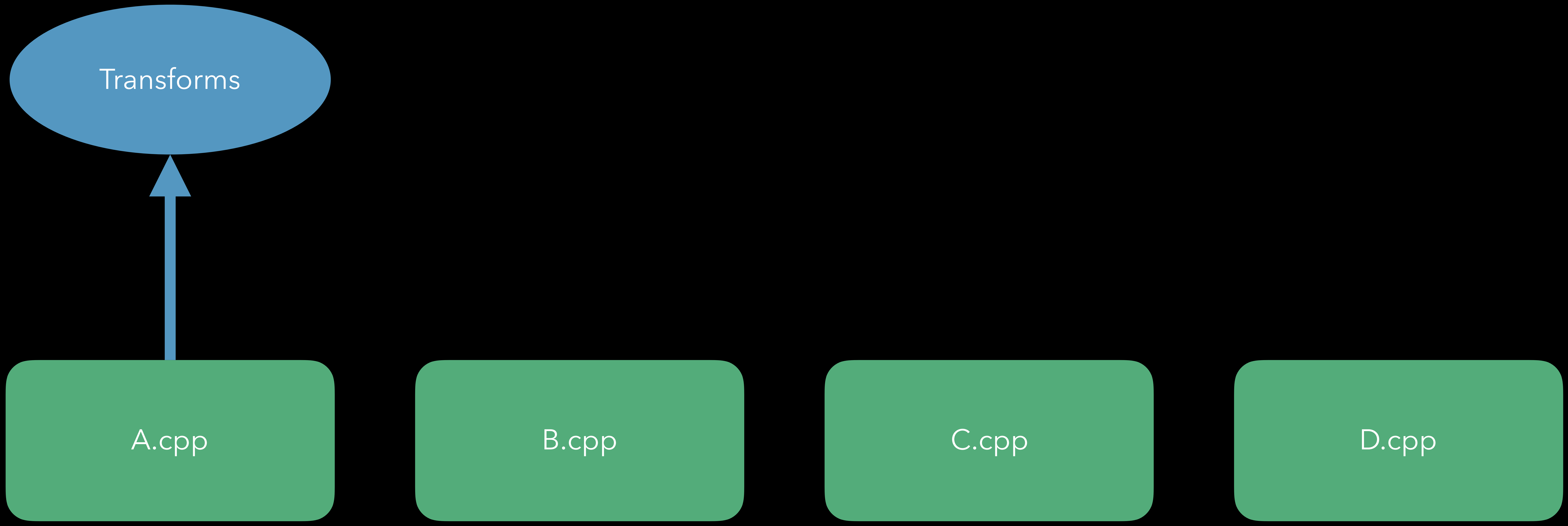

Transforms

A.cpp

B.cpp

C.cpp

D.cpp

Implicit Modules

Module Maps

```
module LLVM_Transforms {
  requires cplusplus
  umbrella "Transforms"
  module * { export * }
}
```

Implicit Modules

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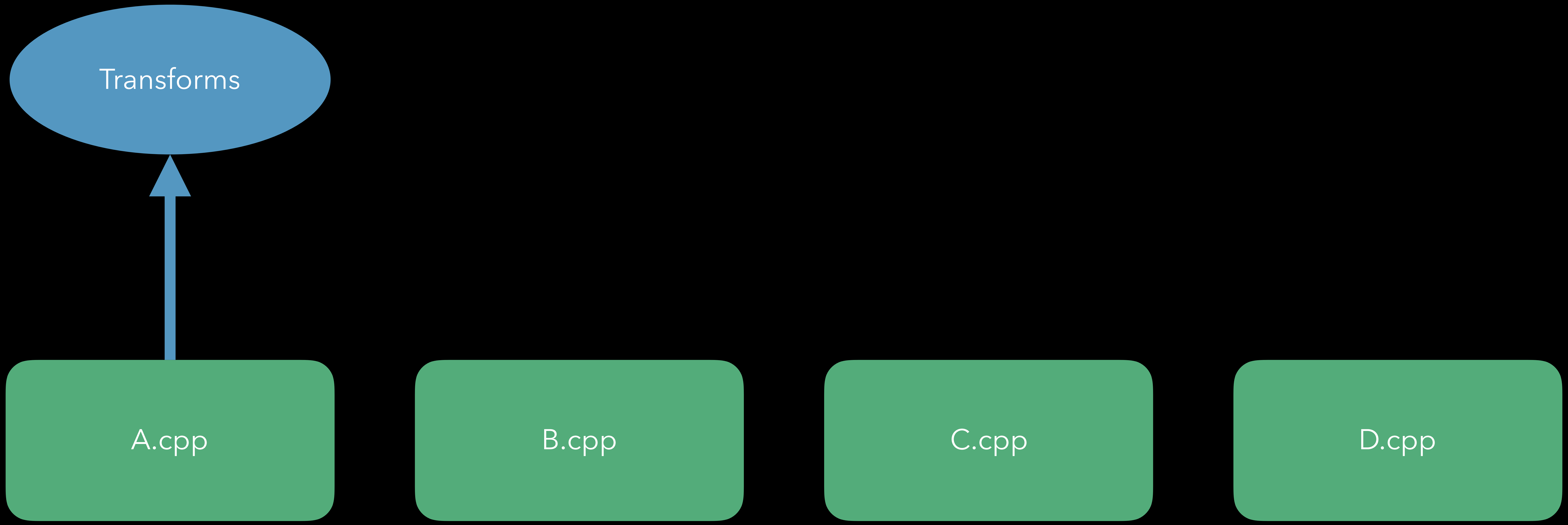

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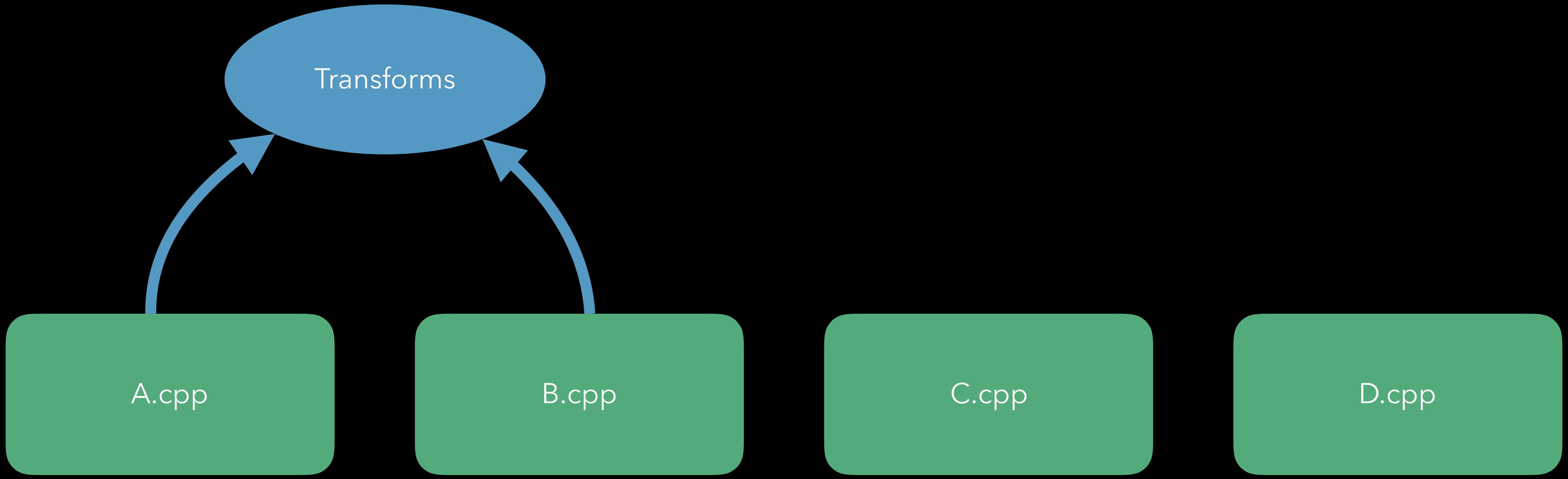

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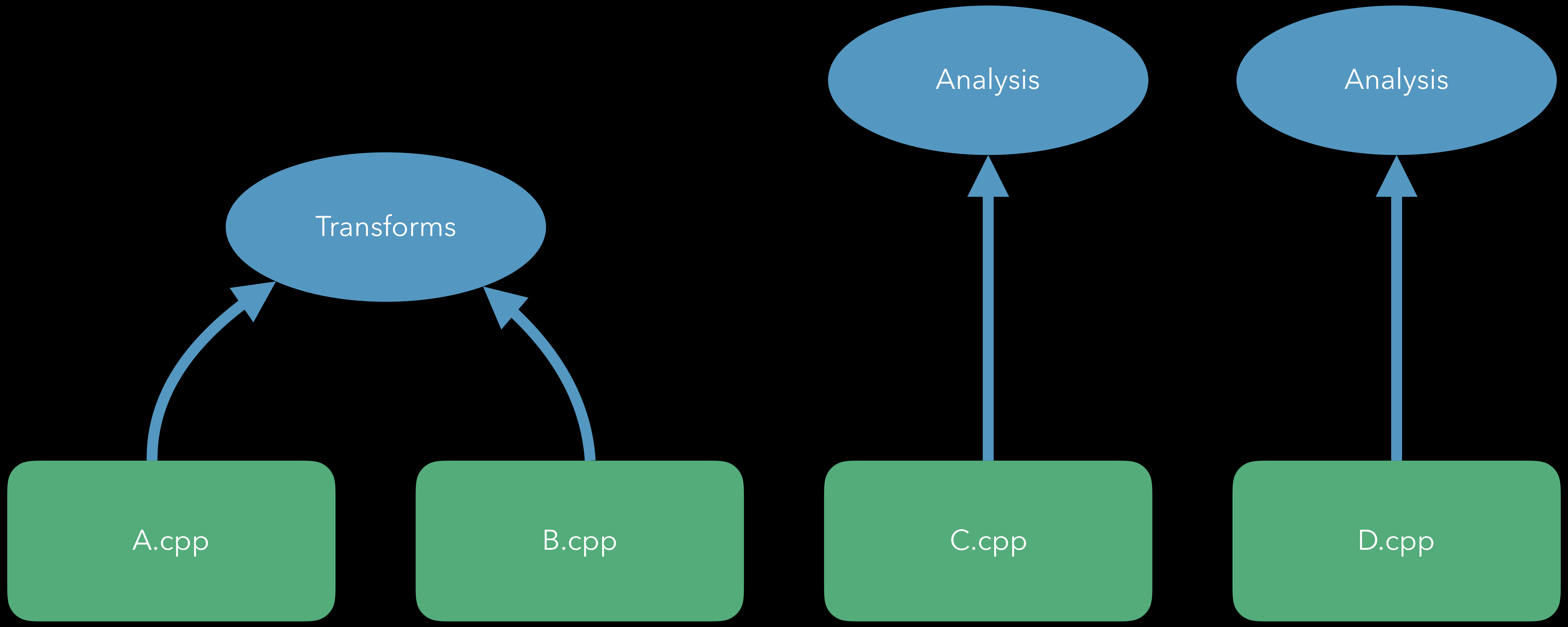

