Swift Explicitly-Built Modules

Artem Chikin

LLVM Dev Meeting 2024

Modules in Swift

By-design, Swift programs are composed of a number of modules which represent units of code distribution and correspond to binary products.

SDelegate.swift

```swift
import UIKit
import SwiftUI

public class SceneDelegate: UIResponder, UIWindowSceneDelegate {

    public var window: UIWindow?

    public func scene(_ scene: UIScene,
                      willConnectTo session: UISceneSession) {
        let contentView = ContentView()
        if let windowScene = scene as? UIWindowScene {
            let window = UIWindow(windowScene: windowScene)
            self.window = window
            window.makeKeyAndVisible()
        }
    }
}
```

Helper.swift

```swift
import UIKit
import SwiftUI

public class SomeOtherClass: UIResponder, UIWindowSceneDelegate {

    public var makethismoredifferent: UIWindow?

    public func andmakesense(_ scene: UIScene,
                             willConnectTo session: UISceneSession) {
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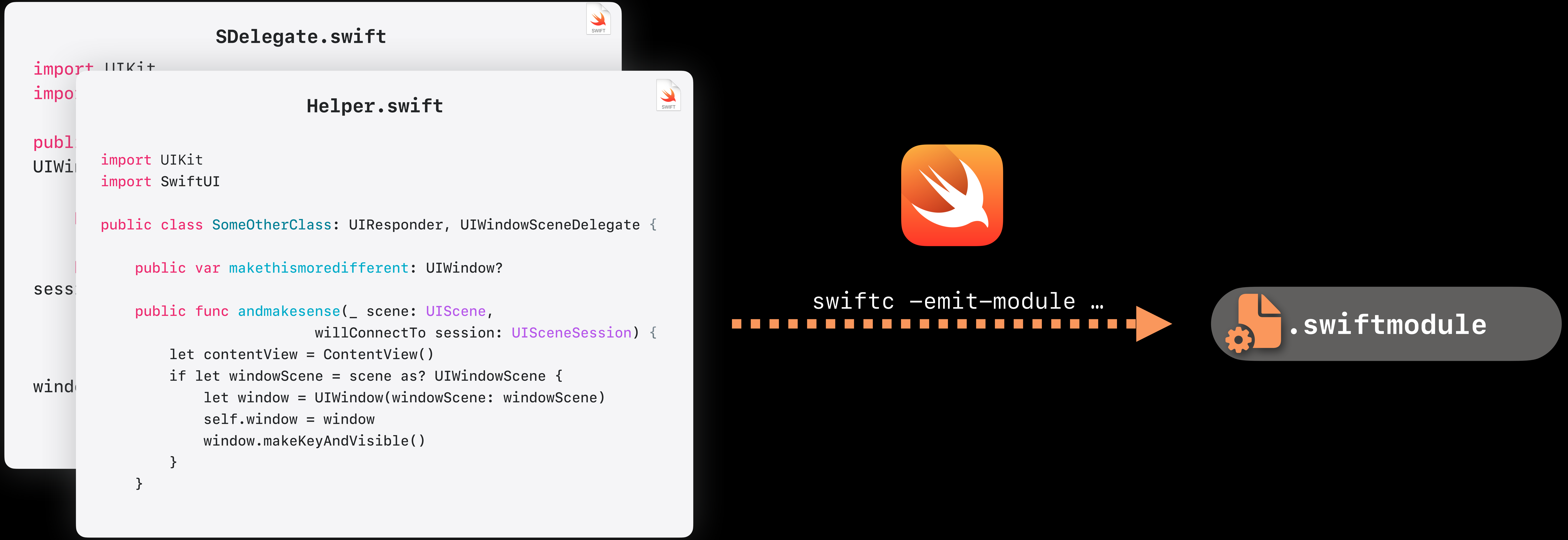

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```
swiftc -emit-module …
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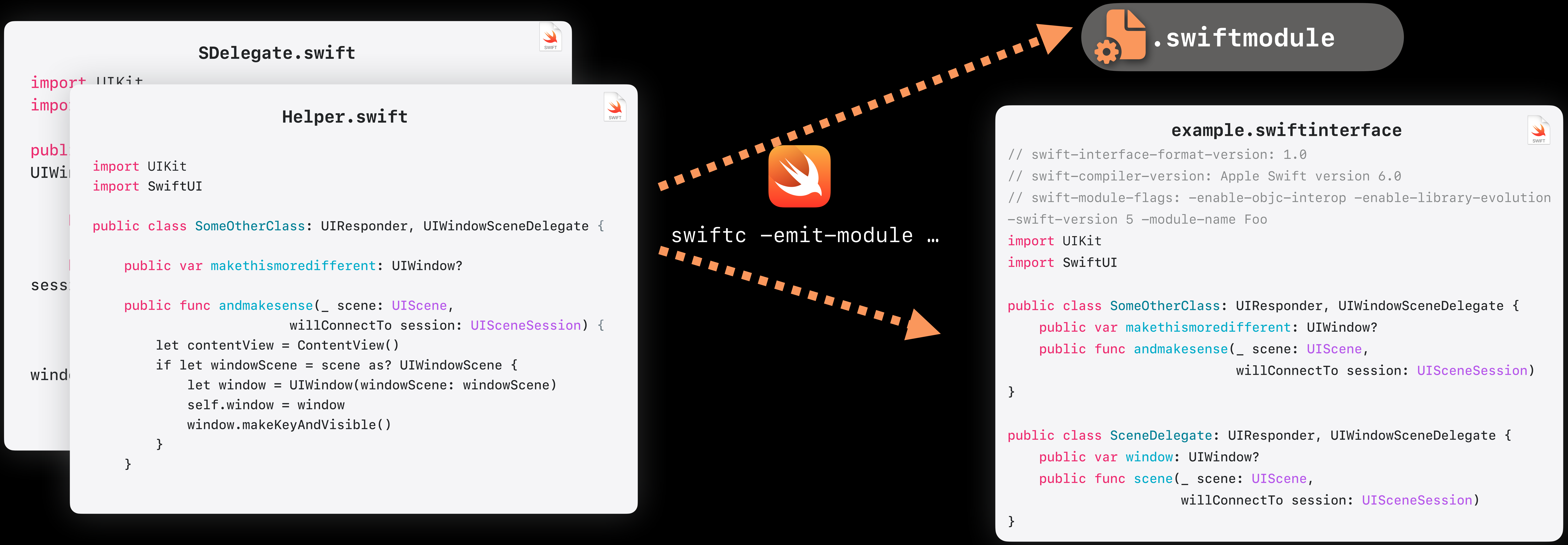

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        }
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```

```
swiftc -emit-module …
```

example.swiftinterface

```
// swift-interface-format-version: 1.0
// swift-compiler-version: Apple Swift version 6.0
// swift-module-flags: -enable-objc-interop -enable-library-evolution
-swift-version 5 -module-name Foo
import UIKit
import SwiftUI

public class SomeOtherClass: UIResponder, UIWindowSceneDelegate {
    public var makethismoredifferent: UIWindow?
    public func andmakesense(_ scene: UIScene,
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}

public class SceneDelegate: UIResponder, UIWindowSceneDelegate {
    public var window: UIWindow?
    public func scene(_ scene: UIScene,
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}
```

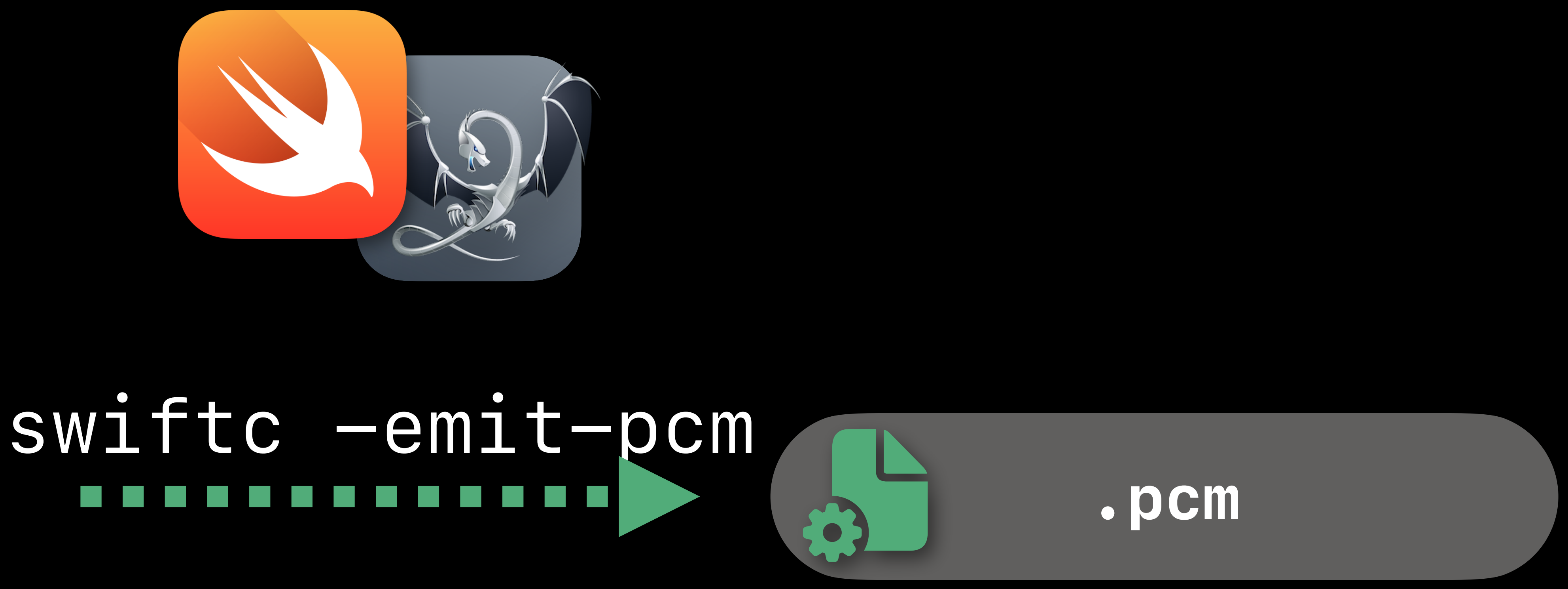
C/Obj-C/C++ Modules in Swift

Swift directly interoperates with C/Objective-C/C++ code. Doing so at scale requires modularized header interfaces.

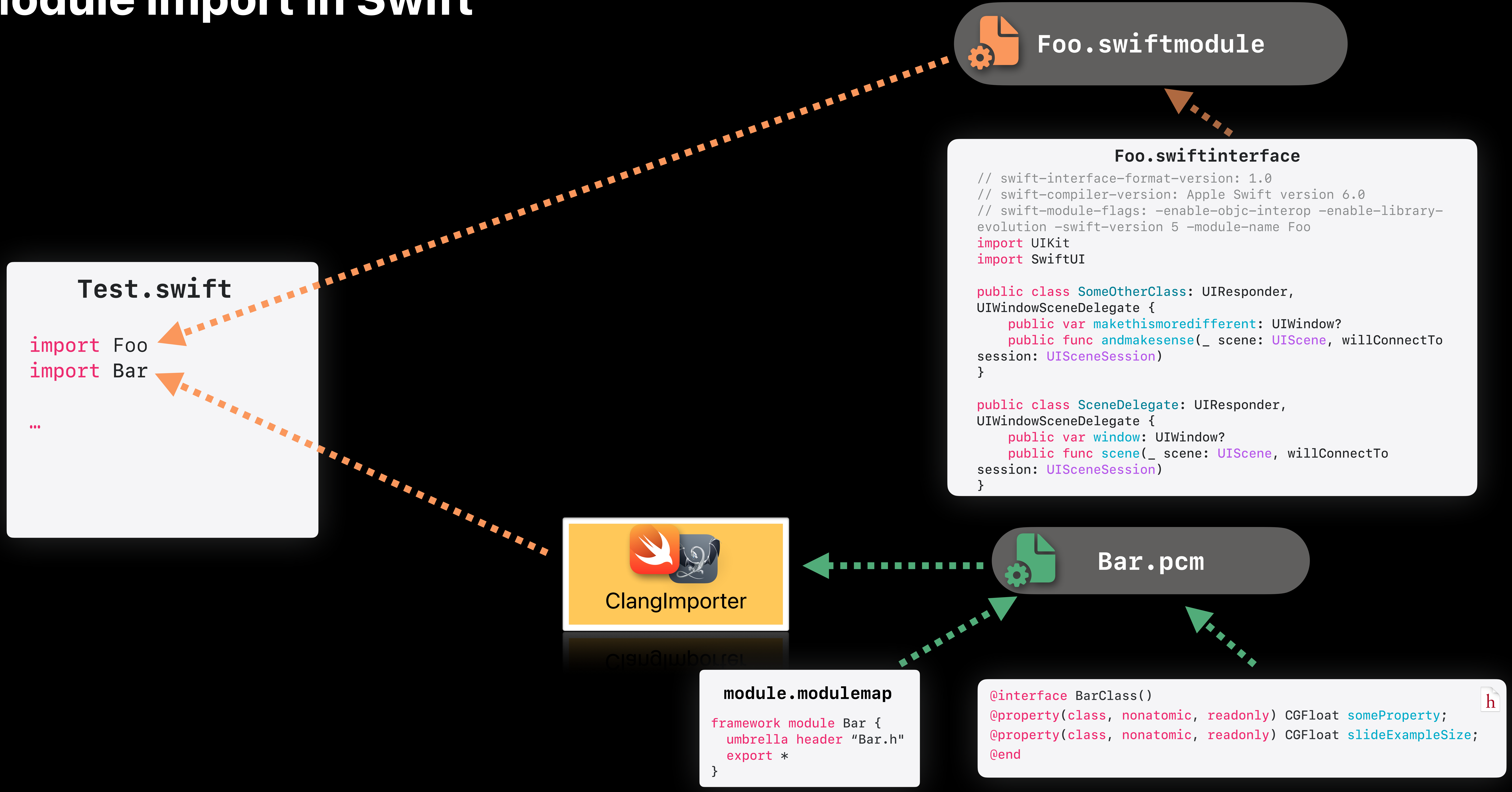
module.modulemap