Transcforms

Analysis

Analysis

A.cpp

B.cpp

C.cpp

D.cpp

Implicit Modules

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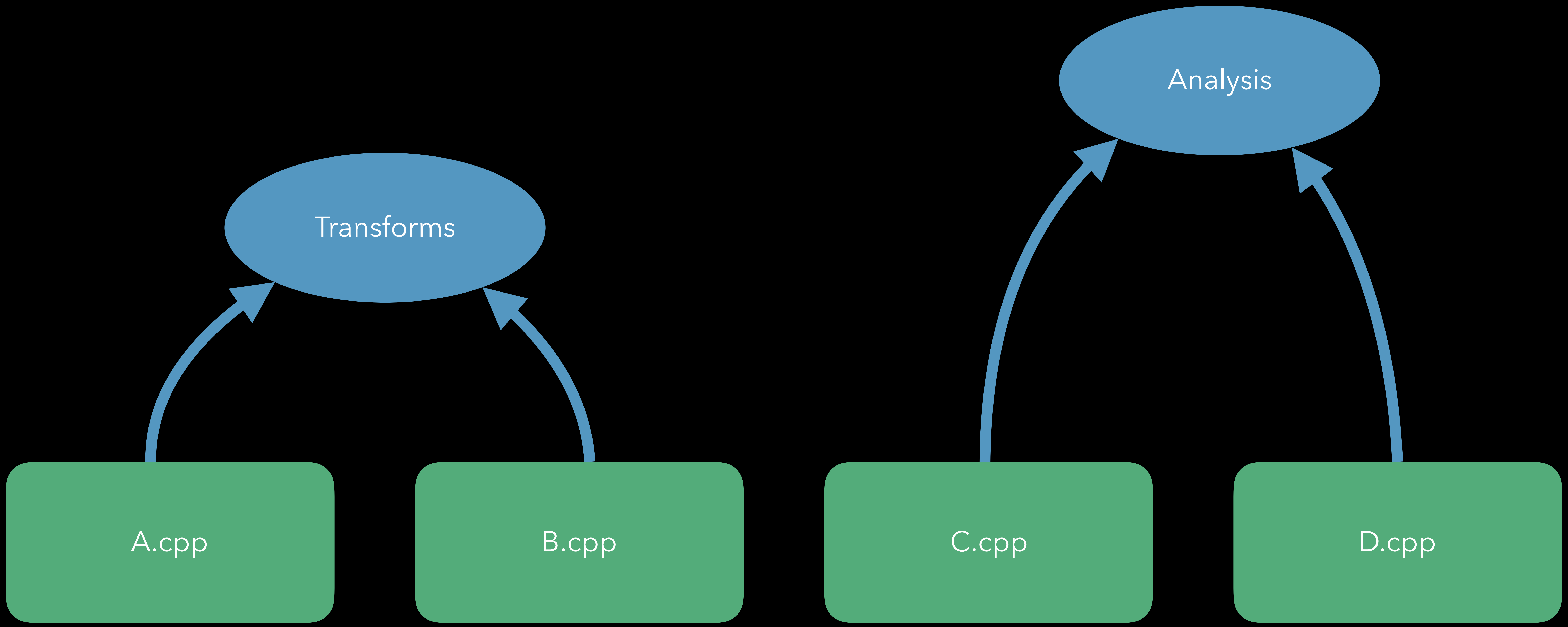

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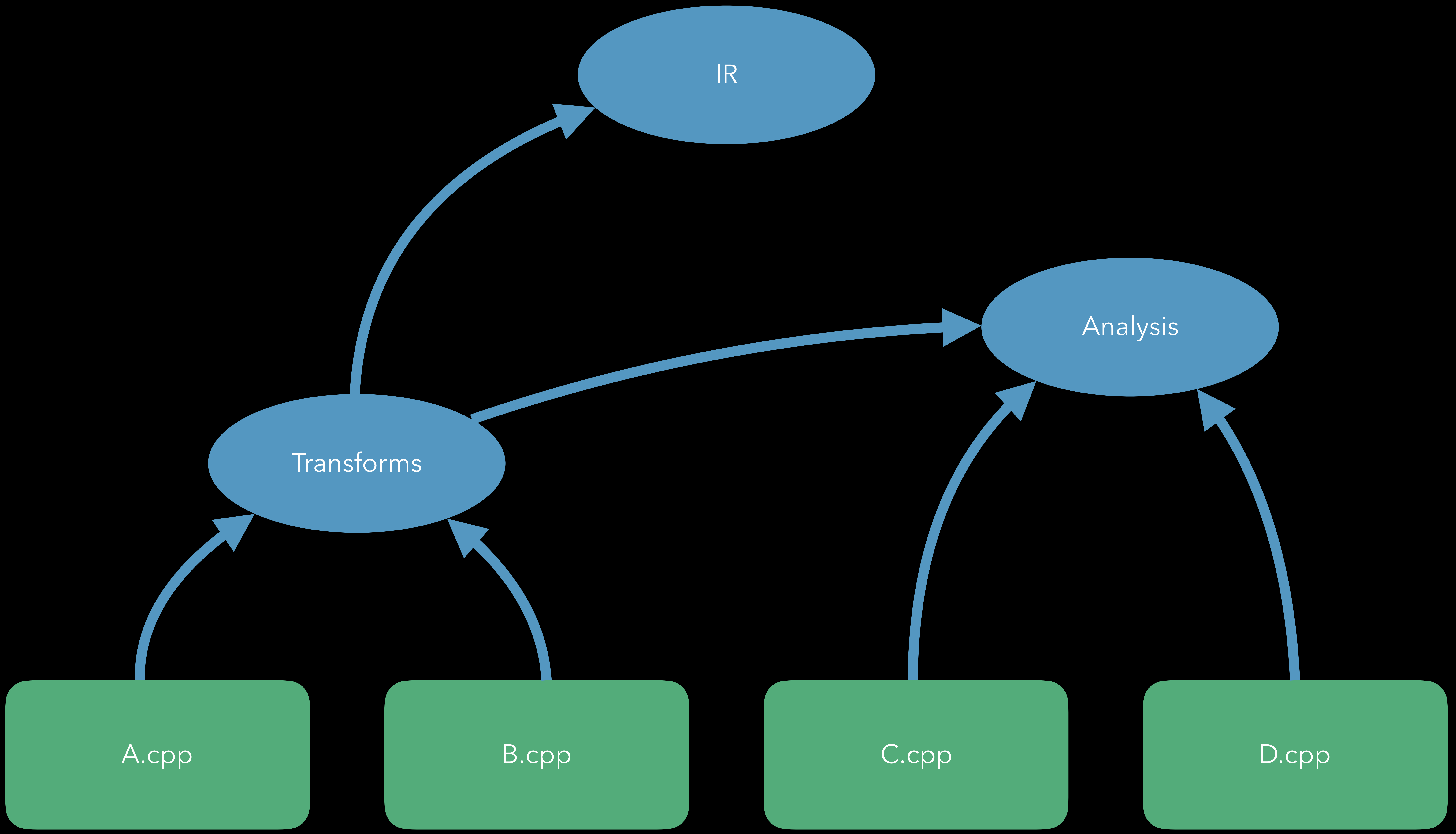

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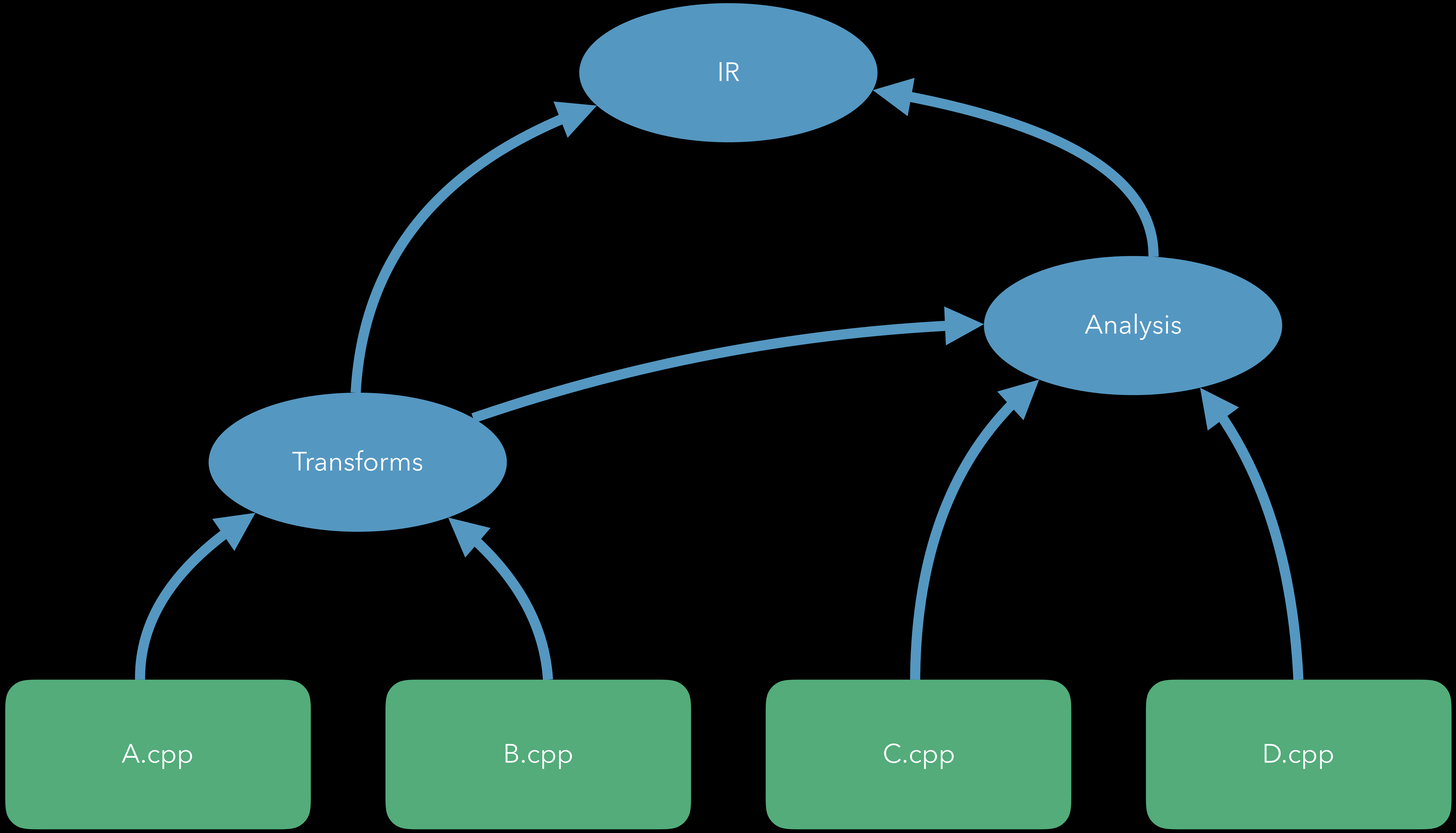

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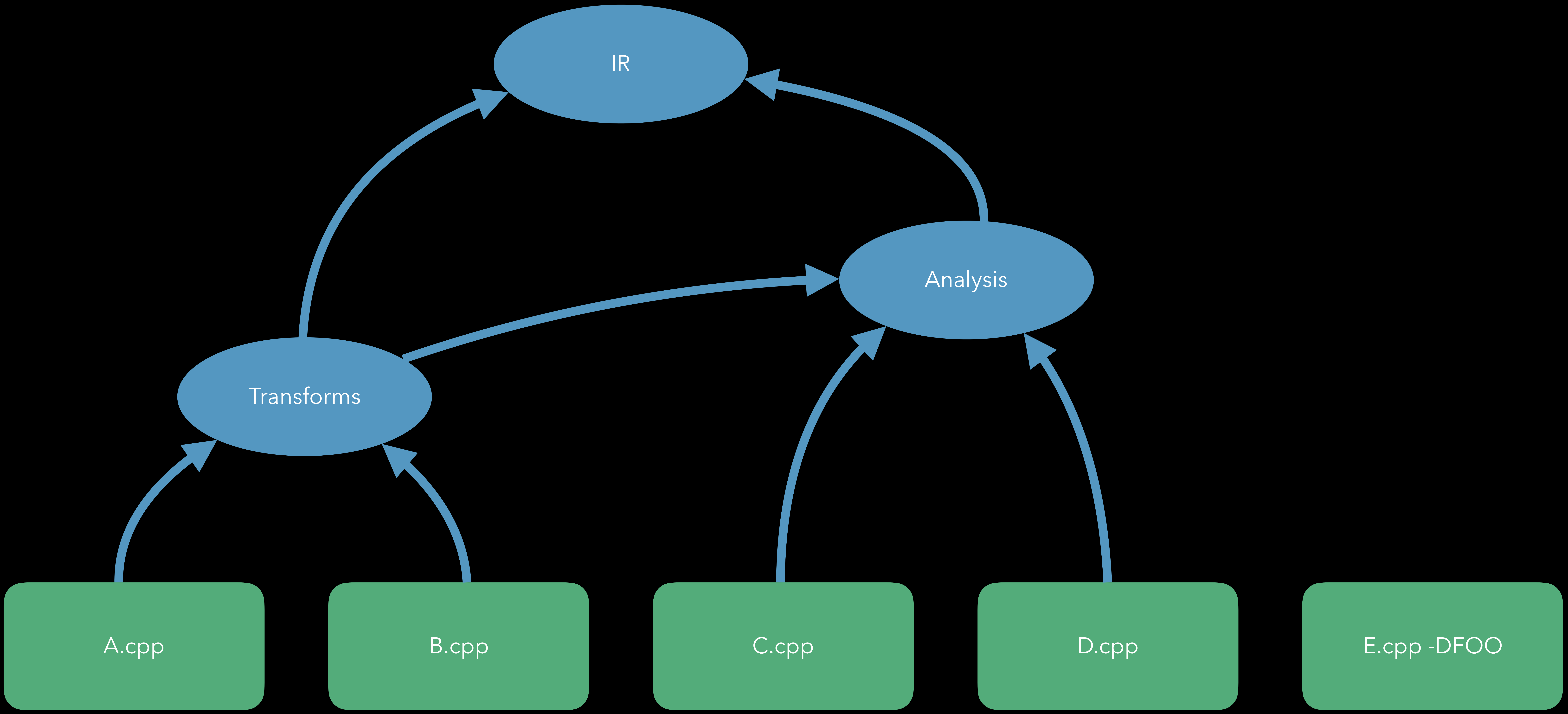