```
framework module UIKit {
  umbrella header "UIKit.h"
  export *
}
```

```
@interface UIFont (UIFontSystemFonts)
@property(class, nonatomic, readonly) CGFloat labelFontSize;
@property(class, nonatomic, readonly) CGFloat buttonFontSize;
@property(class, nonatomic, readonly) CGFloat smallSystemFontSize;
@property(class, nonatomic, readonly) CGFloat systemFontSize;
@property(class, nonatomic, readonly) CGFloat defaultFontSize;
@property(class, nonatomic, readonly) CGFloat systemMinimumFontSize;
@end
```



Module import in Swift



Test.swift

```
import Foo
import Bar

…
```

Foo.swiftinterface

```
// swift-interface-format-version: 1.0
// swift-compiler-version: Apple Swift version 6.0
// swift-module-flags: -enable-objc-interop -enable-library-
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public class SomeOtherClass: UIResponder,
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    public func andmakesense(_ scene: UIScene, willConnectTo
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}

public class SceneDelegate: UIResponder,
UIWindowSceneDelegate {
    public var window: UIWindow?
    public func scene(_ scene: UIScene, willConnectTo
session: UISceneSession)
}
```

module.modulemap

```
framework module Bar {
  umbrella header "Bar.h"
  export *
}
```

```
@interface BarClass()
@property(class, nonatomic, readonly) CGFloat someProperty;
@property(class, nonatomic, readonly) CGFloat slideExampleSize;
@end
```

Module Resolution in Swift

Each imported named module may require compilation into its associated binary product consumable by the client compiler.

Module Resolution in Swift

Implicit discovery and compilation

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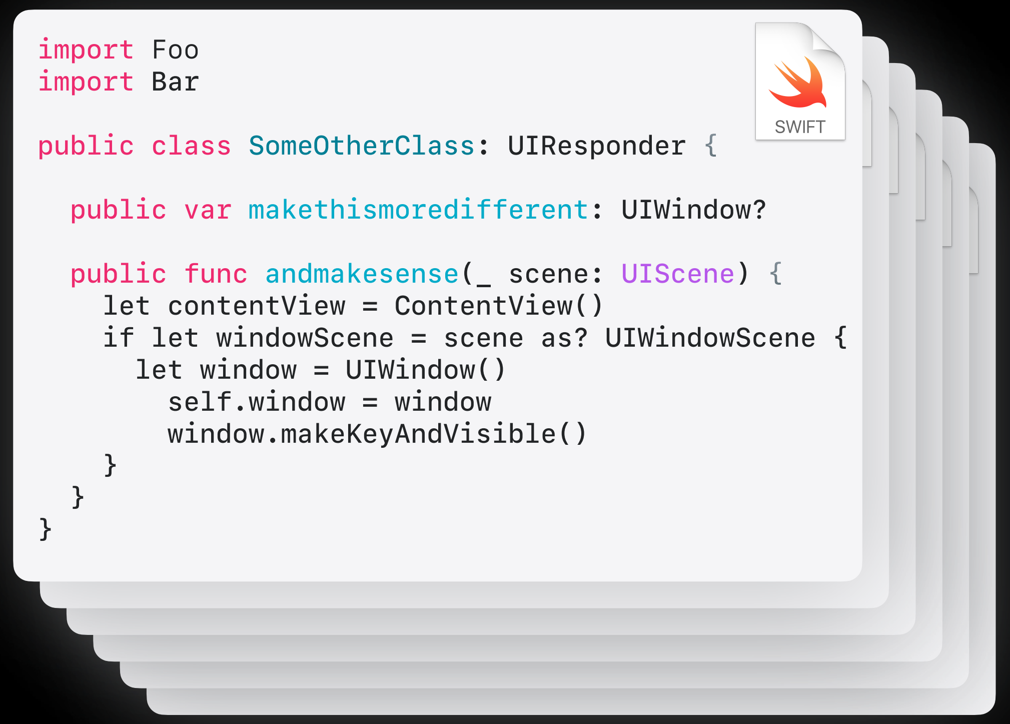

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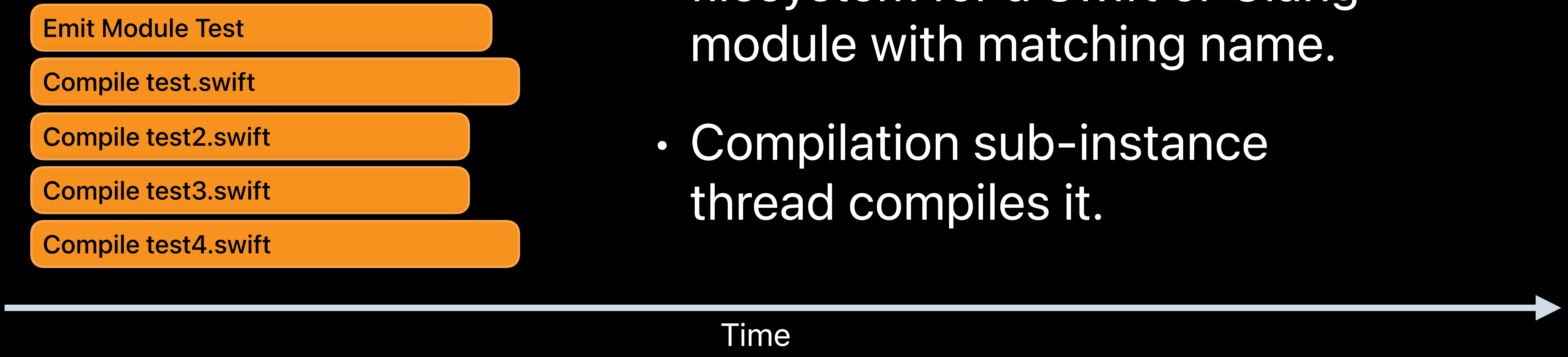