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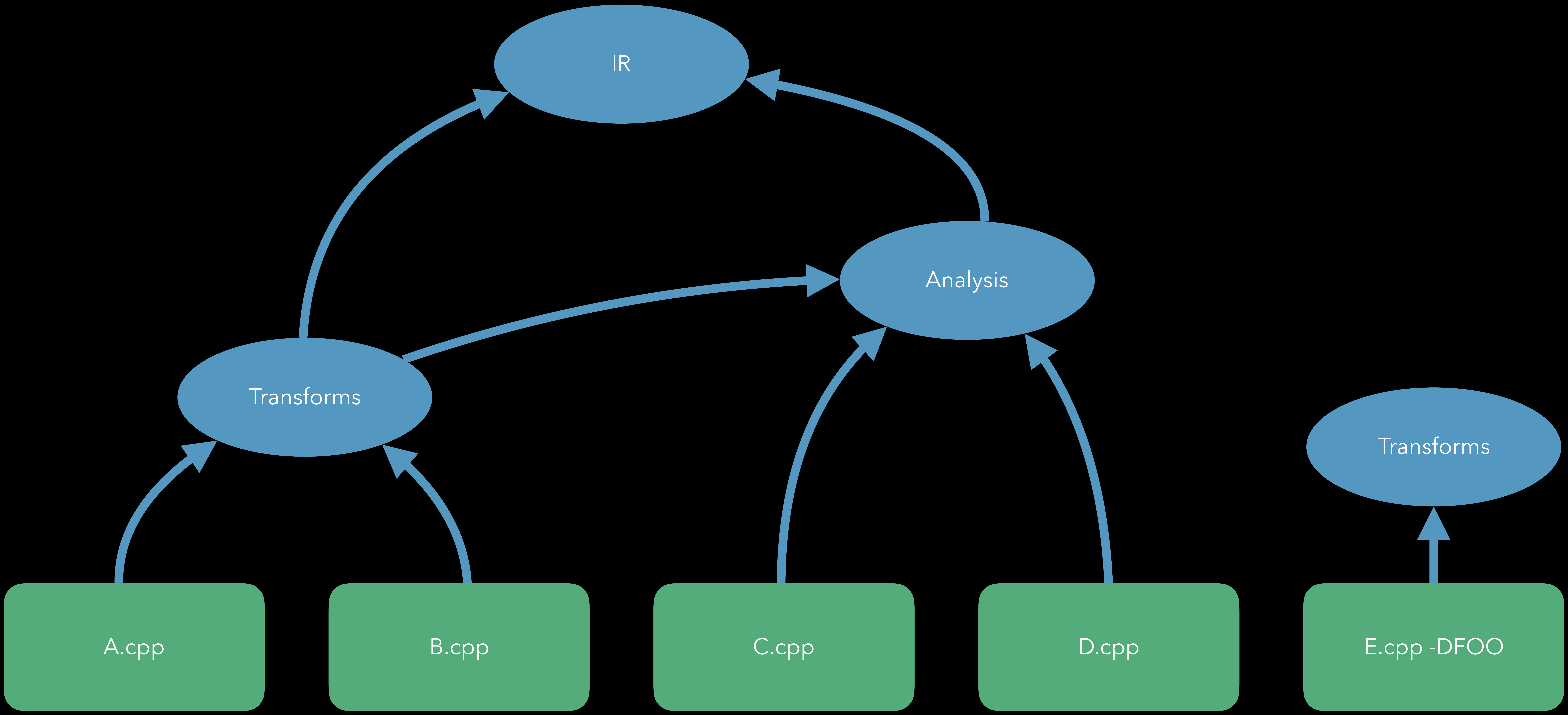

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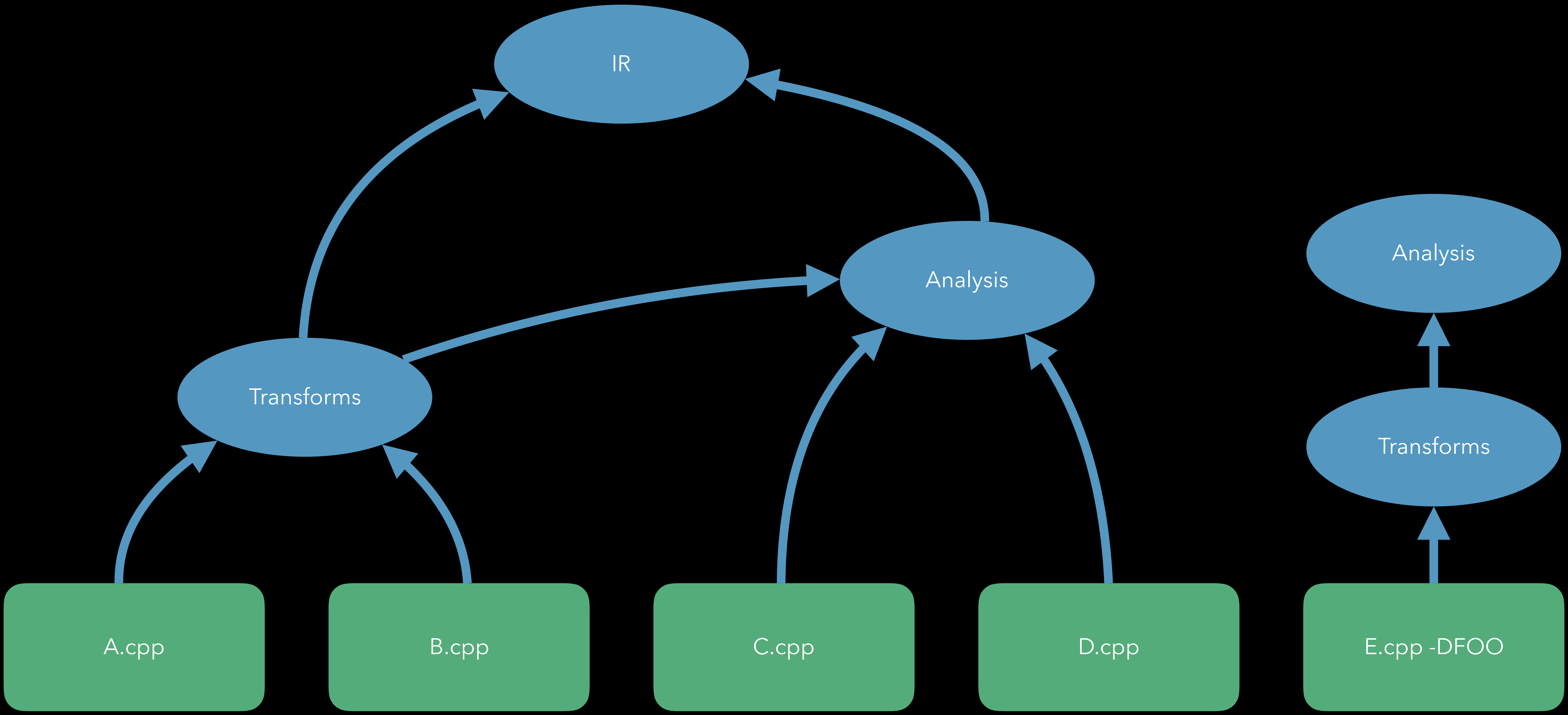

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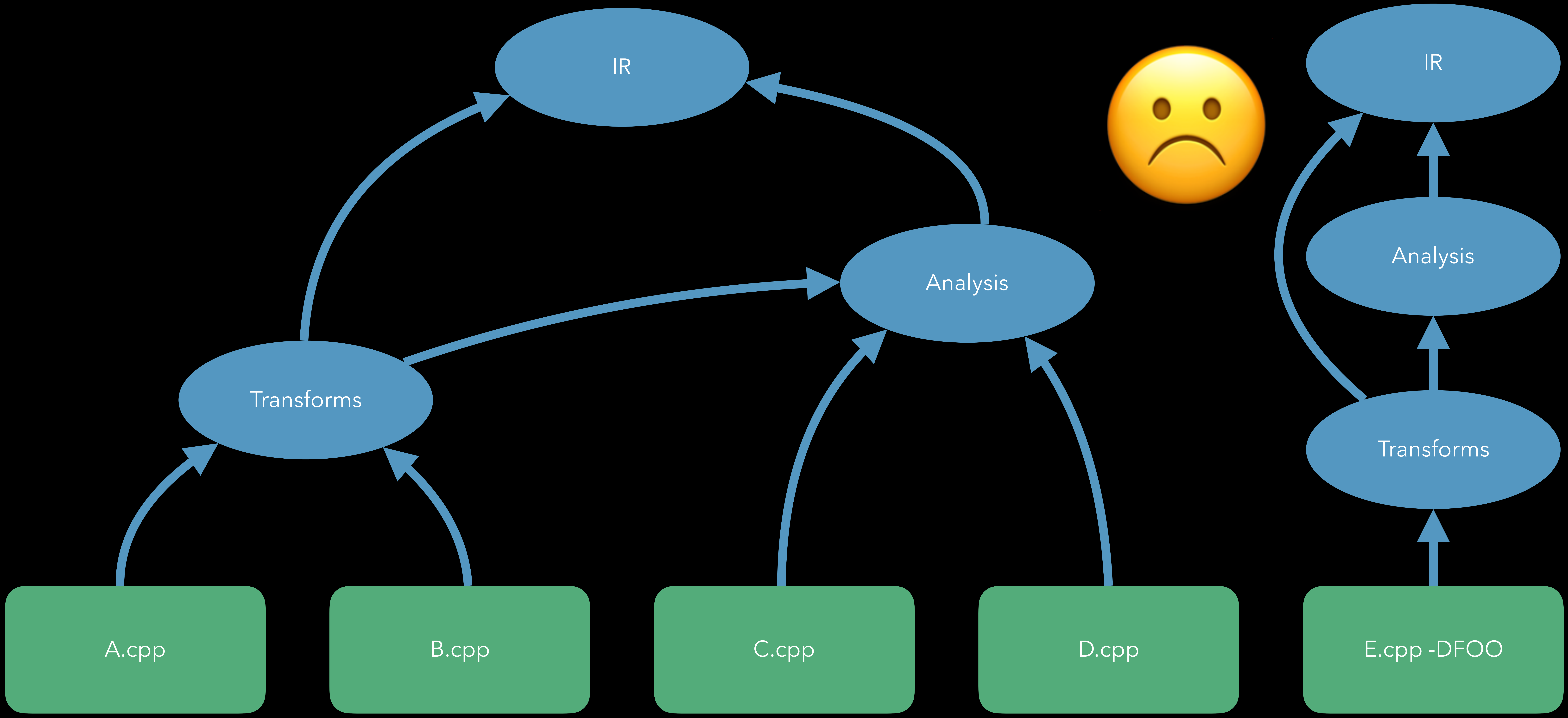

Explicit Modules

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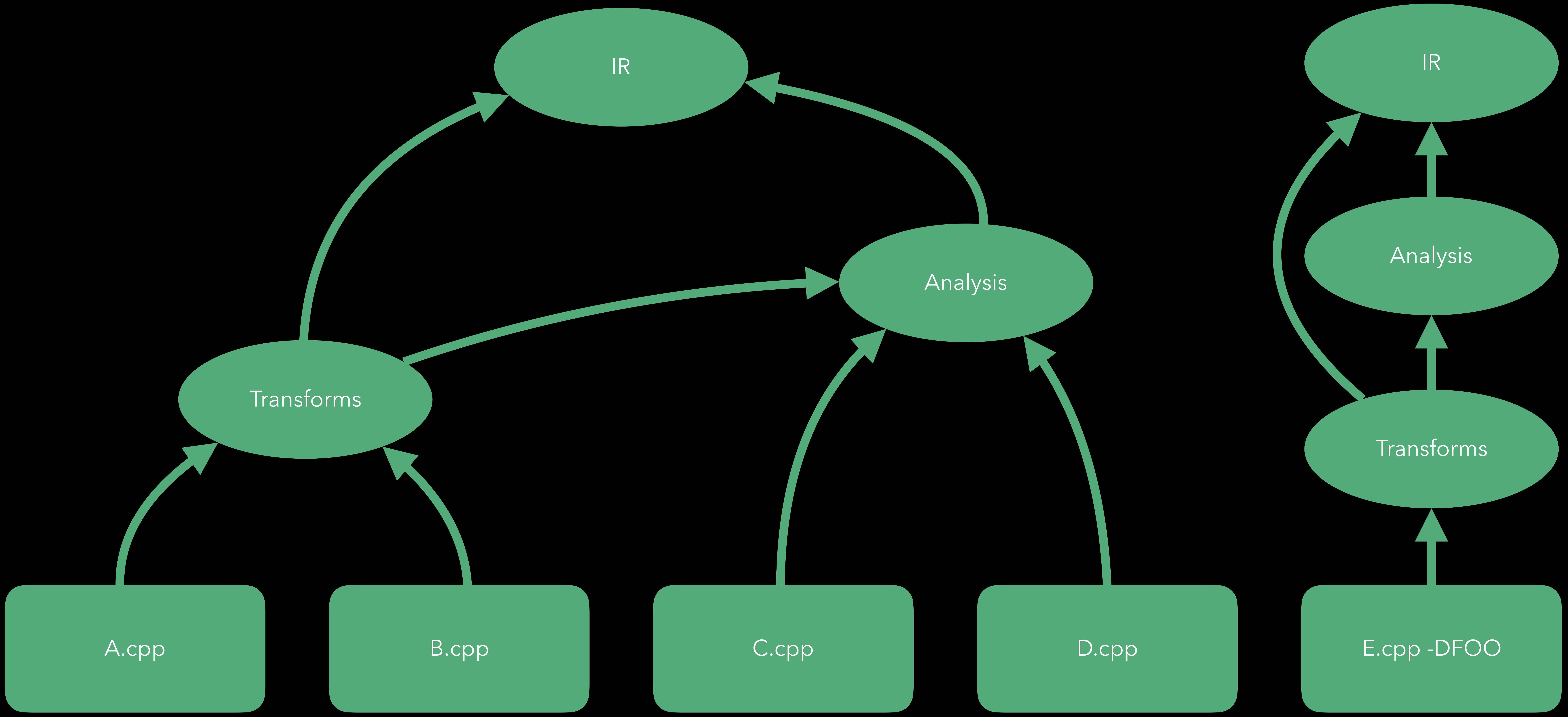


Explicit Clang Modules

- Better model: knowing modular dependencies before compiling
  - Allow more robust and reproducible builds 👍
  - Faster builds 🏎️
- Constraint: users shouldn’t have to specify modular dependencies
- Problem: which modules are needed?
- Solution: dependency discovery build phase for a build target

Clang Modules

Dependency Scanning

Fast Dependency Scanning

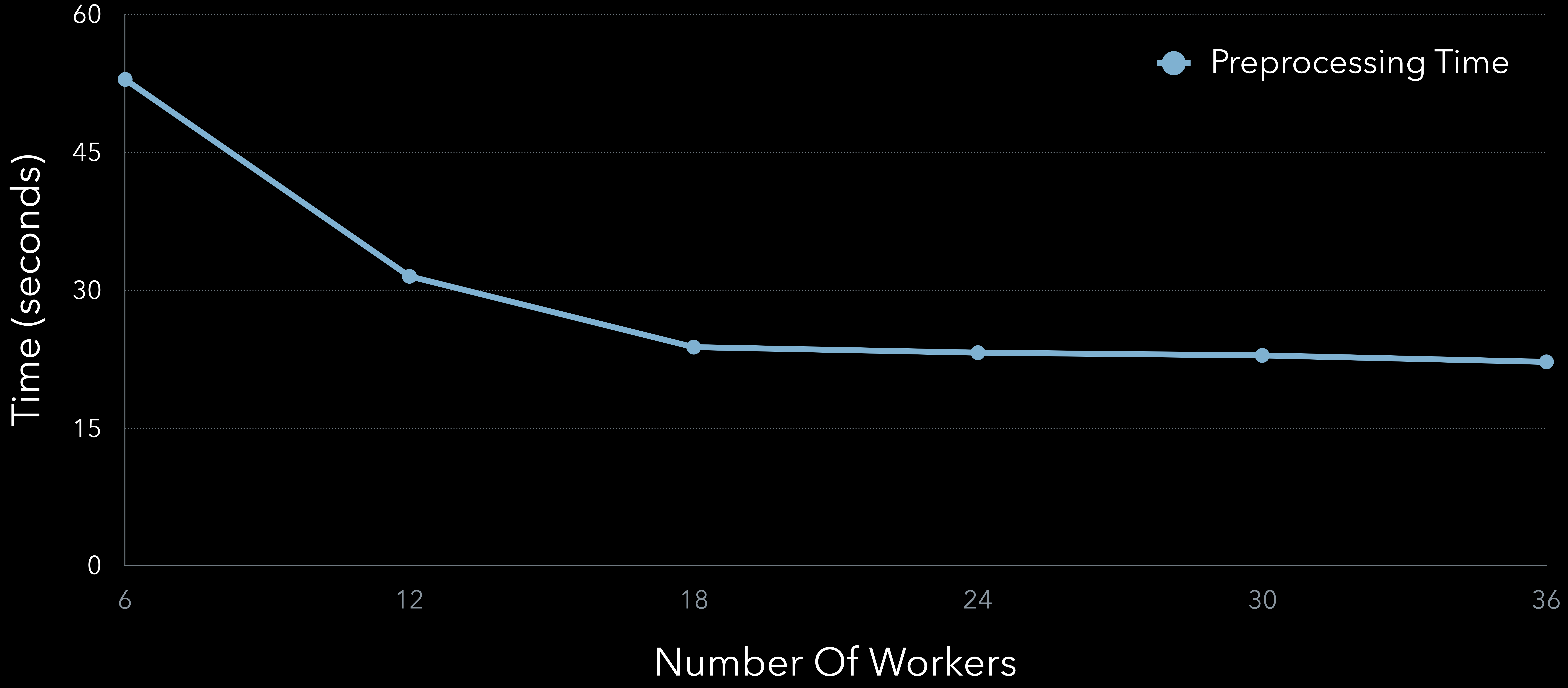
Dependency Extraction

Future Work

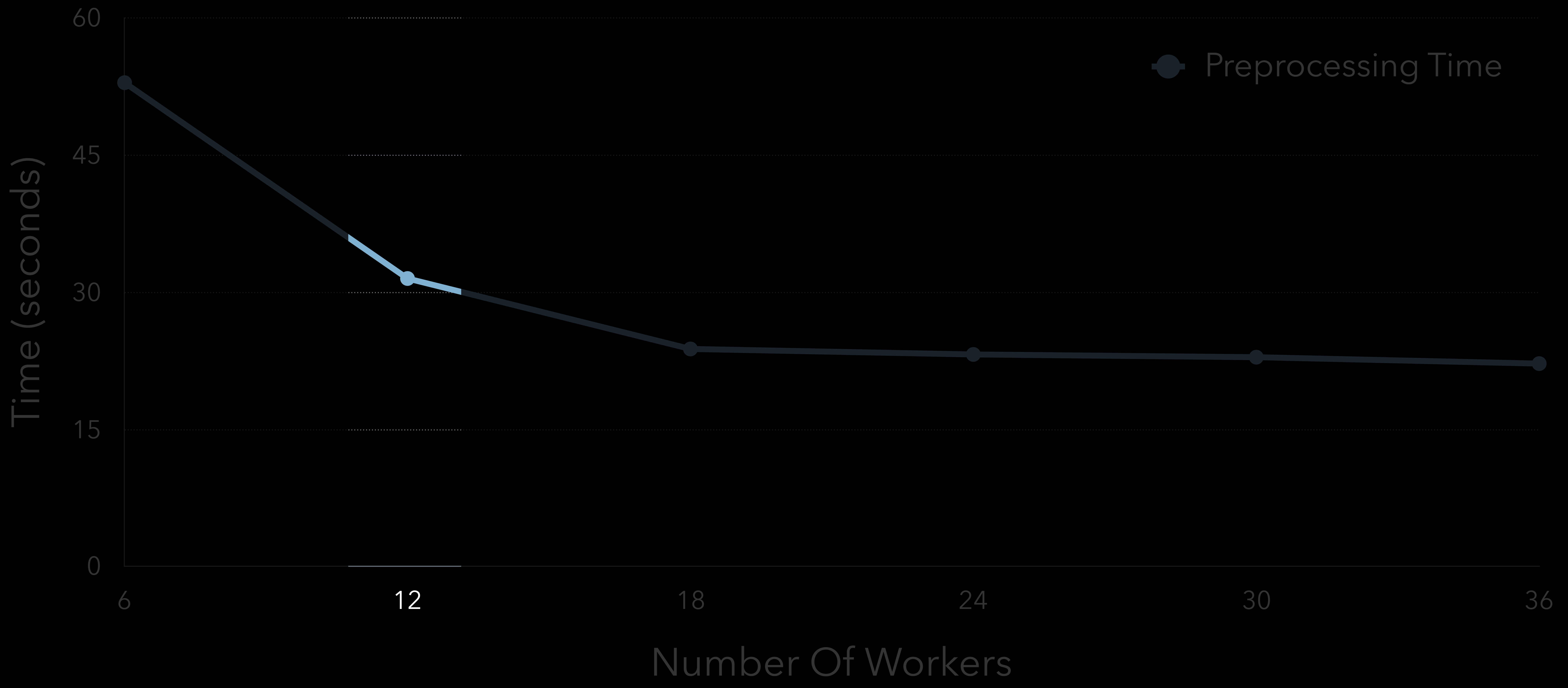
Canonical Dependency Scanning Phase

- Preprocess all translation units of a build target
- Write out included files into a .d
  - `clang -cc1 -Eonly -MT -dependency-file foo.d foo.c`
- How fast is the preprocessor?

Clang and LLVM sources: preprocessing time on an 18-Core iMac Pro



Clang and LLVM sources: the 12 workers scenario



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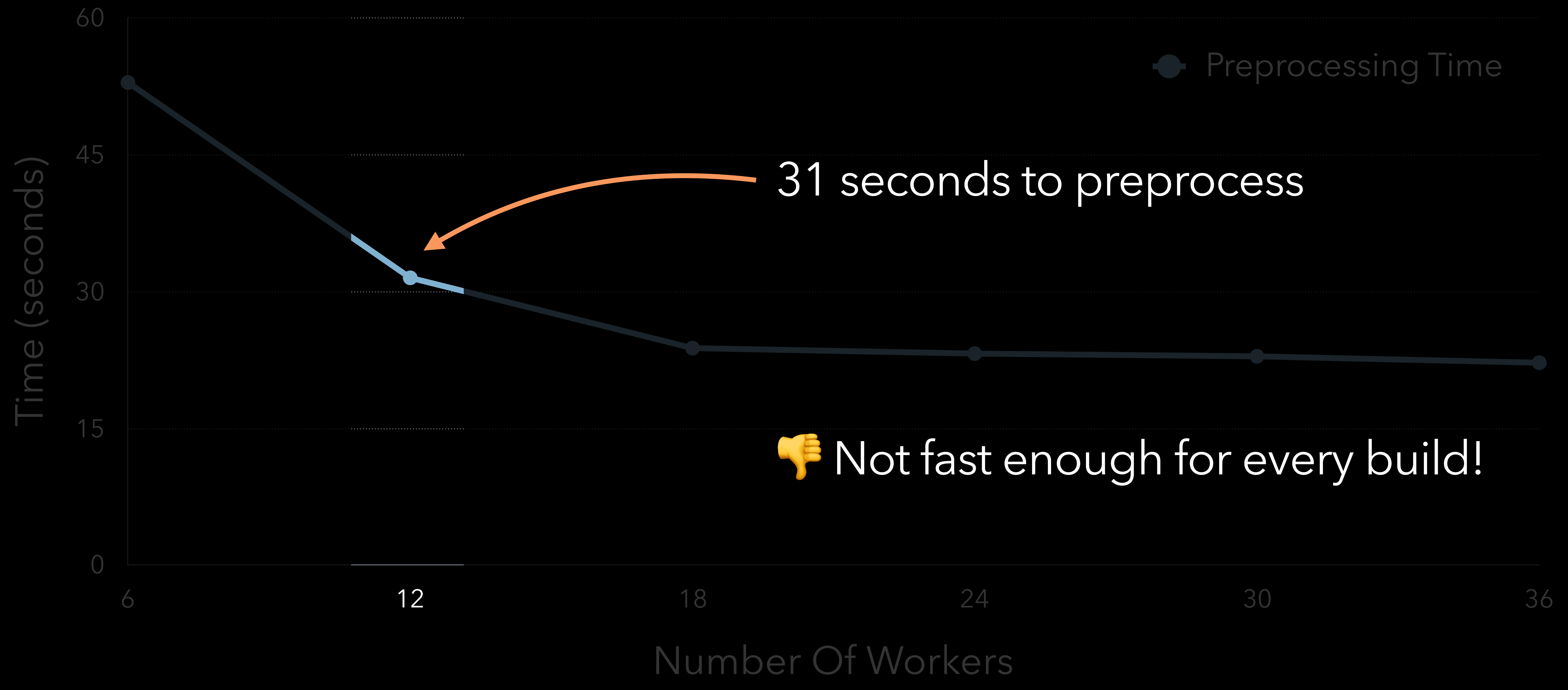

31 seconds to preprocess

👎 Not fast enough for every build!