- Compiler searches the filesystem for a Swift or Clang module with matching name.
- Compilation sub-instance thread compiles it.

Module Resolution in Swift

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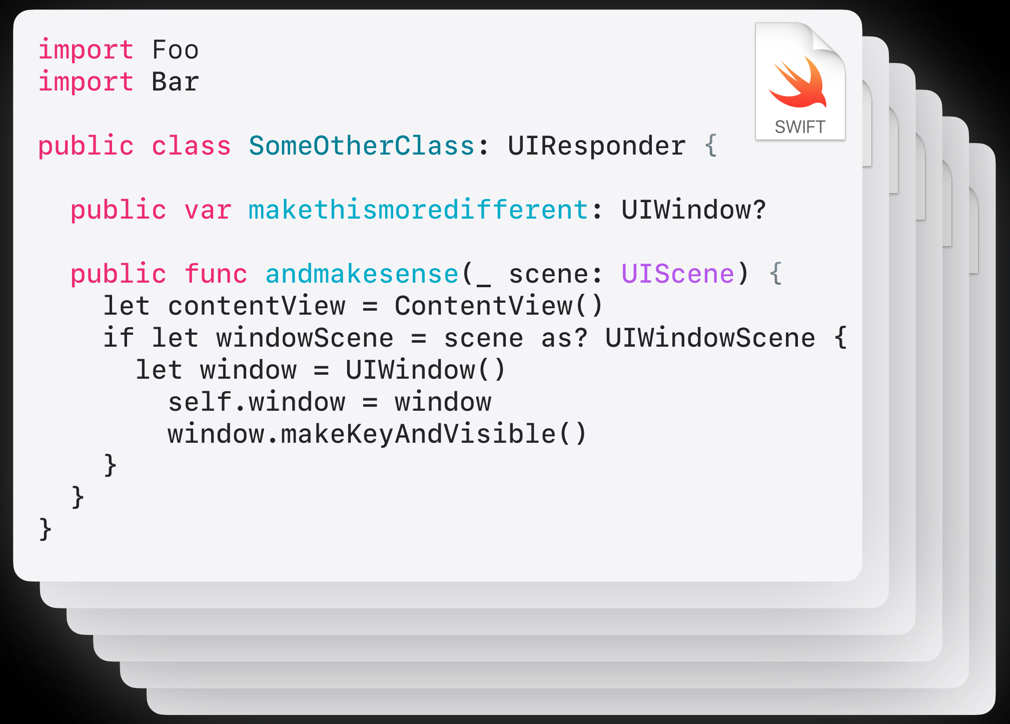

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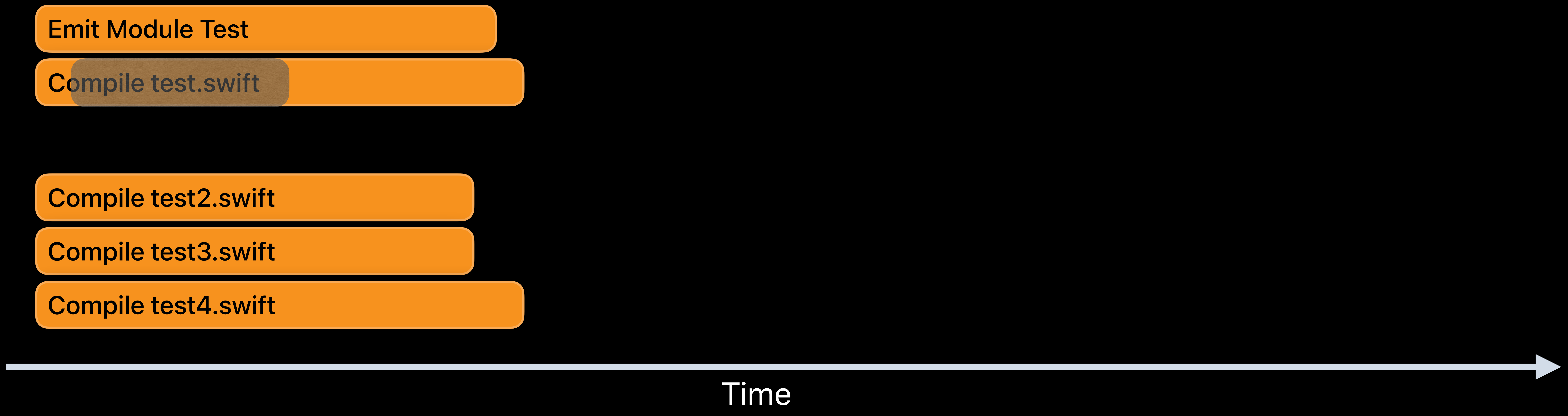

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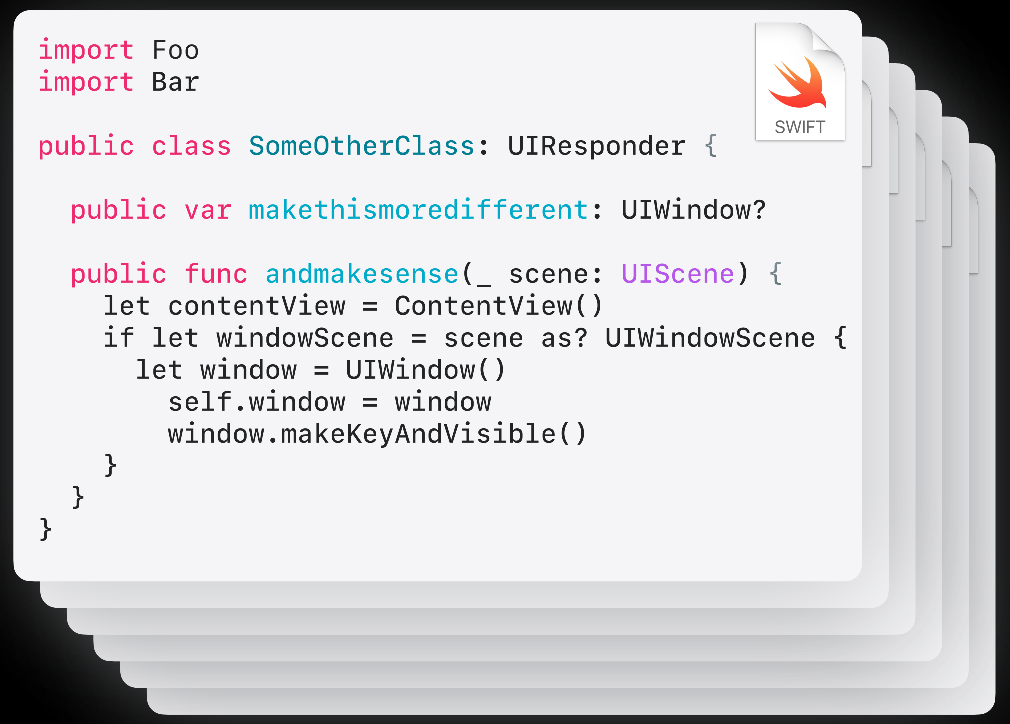

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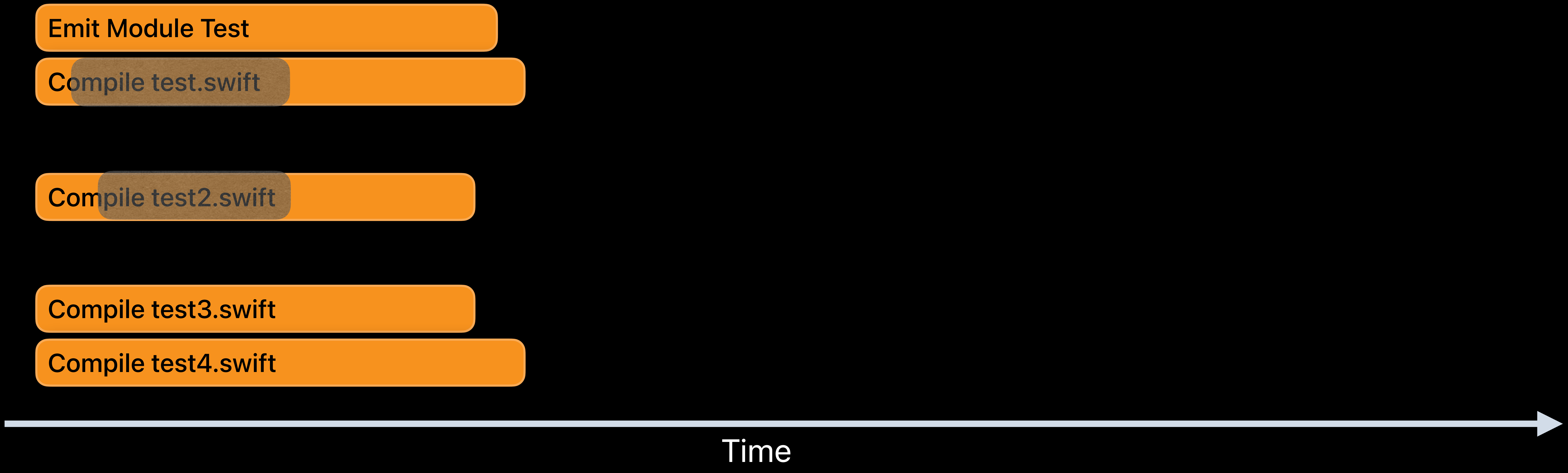

Module Resolution in Swift

Implicit discovery and compilation

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SWIFT
Emit Module Test
Compile test.swift
Compile test2.swift
Compile test3.swift
Compile test4.swift
Time

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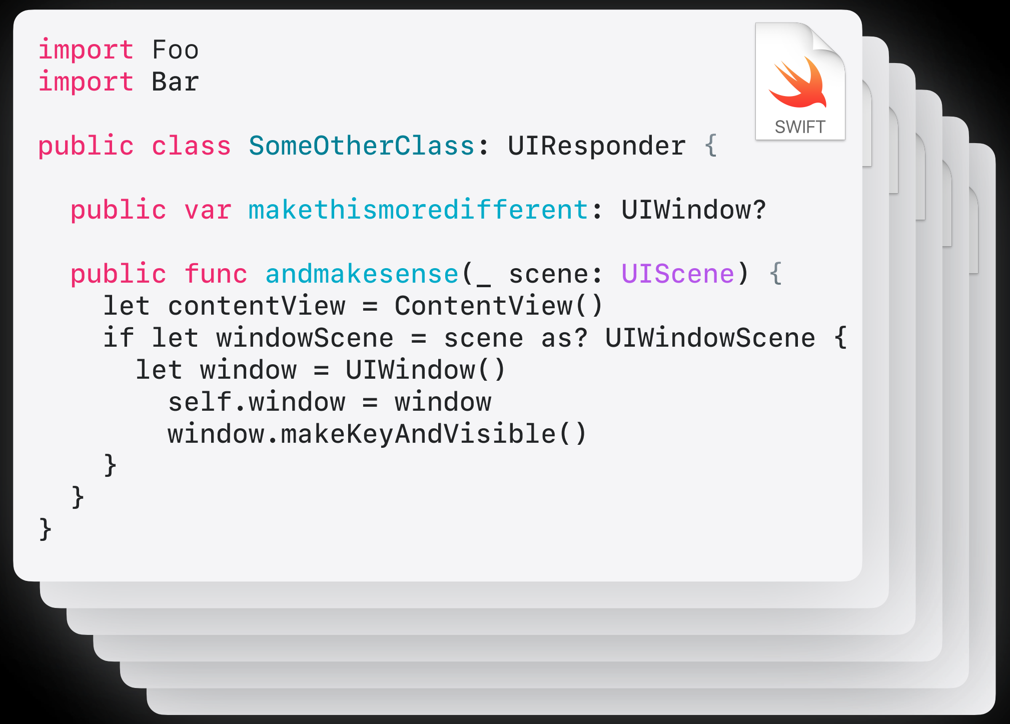

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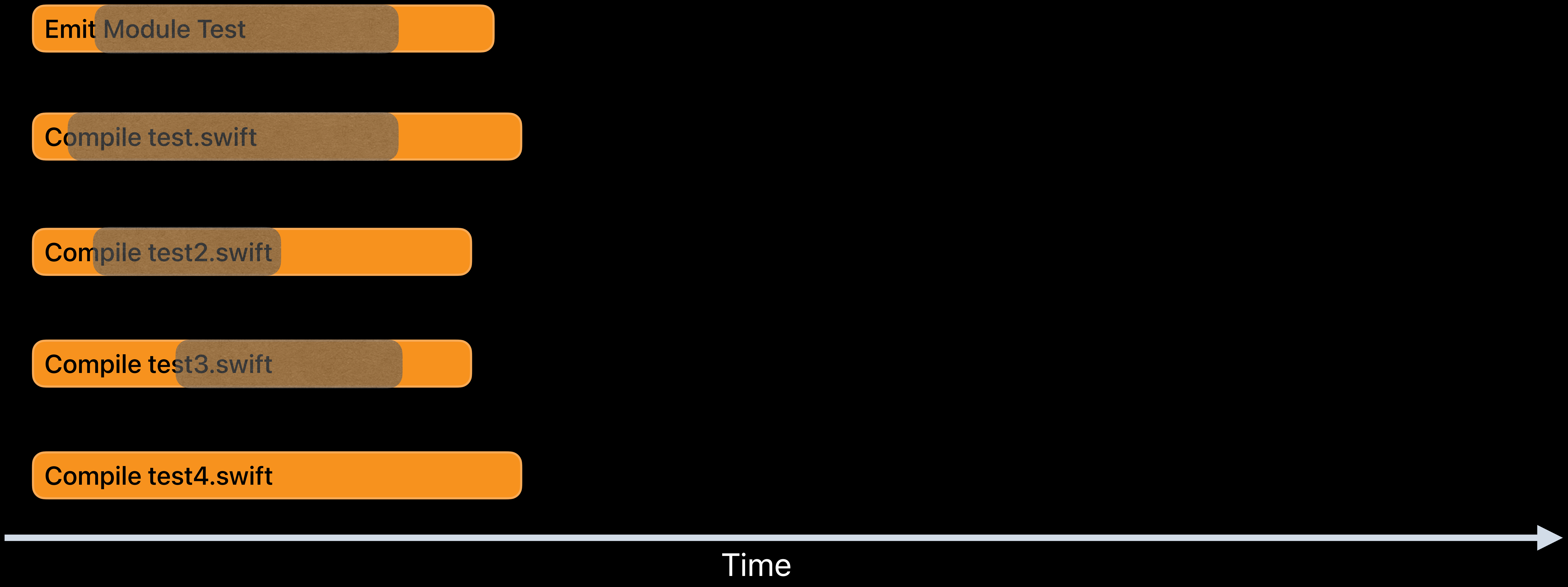

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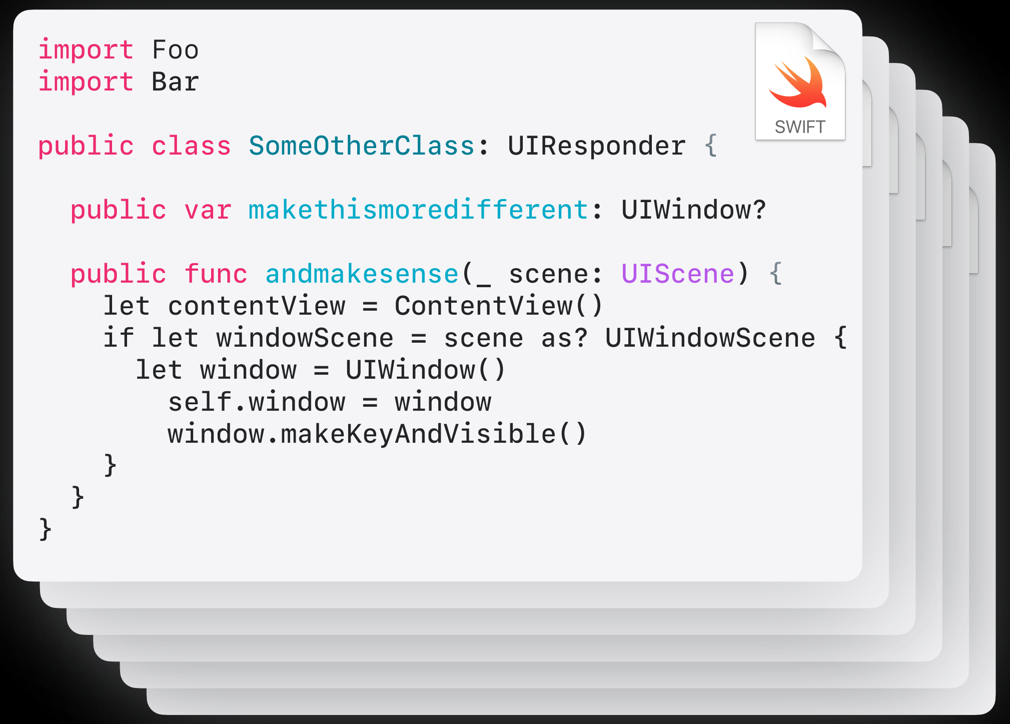

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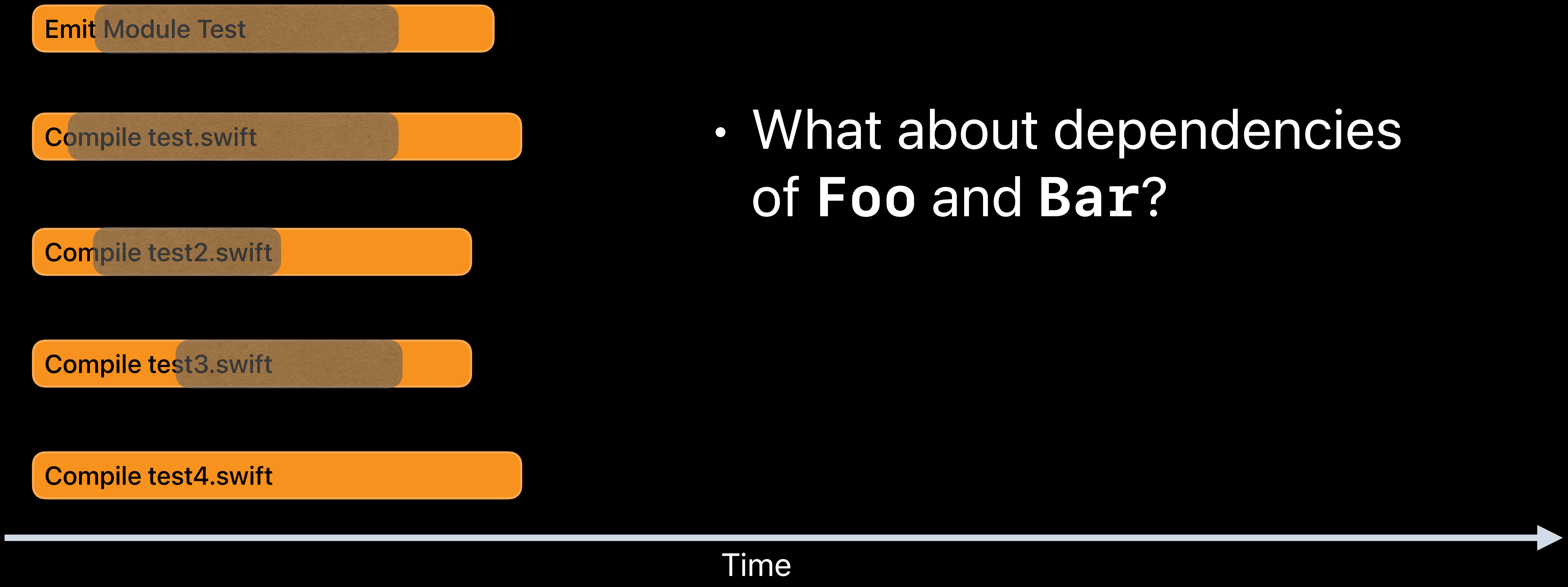

- What about dependencies of **`Foo`** and **`Bar`**?

Module Resolution in Swift

Implicit discovery and compilation

Each imported named module may require compilation into its associated binary product consumable by the client compiler.

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SWIFT
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```swift
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- What about dependencies of **`Foo`** and **`Bar`**?

Sub-instance thread creation for dependency compilation is recursive.

Module Resolution in Swift

Implicit discovery and compilation

Emit Module Test
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Time
SWIFT

```
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}
```

Opaque to the Build System

Peer task waiting with no forward progress

Non-isolated compilation tasks

Nested compilation context hard to reason about

Filesystem locking

Late error discovery

Module Resolution in Swift

Explicitly Built Modules

Clang 💙 Explicit Modules **Swift ❤️ Explicit Modules**

[1] *J. Svoboda: Implicitly discovered, explicitly built Clang modules (EuroLLVM 2022)*

Module Resolution in Swift

Explicitly Built Modules

Dependency Scan

Build Modules

Build Source

Module Resolution in Swift

Explicitly Built Modules

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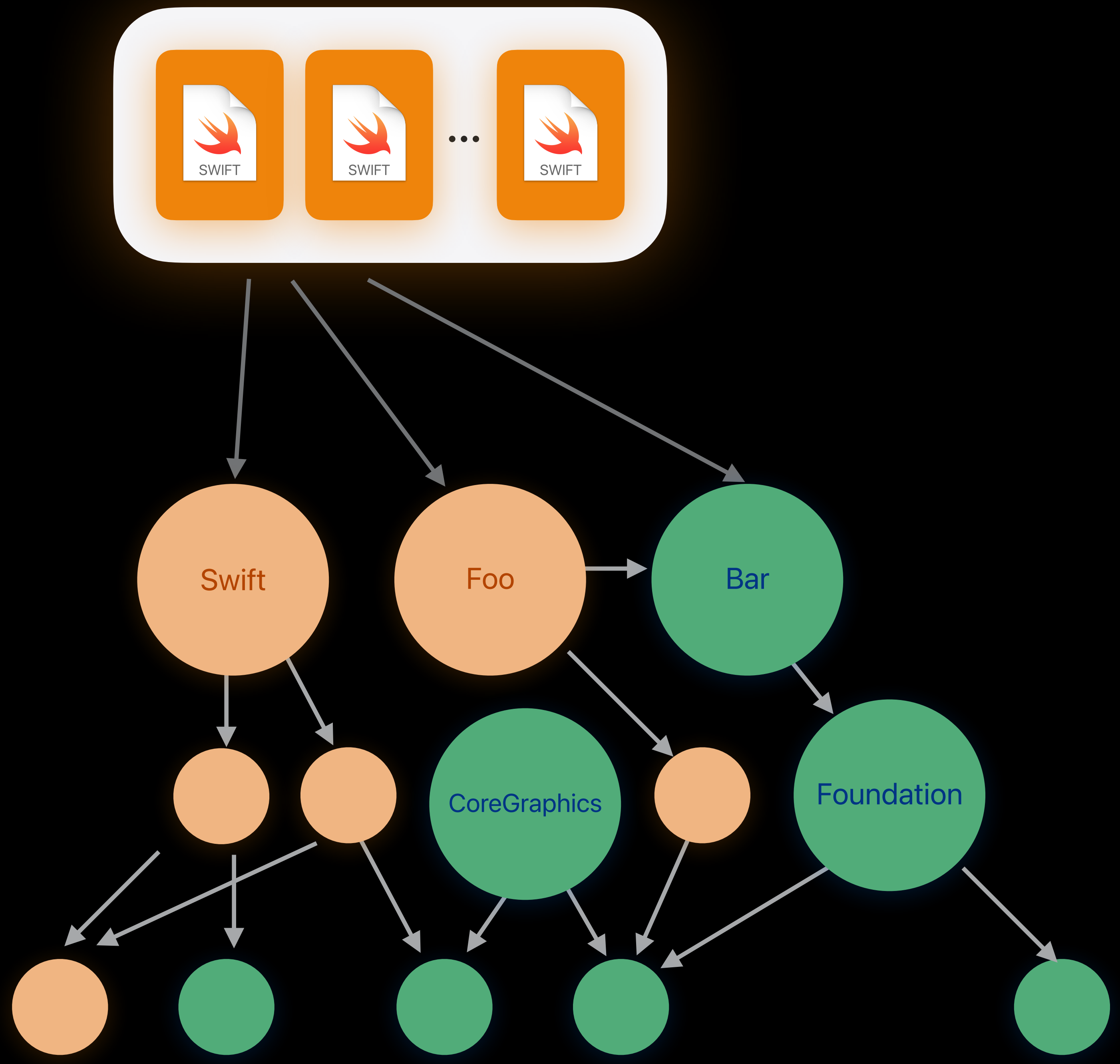