Clang Modules

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What Does The Preprocessor Do?

```
#ifndef HEADER_FILE
#define HEADER_FILE

#include “Compiler.h”

// Clang is an awesome tool!
class Clang: public Compiler {
public:
  void buildAllCode();
#ifndef NDEBUG
  void dump();
#endif
};

#endif
```

Lex tokens…

Evaluate `#ifndef` & `#define`

Lex more tokens…

Include “`Compiler.h`”

Lex more tokens…

Lex even more tokens 😫

Reducing Preprocessor Workload

```
#ifndef HEADER_FILE
#define HEADER_FILE

#include “Compiler.h”

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Source Minimization

```
#ifndef HEADER_FILE
#define HEADER_FILE
#include “Compiler.h”
#endif
```

Source Minimization

```
#ifndef HEADER_FILE
#define HEADER_FILE
#include “Compiler.h”
#endif
```

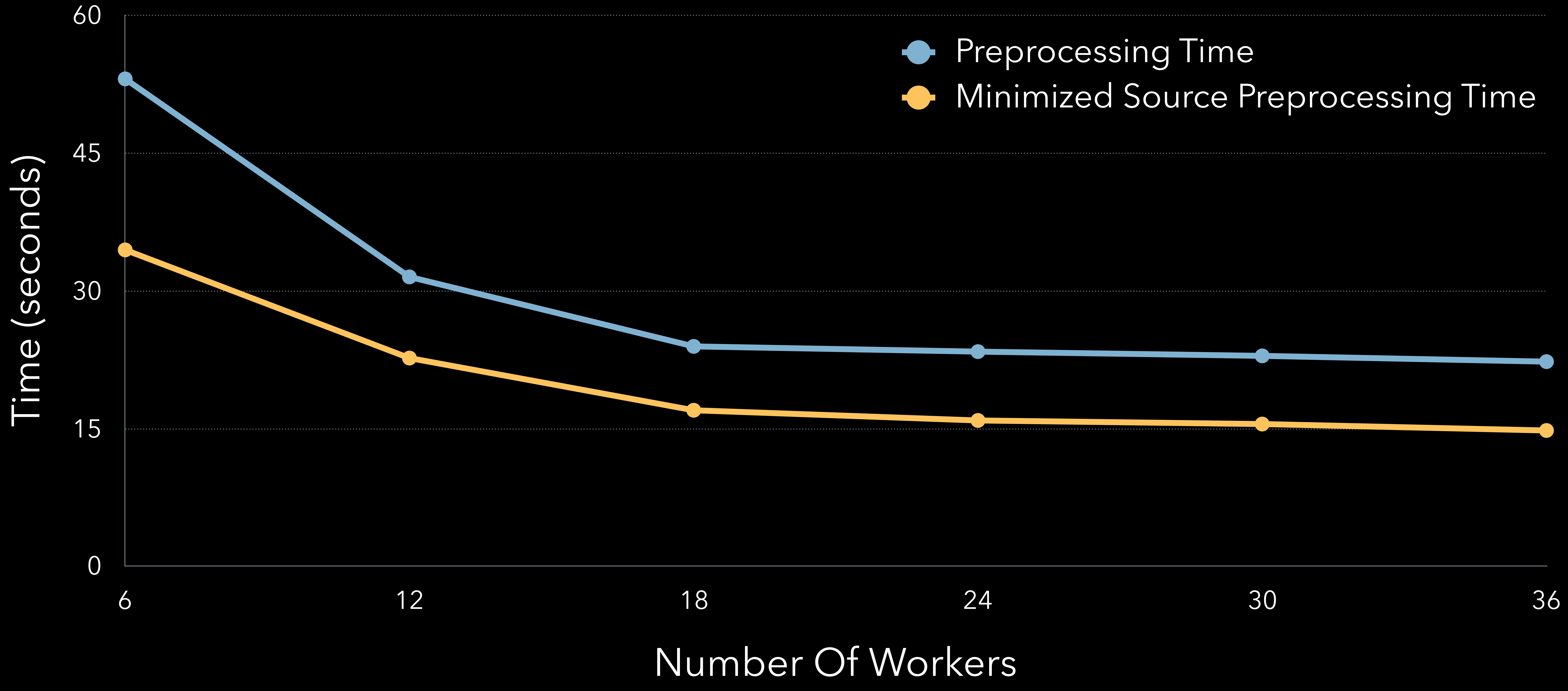
💡

Keep directives that may affect dependency list

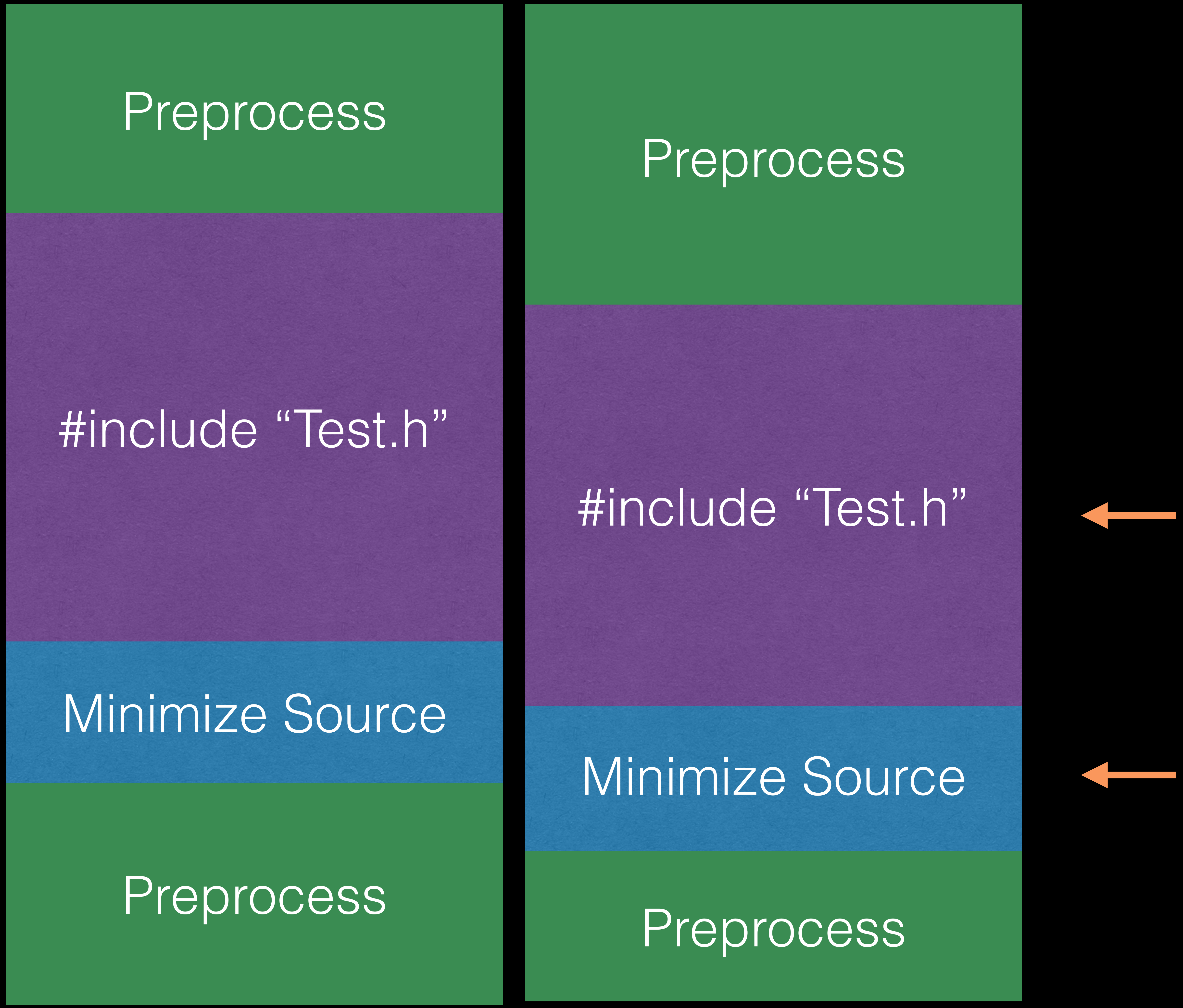
Strip everything else

Context free: source reused in any compilation

Clang and LLVM sources: 30% faster preprocessing



Problem: Clang Invocations



Parallel invocations do redundant work

Read the same file twice

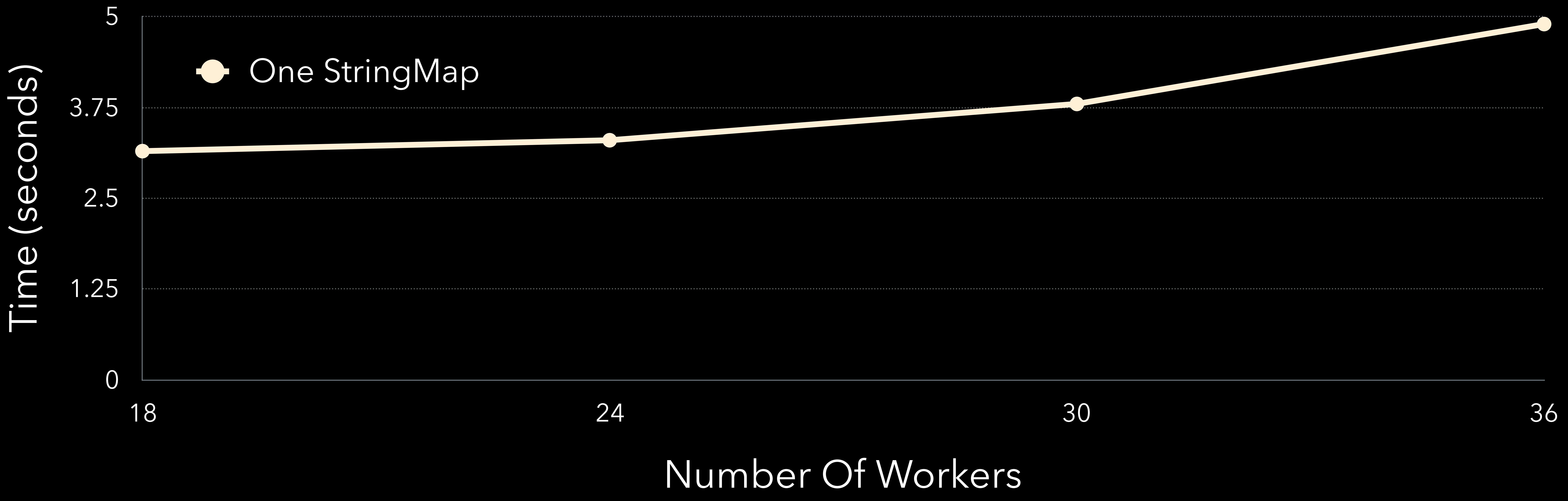
Minimize the same file twice

Introducing clang-scan-deps

- Library and command line tool for dependency scanning
  - Tool currently accepts compilation database and emits dependencies
- Runs preprocessor invocations in parallel
- Efficient: Reads and minimizes a source file only once
  - one shared `FileSystem` with shared minimized file cache
  - one shared `FileManager`

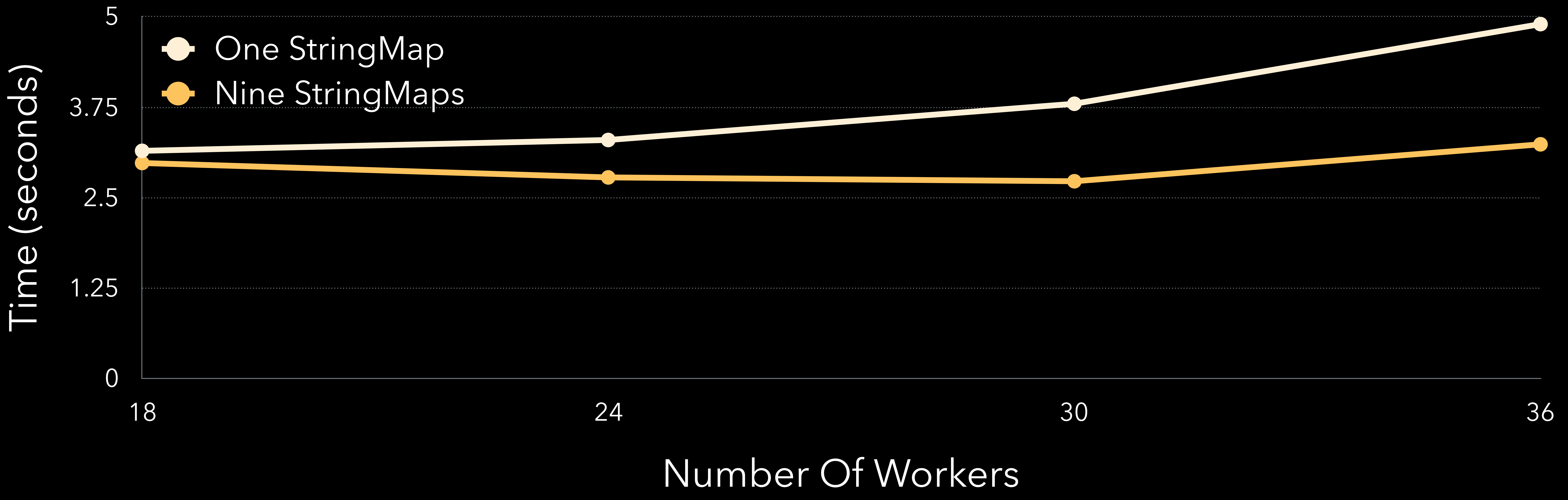
Minimized File Cache

- Maps from file name to cache entry
- Shared by worker threads: lock required access the `StringMap`
- High lock contention for many threads



Optimizing Minimized File Cache

- Solution: Array of `StringMap` addressed by hash of file name



Preprocessor Block Skipping

```
#ifdef NOT_TAKEN

// Important comment
#include “LexMeNot.h”

#elif

#include “IAmLexed.h”

#endif
```

When this **`#ifdef`** is not taken…

The tokens inside it are lexed…

Until the **`#elif`** is found

Took up to 10-15% of time in our profiles 😫

Optimizing Preprocessor Block Skipping

```
#ifdef NOT_TAKEN

// Important comment
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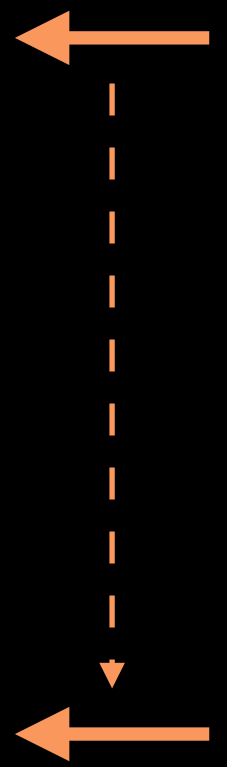
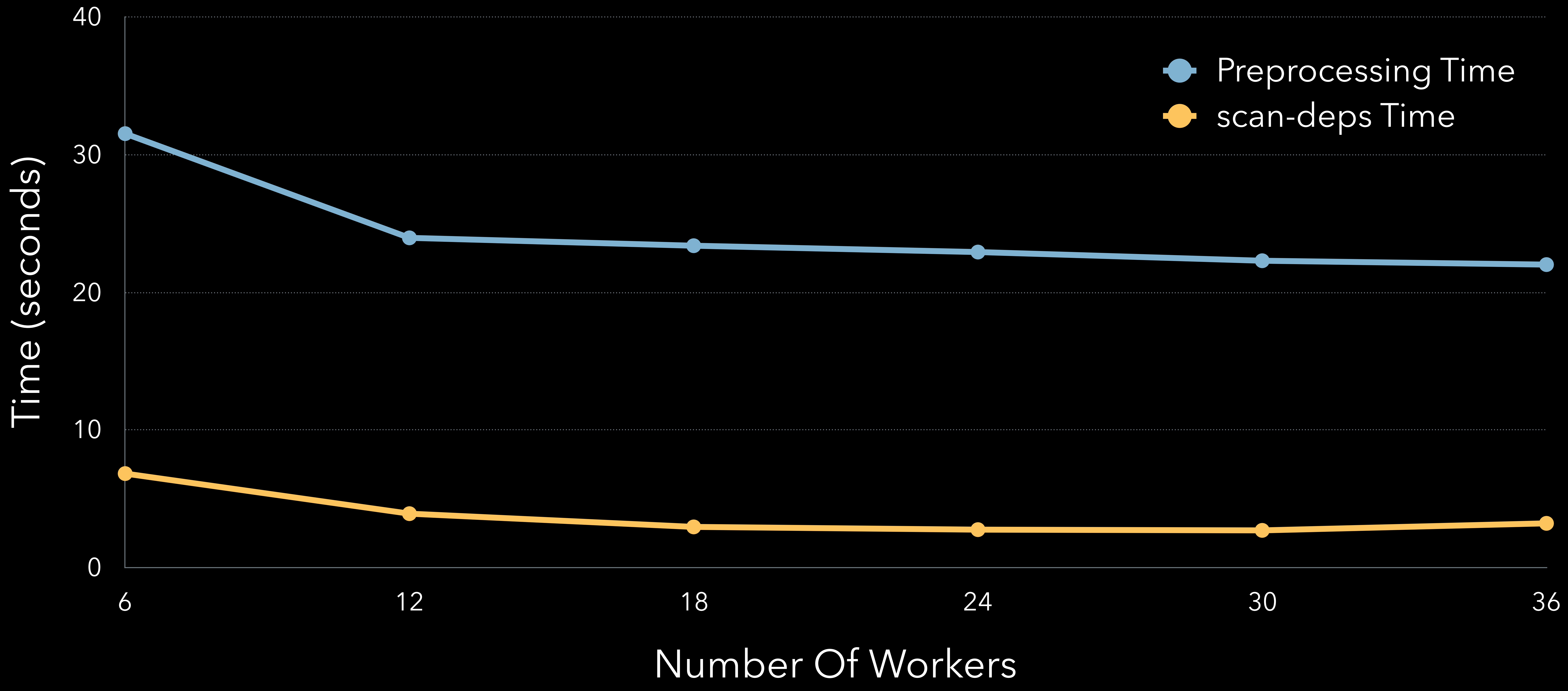


When this **`#ifdef`** is not taken…

Skip to **`#elif`**: add offset to Lexer’s pointer

Offset computed when minimizing file 😃

Clang and LLVM sources: 5-10x faster dependency scanning



Things We Aren’t Going To Support

```
#define AT_IMPORT @import

AT_IMPORT Foundation;

#define WHY(X) _##X ("clang module import X")

WHY(Pragma);
```

➡ We want to disallow this behavior in Clang

Modular Dependencies

- clang-scan-deps builds implicit modules with minimized files
  - For now still uses old implicit module build machinery 🙈
- Dependencies are extracted from the fast implicit build

Clang Modules

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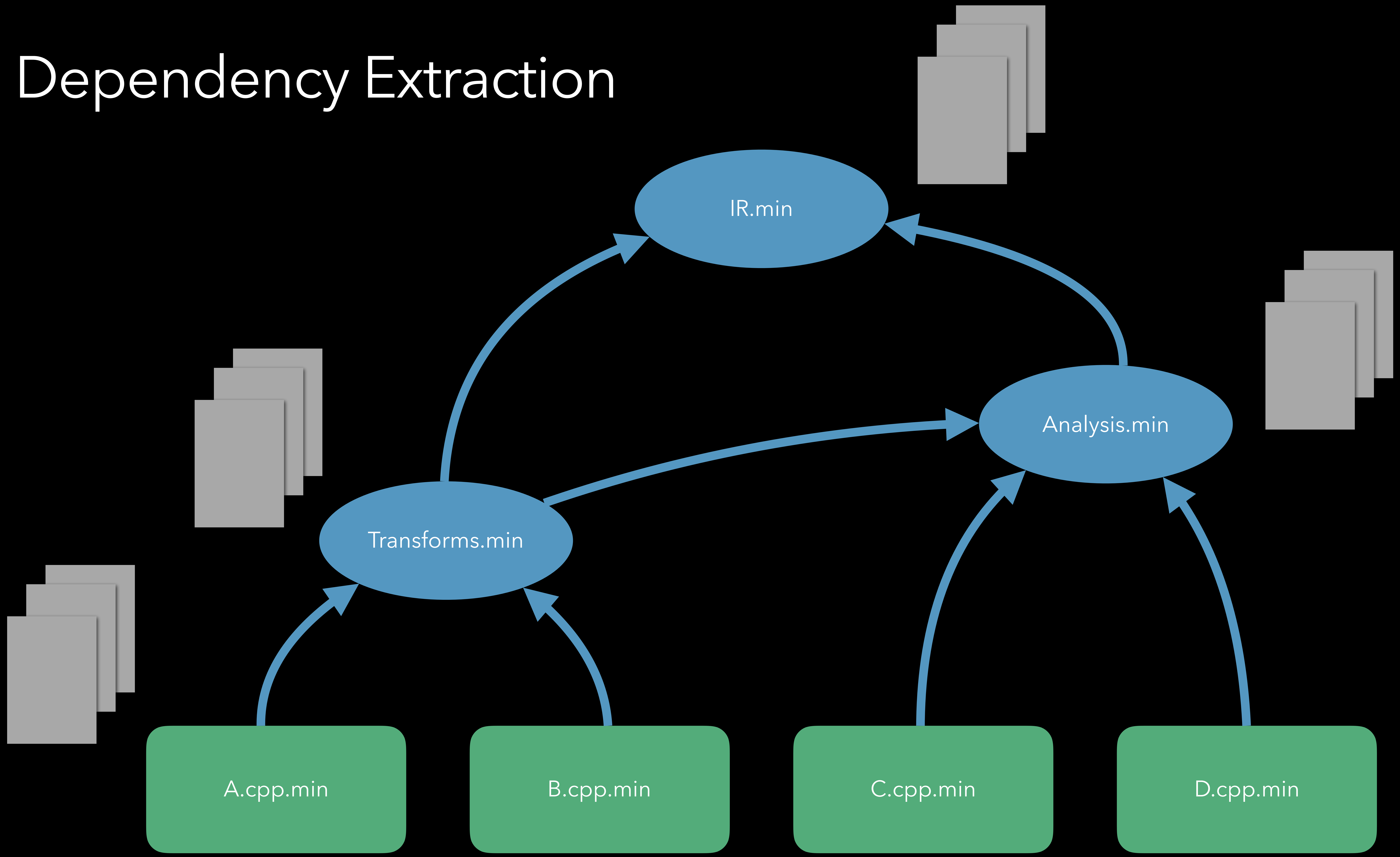
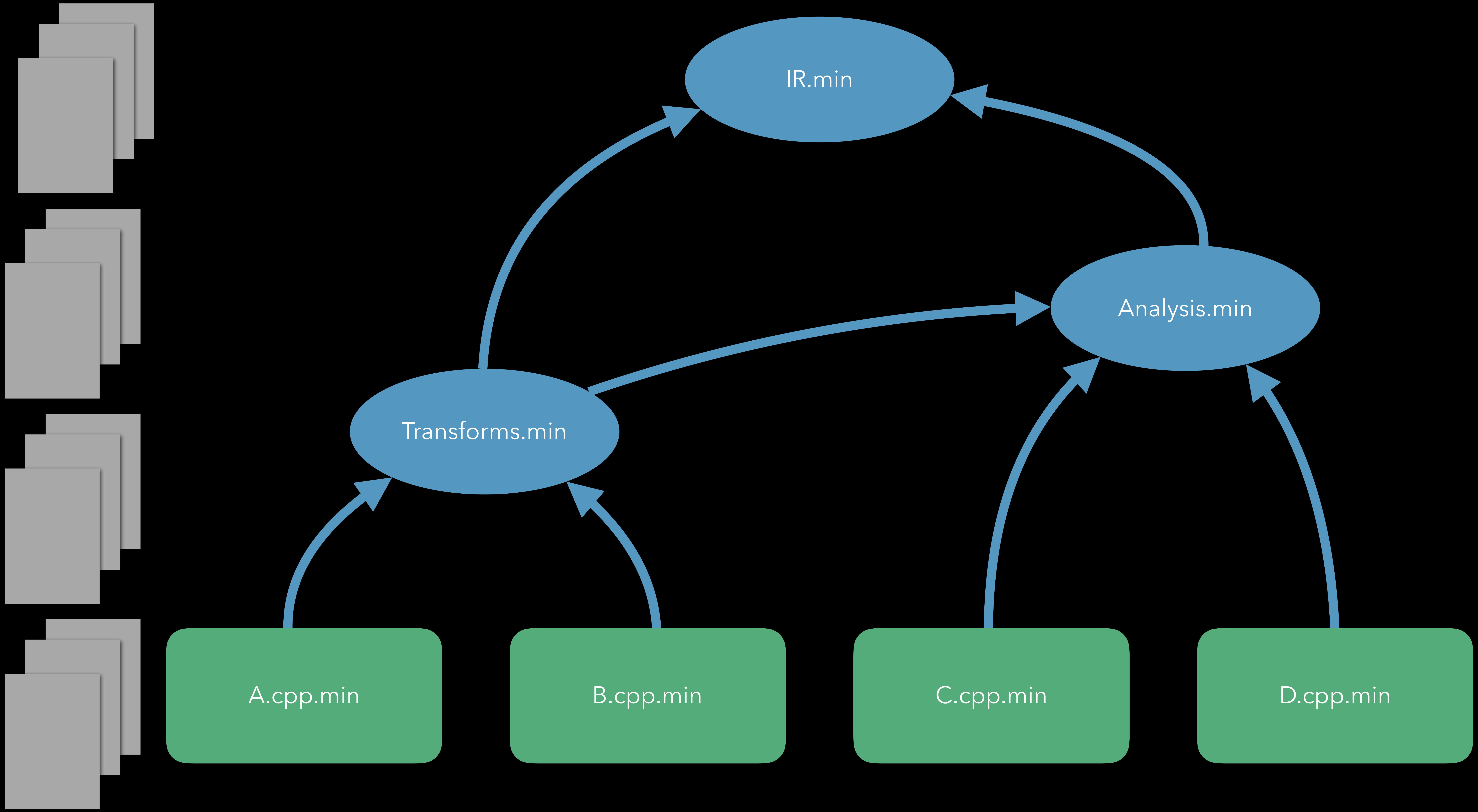
Dependency Extraction