Module Resolution in Swift

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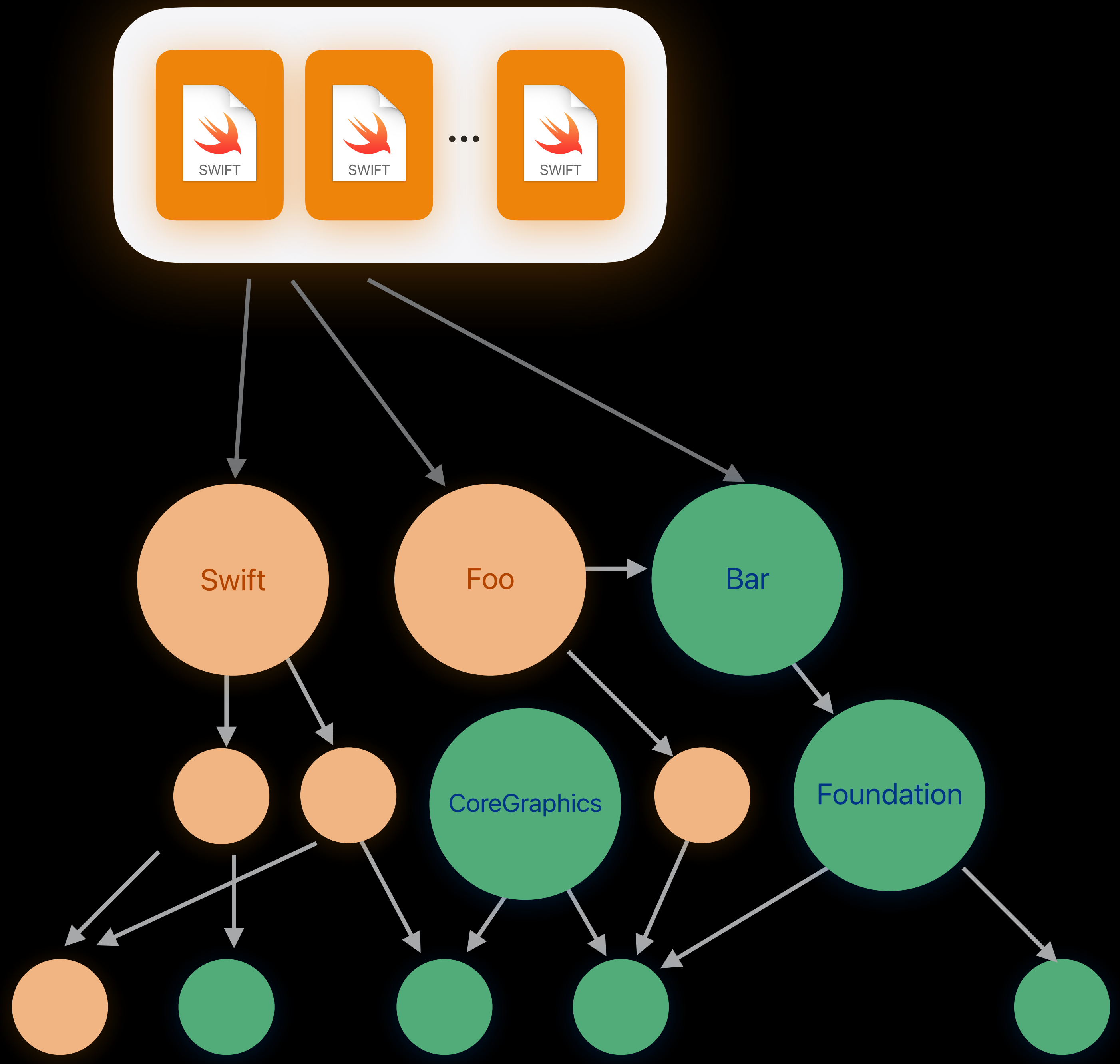
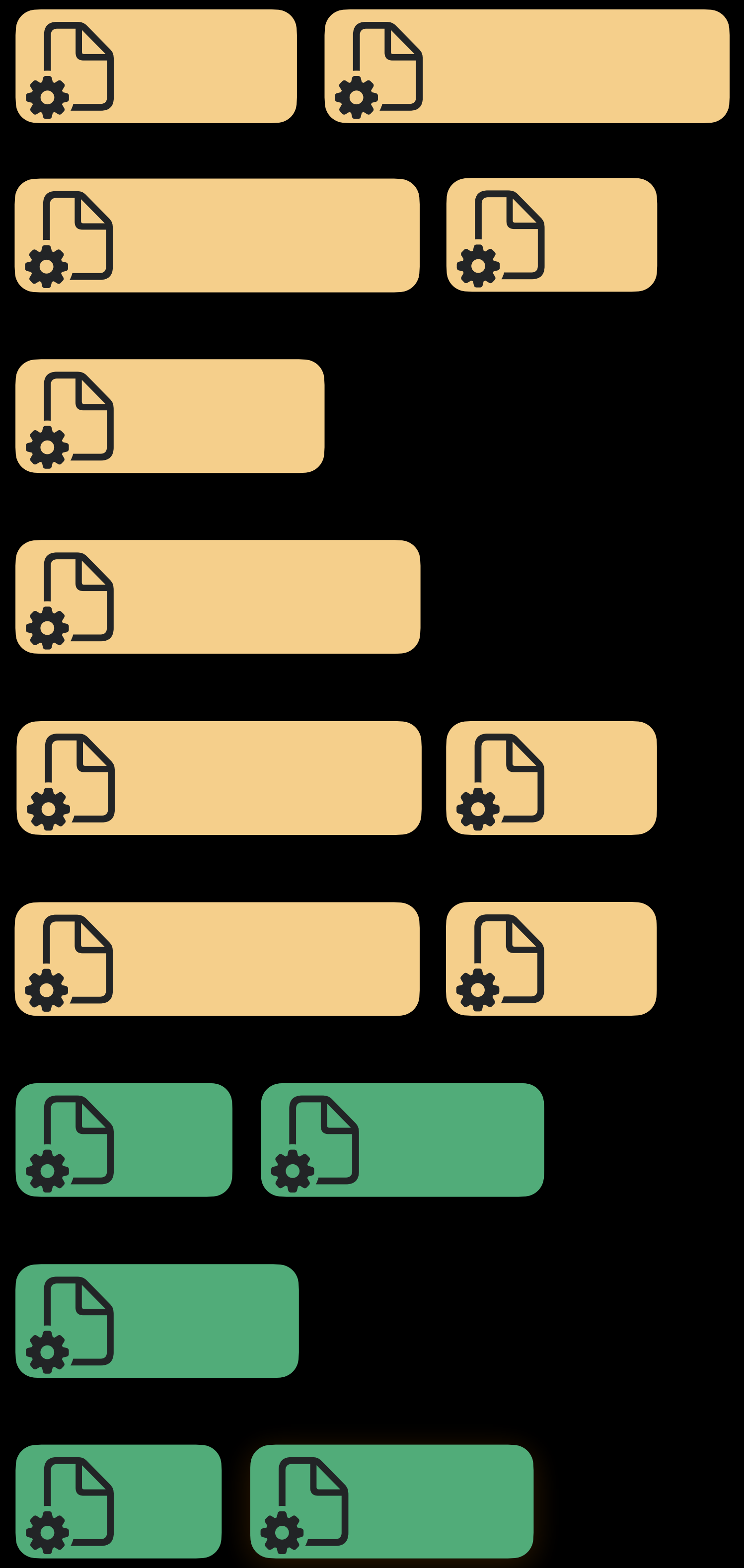
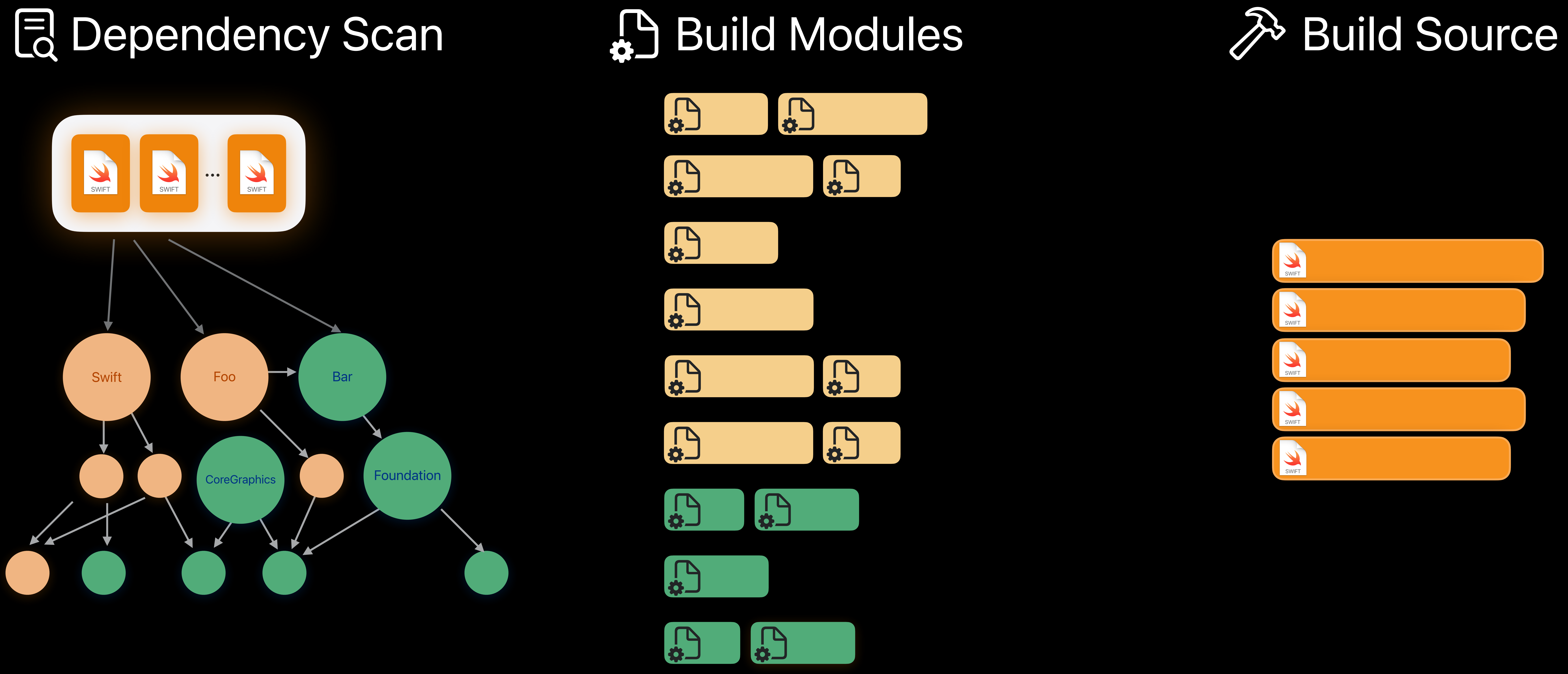




Module Resolution in Swift

Explicitly Built Modules



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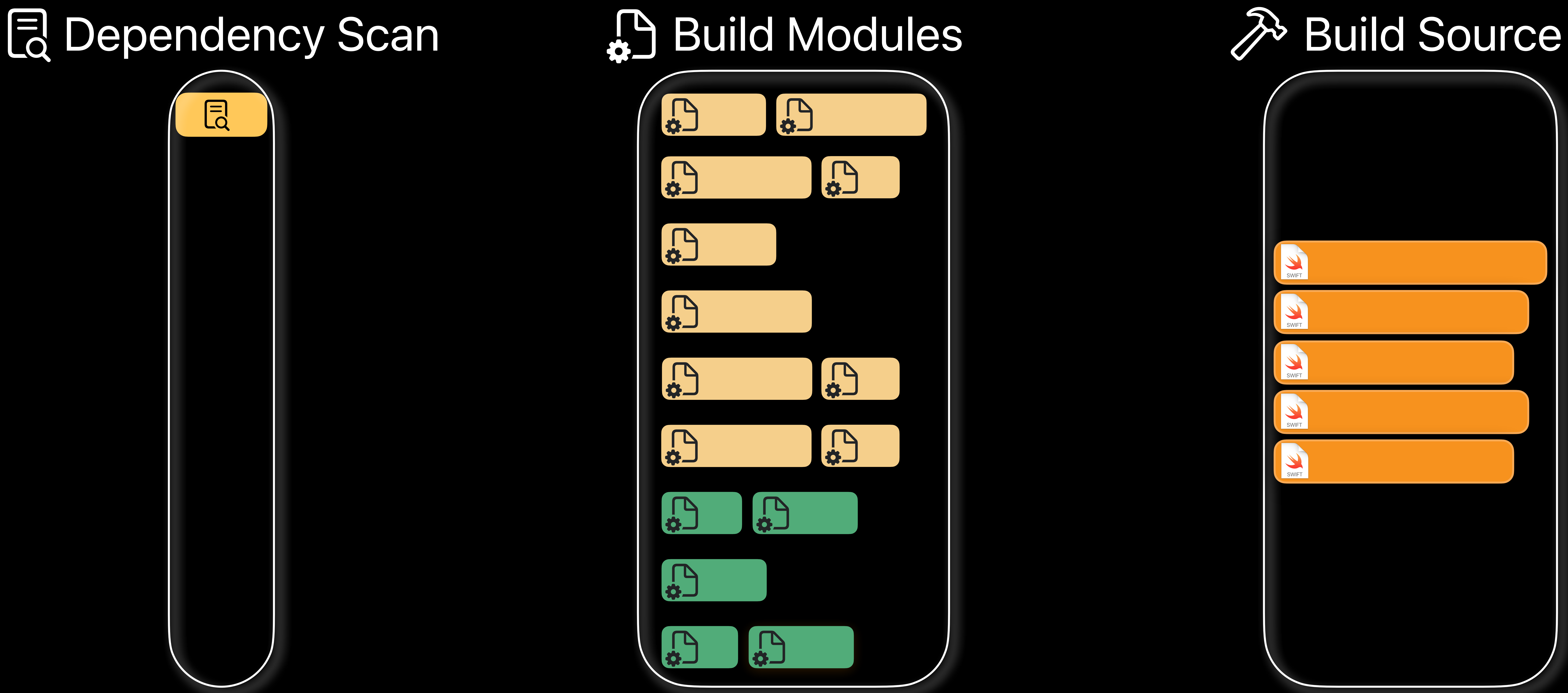

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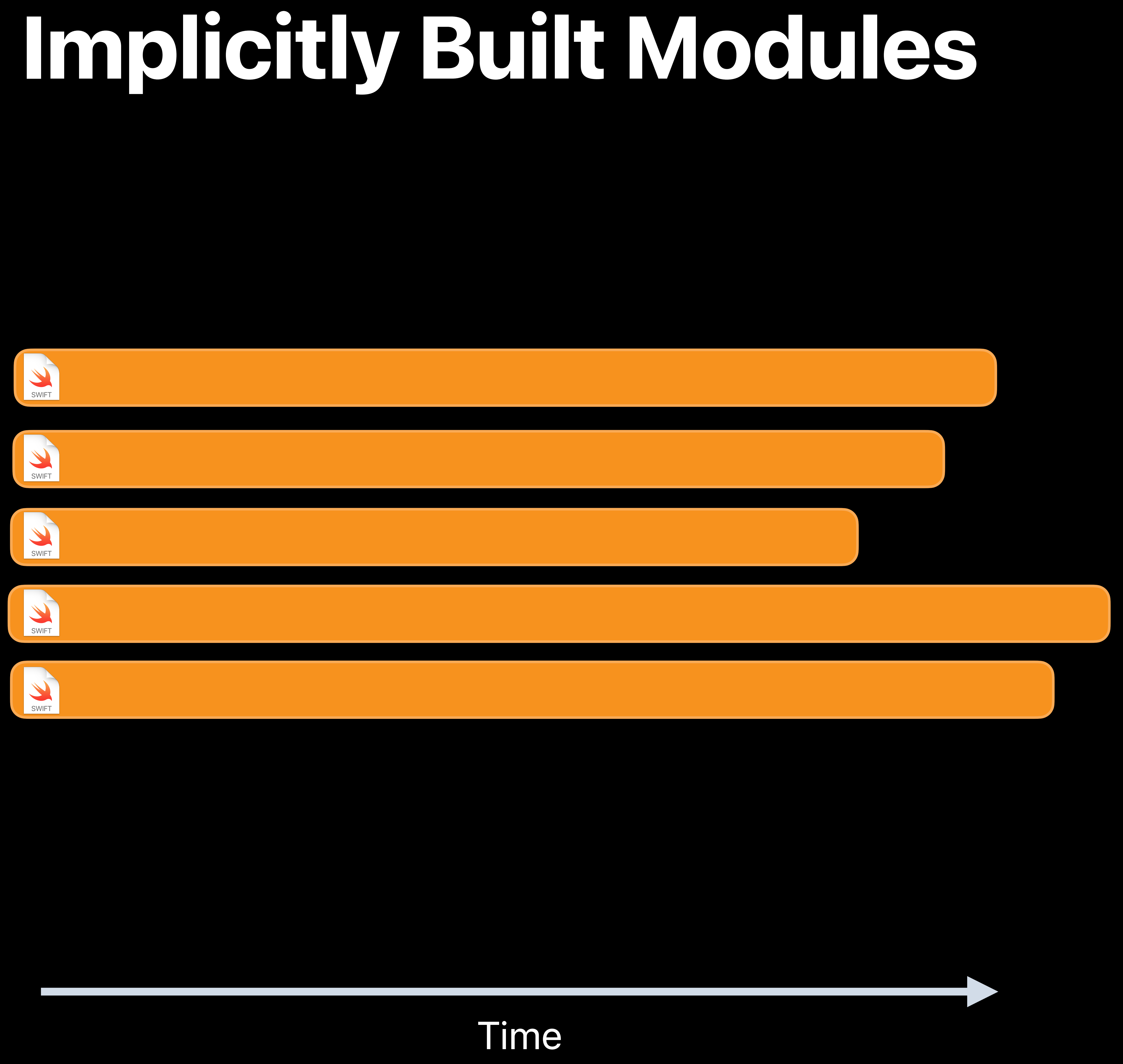
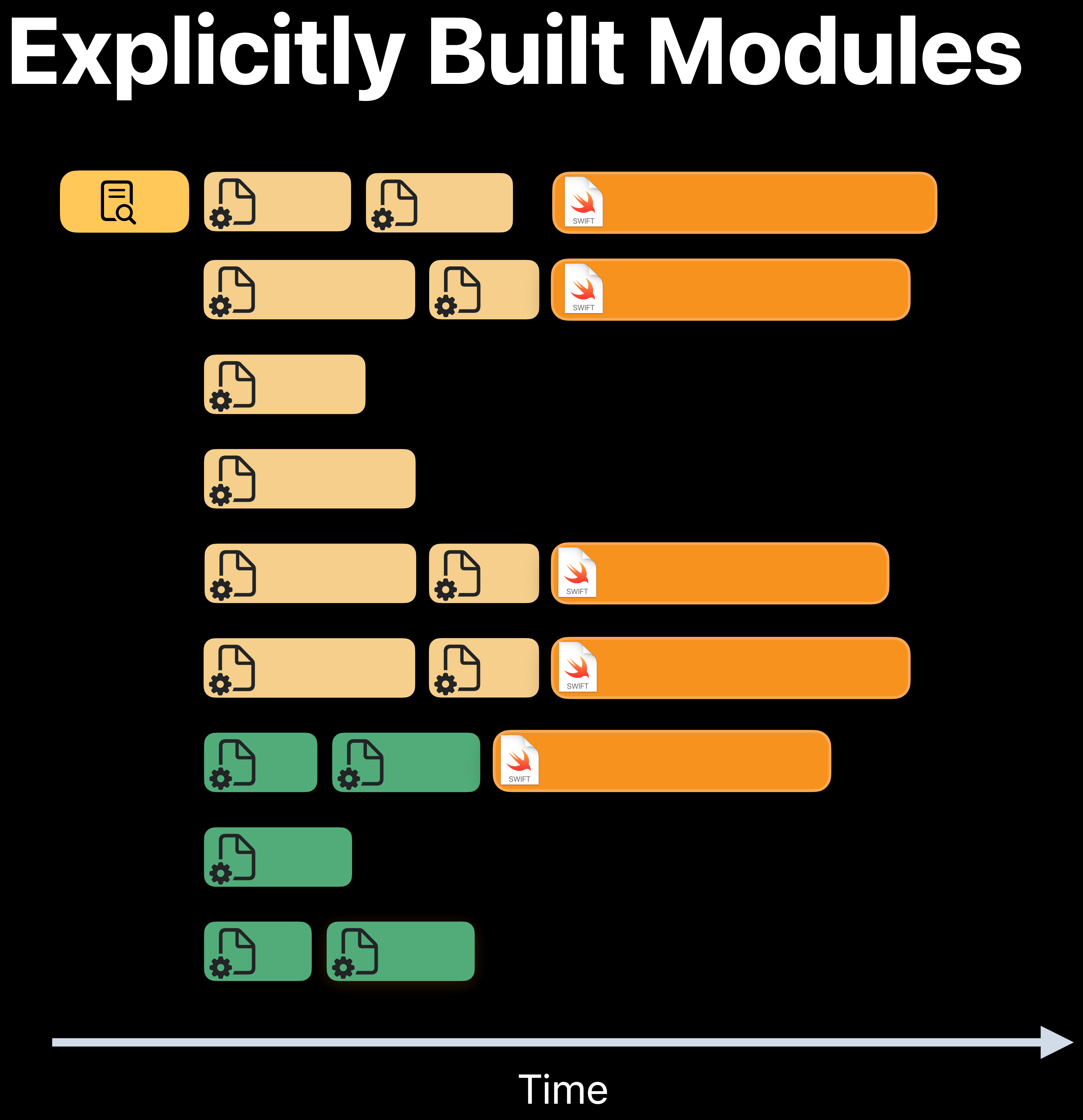
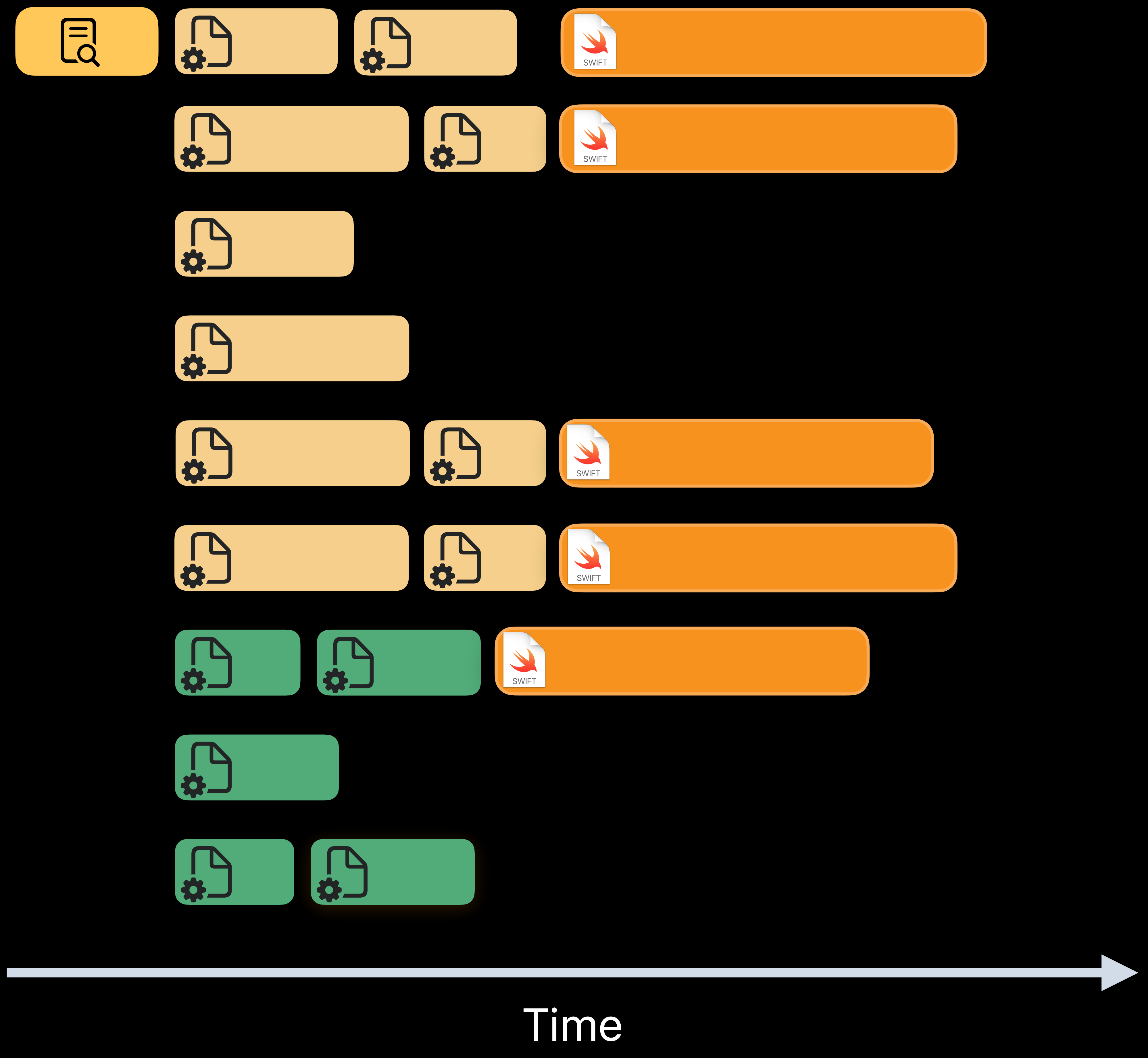




Module Resolution in Swift

Explicitly Built Modules

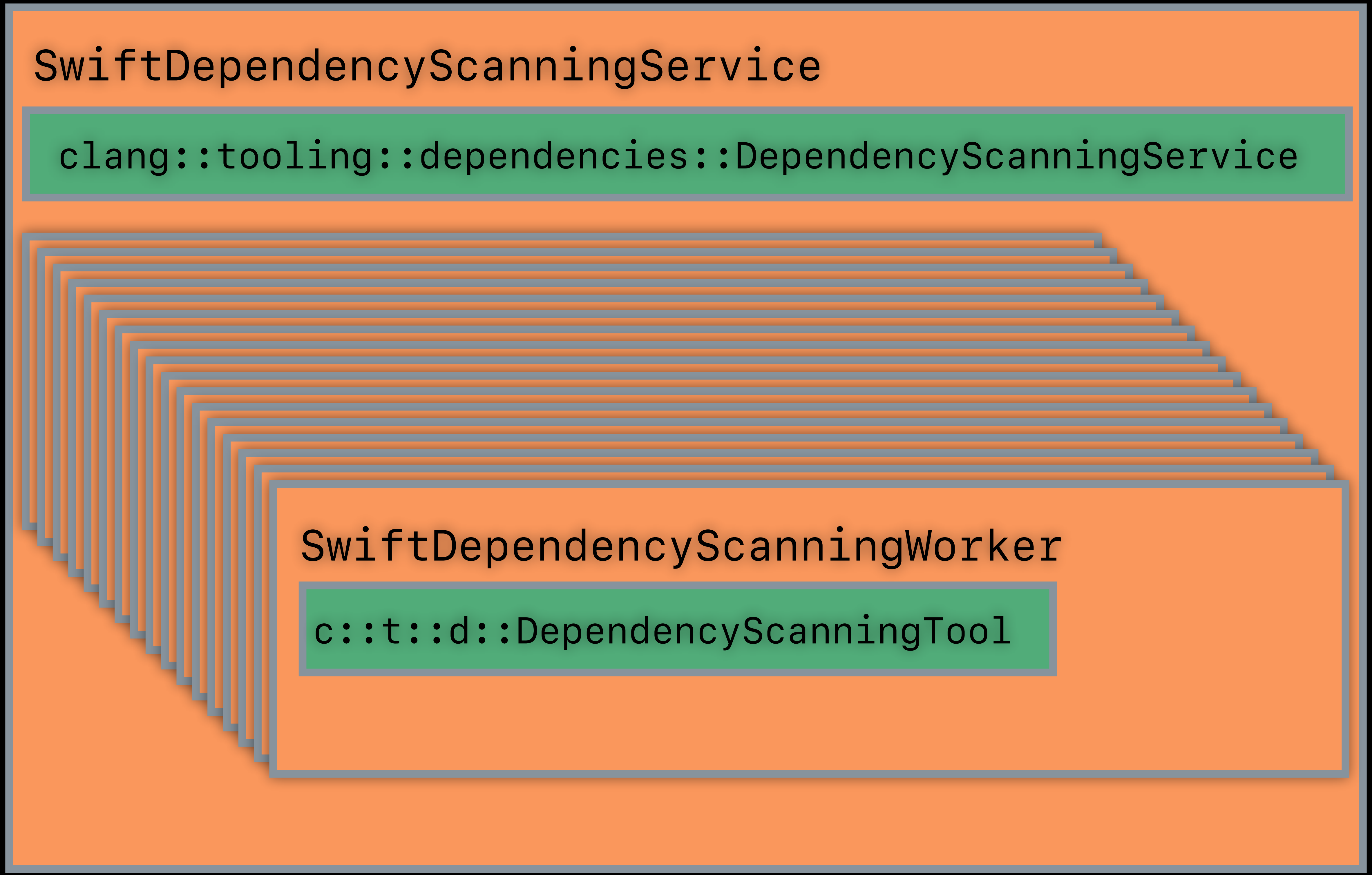


- More scheduling parallelism opportunities
- Distributable Build