Dependency Extraction



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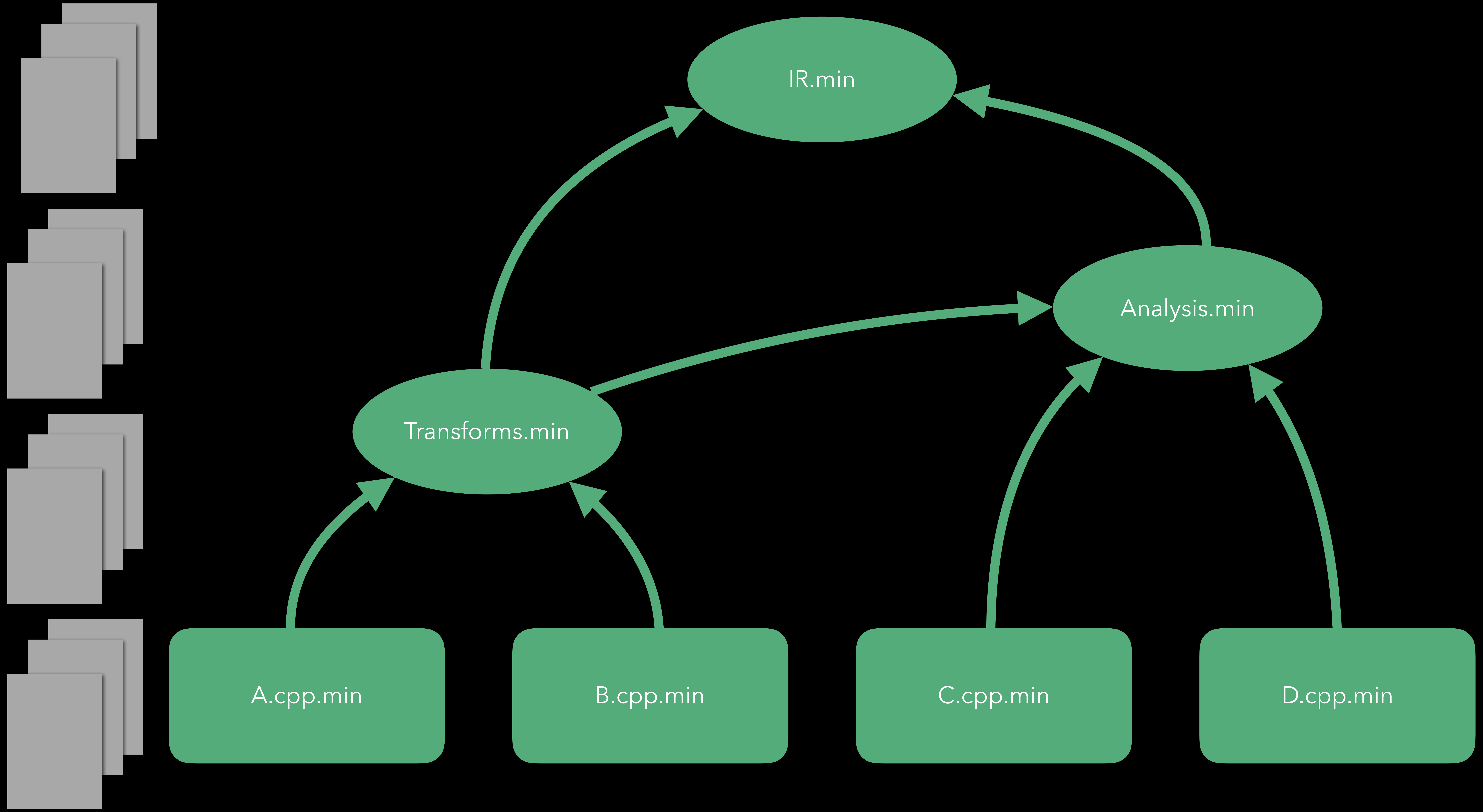
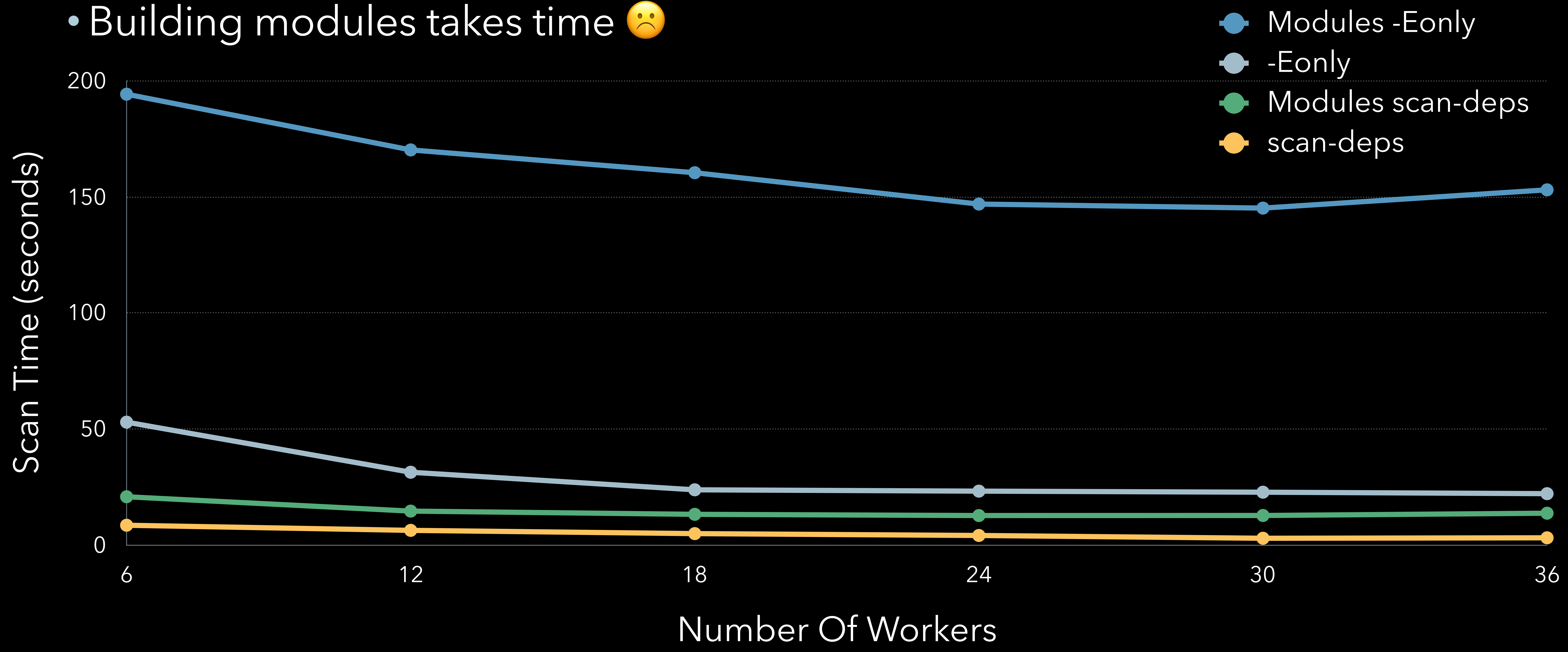


Dependency Extraction

```
build LLVM_Transforms.pcm: cxx_explicit_module
    llvm/include/llvm/module.modulemap | LLVM_IR.pcm LLVM_Analysis.pcm std.pcm
  module_id = LLVM_Transforms
  moduledeps = -fmodule-file=LLVM_Config_Config.pcm -fmodule-file=std.pcm
               -fmodule-file=LLVM_IR.pcm -fmodule-file=LLVM_Analysis.pcm
  args = builds/release/bin/clang++ -cc1 -fmodules ...
```

Initial Results - Scanning

- Faster than modules -Eonly and -Eonly, but slower than scan-deps
- Building modules takes time ☹️



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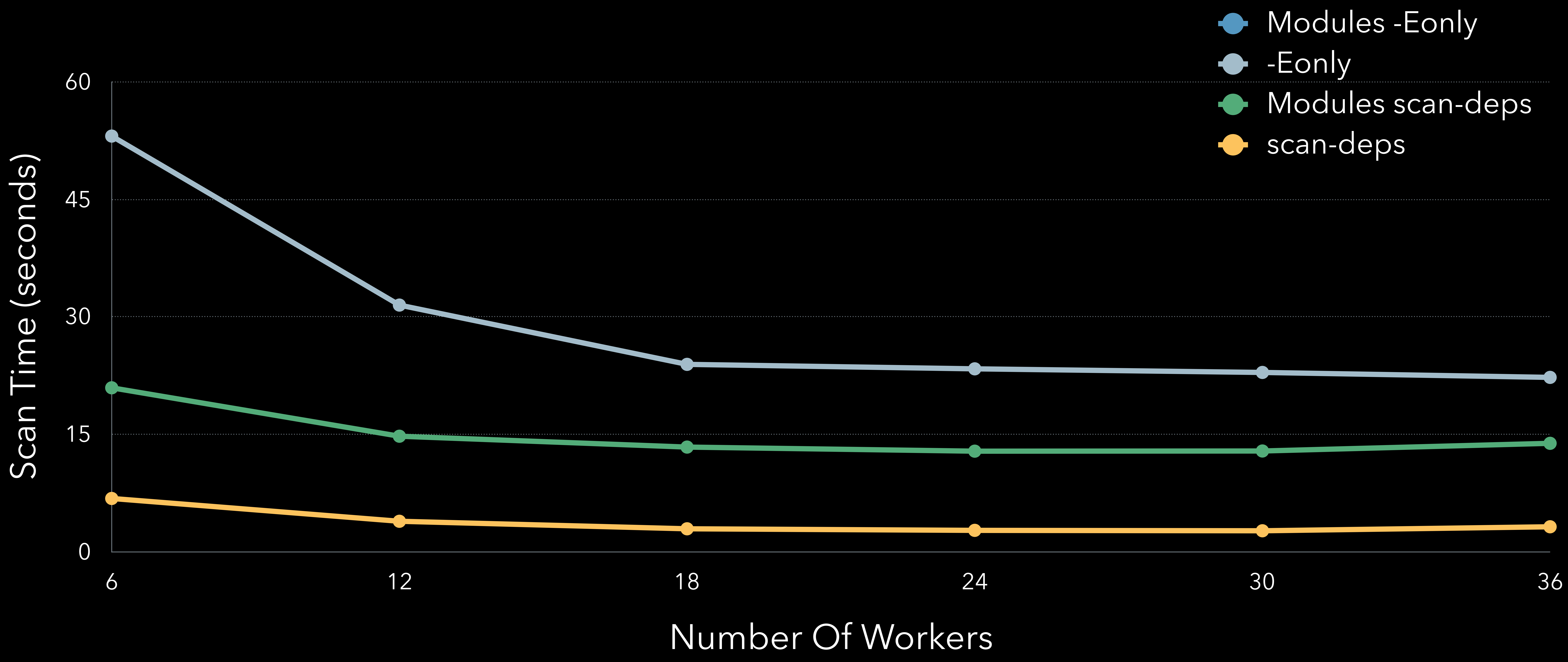
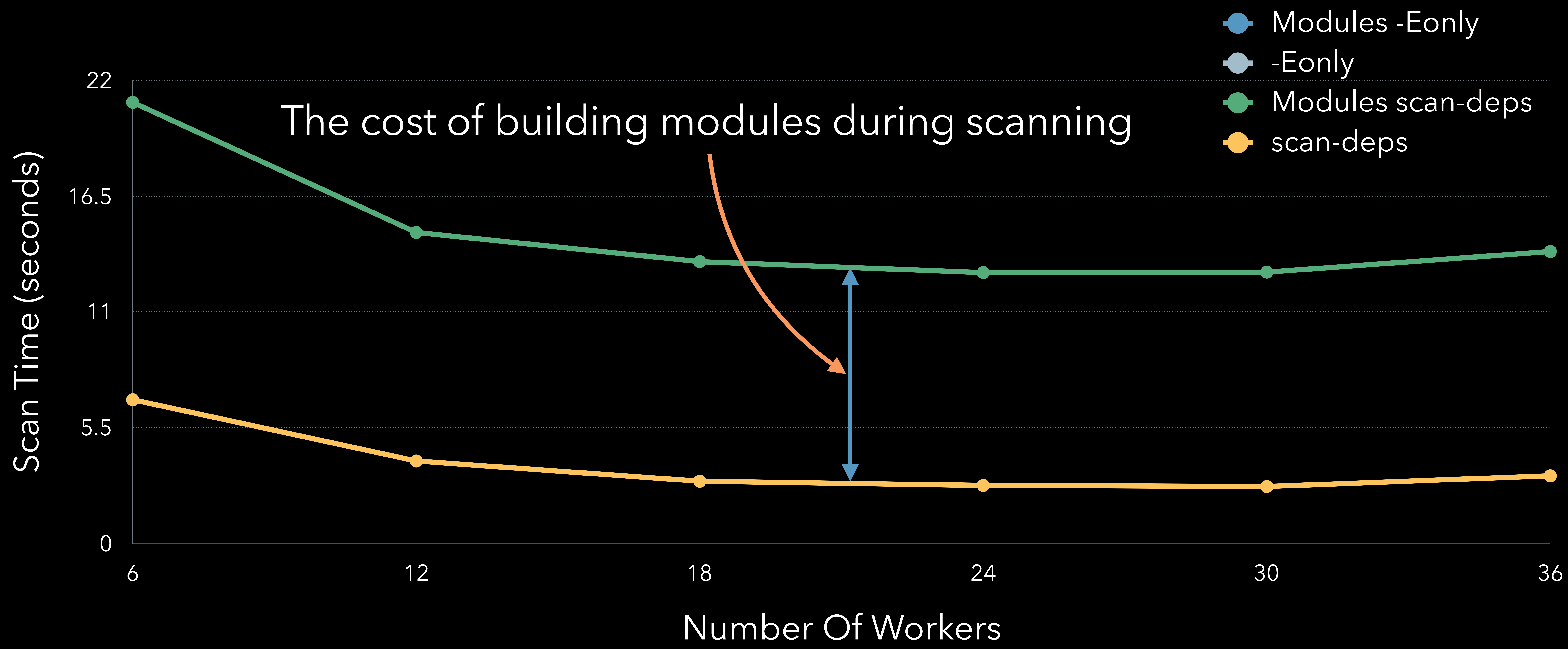


Initial Results - Scanning



The cost of building modules during scanning

Initial Results - Building

- About 5-15% speedup on an 18-Core iMac Pro

Implicit
Scan + Explicit
Explicit
1300
975
650
325
0
Build Time (seconds)
6
12
18
24
30
36
Number Of Workers

Bugs 🐞

- Implicit and Explicit modules behave differently
- Different ideas about textual headers vs. modular headers
    - Changes dependencies
- Implicit creation of module maps for frameworks
- Different code paths

Clang Modules

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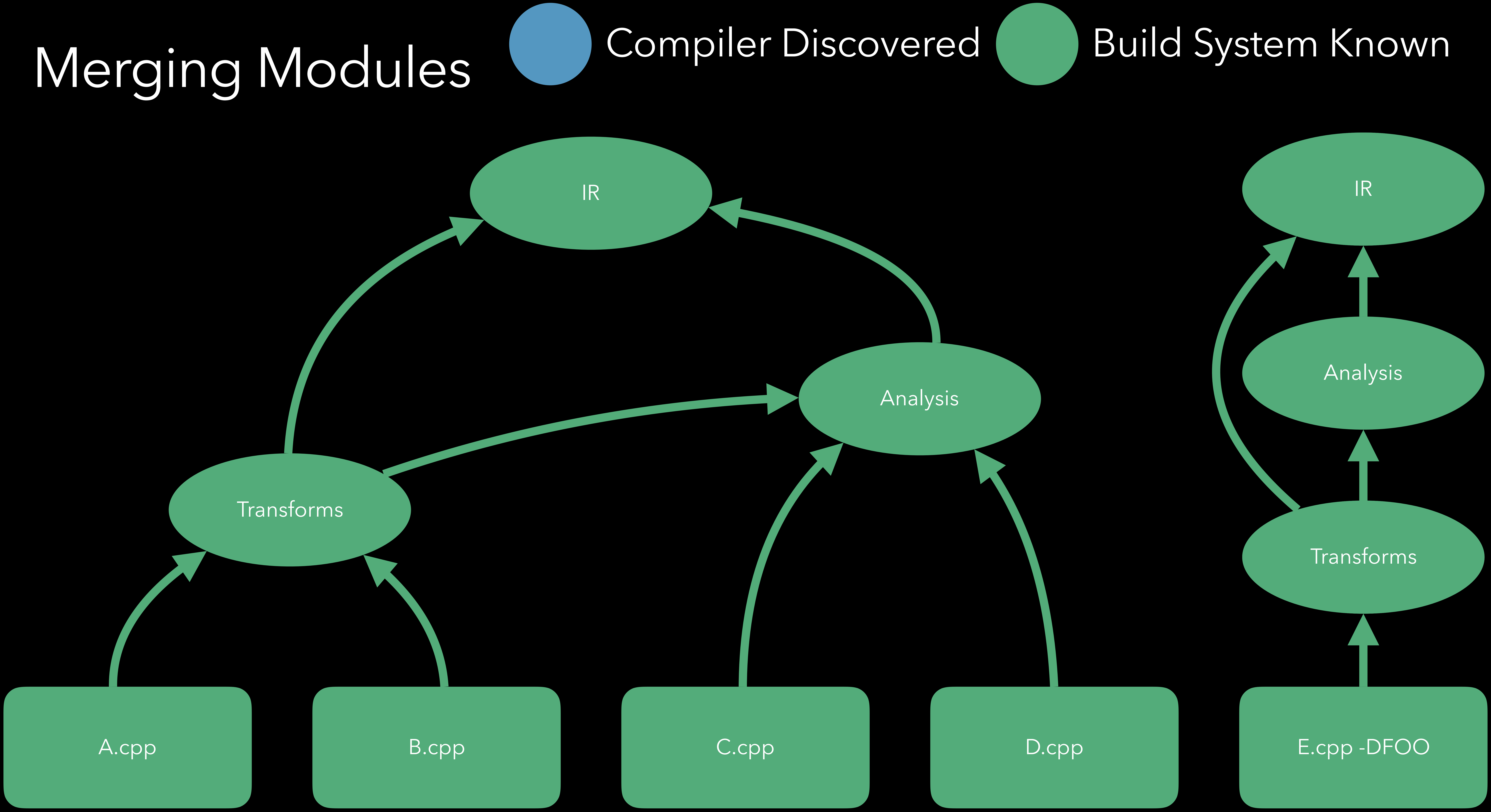
Future Work

Future Work

- Optimize
  - Don’t build modules, just need deps
  - Cache results, don’t write to disk
  - Incremental
  - Merge the build graph for compatible modules

Merging Modules



Merging Modules

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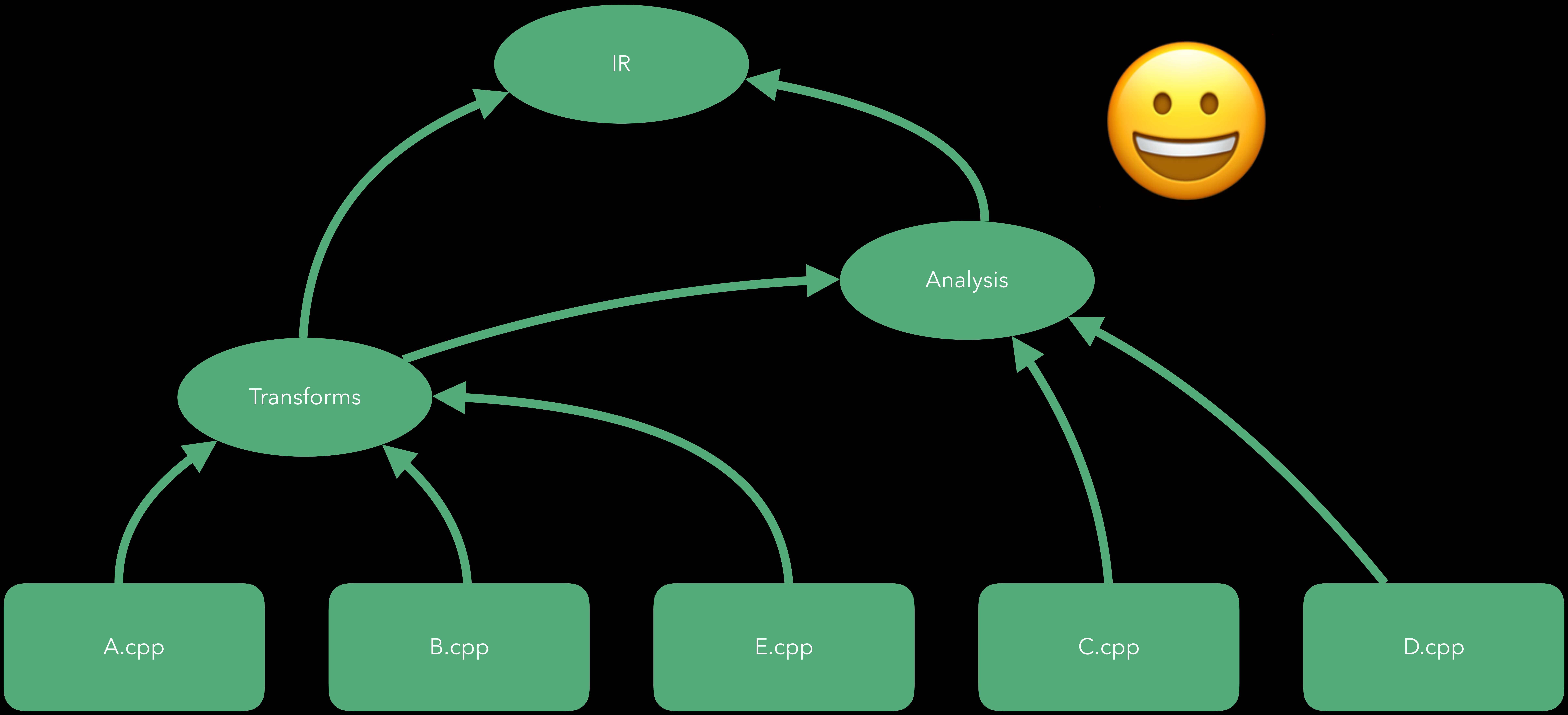

Future Optimization

Future Work

- Optimize
  - Don’t build modules, just need deps
  - Cache results, don’t write to disk
  - Incremental
  - Merge the build graph for compatible modules
- C++20 Modules
  - Support for `import module` and `import <header>`
- Upstream
  - Patches: https://reviews.llvm.org/D55463, D60233

Questions?

clang-scan-deps – Fast Dependency Scanning For Explicit Modules
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