- Deterministic, explainable
- Isolated Compilation Tasks
- Simpler Debugging
- Earlier actionable error detection

Module Resolution in Swift

Explicitly Built Modules

Dependency Scanner

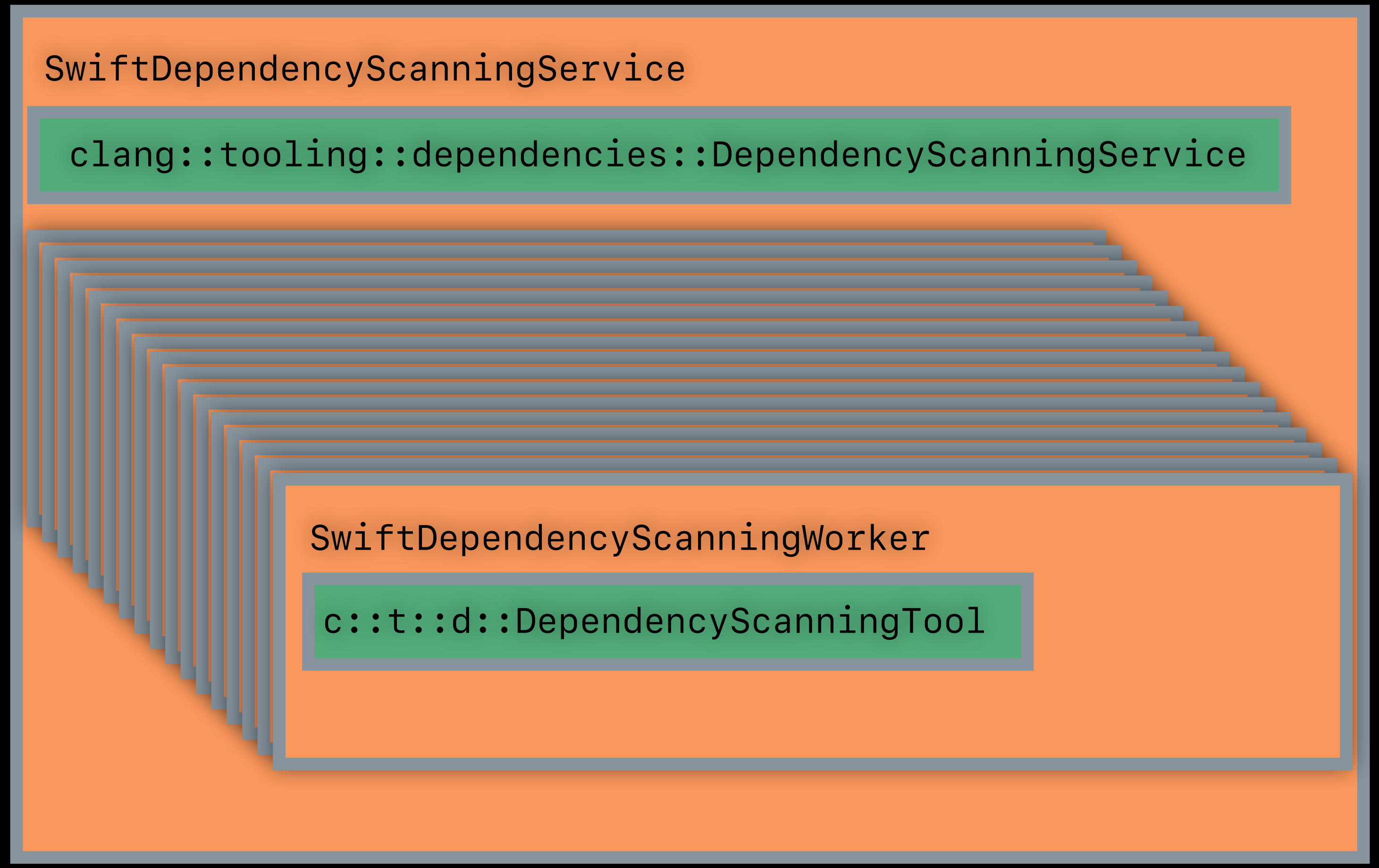

SwiftDependencyScanningService
clang::tooling::dependencies::DependencyScanningService
SwiftDependencyScanningWorker
c::t::d::DependencyScanningTool

[2] *A. Lorenz & M.Spencer: clang-scan-deps: Fast Dependency Scanning For Explicit Modules (EuroLLVM 2019)*

Module Resolution in Swift

Explicitly Built Modules

Dependency Scanner


SwiftDependencyScanningService
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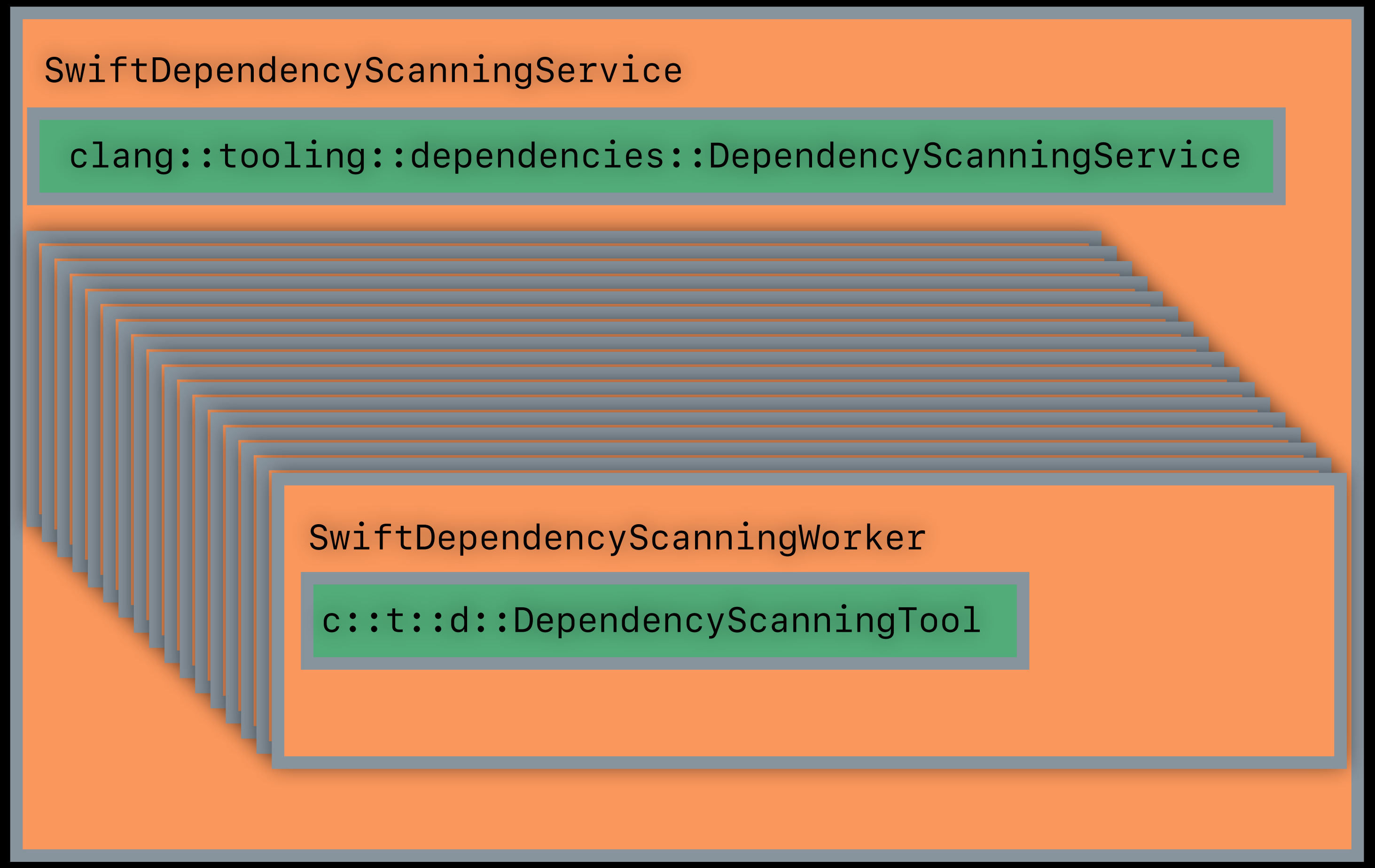
```
let worklist = get_source_imports()
for id in worklist {
  if (dep = worker->findSwiftModule(id))
    worklist.add(dep->getImports)
  else if (dep = worker->clangTool->findClangModule(id))
    Record dep and entire sub-graph
  else
    error("Module not found: \(id)")
}
```

Module Resolution in Swift

Explicitly Built Modules

Dependency Scanner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```
class DependencyScanningTool {
public:
…
  llvm::Expected<ModuleDepsGraph> getModuleDependencies(
      StringRef ModuleName, const std::vector<std::string> &CommandLine,
      StringRef CWD, const llvm::DenseSet<ModuleID> &AlreadySeen,
      LookupModuleOutputCallback LookupModuleOutput);
```

Module Resolution in Swift

Explicitly Built Modules

Dependency Scanner Performance

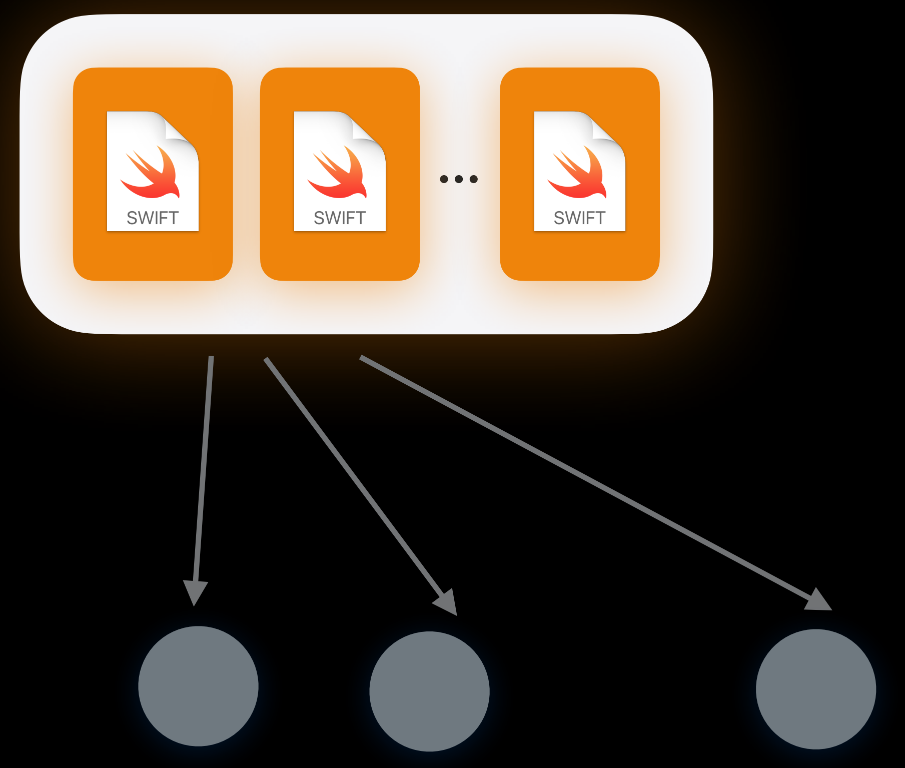
- Scanning performance crucial -> on the build critical path
- Swift module discovery relatively very cheap
- Clang module discovery and recipe formulation expensive:
  - Must parse all headers
  - Must identify full transitive dependency closure
- *Insight*: Once a dependency graph of Swift dependencies has been built, all unresolved imports are Clang modules -> Can be resolved as one large batch

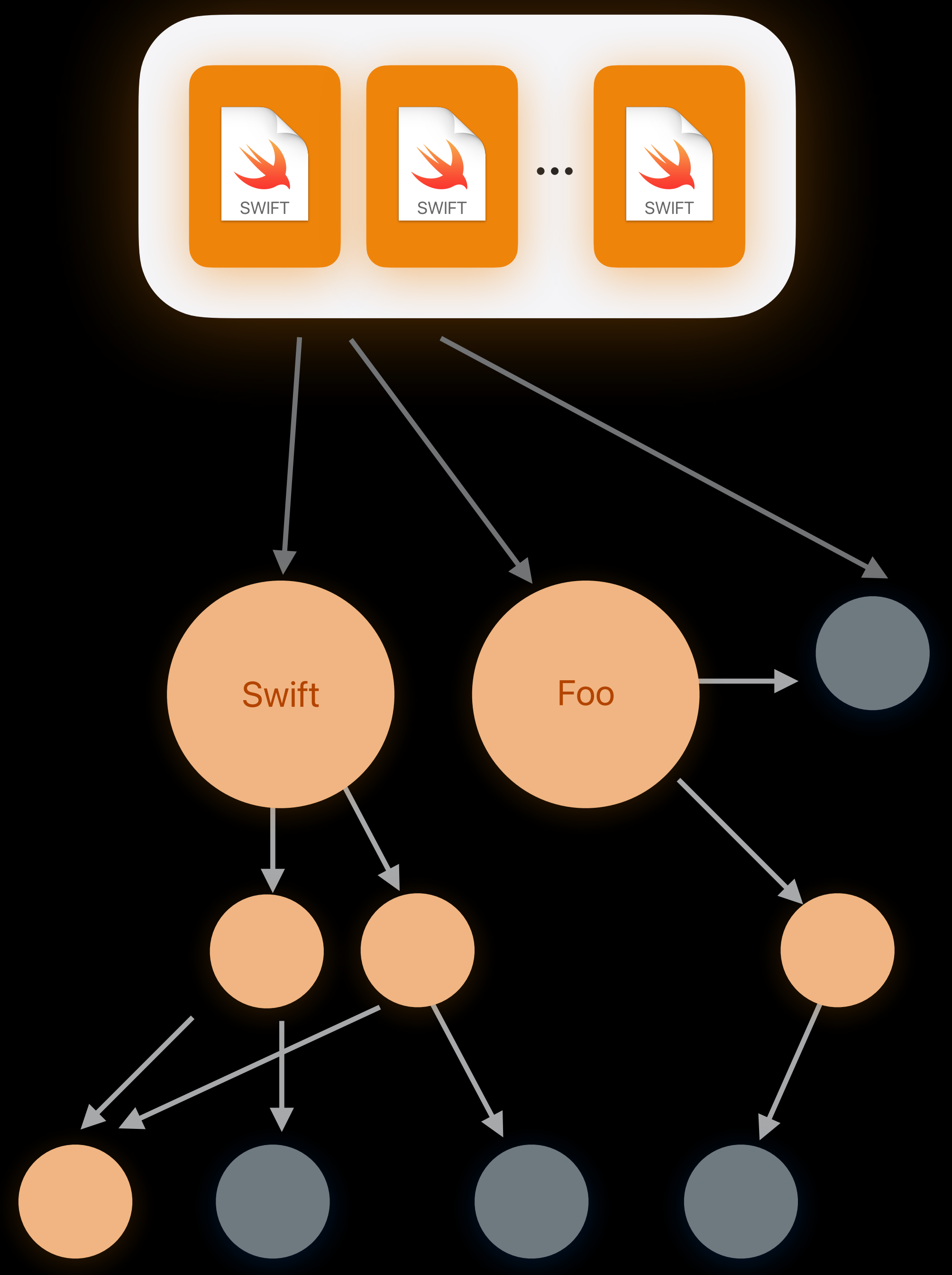
Module Resolution in Swift

Explicitly Built Modules

Dependency Scanner Performance

Batch resolution of Clang dependencies


SWIFT
SWIFT
SWIFT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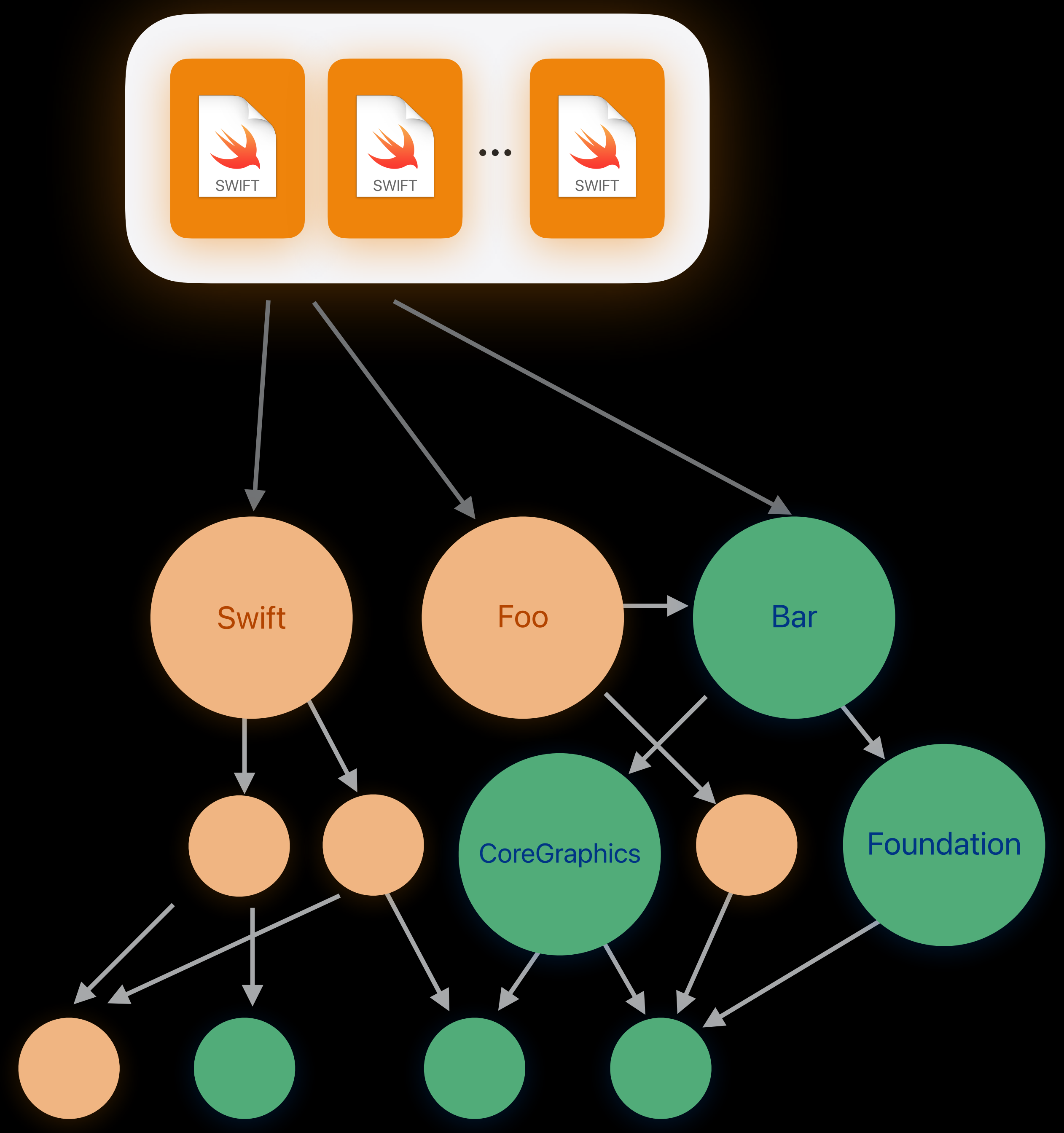
Swift
Foo


SWIFT
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Swift
Foo
Bar
CoreGraphics
Foundation