LLDB Reproducers

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LLVM Developers' Meeting, Brussels, Belgium, April 2019

"The debugger doesn't work"

– Somebody on the internet

LLDB Bugs

```
$ lldb ./a.out
(lldb) target create "a.out"
(lldb) b main.cpp:12
...
(lldb) run
...
(lldb) expr @import Foo
(lldb) expr Bar
cannot materialize variable
```

LLDB Bug Reports

"Hey this doesn't work..."

Bob

Alice

LLDB Bug Reports

"Can you attach the expr log?"

Bob

Alice

LLDB Bug Reports

Expression log

Bob

Alice

LLDB Bug Reports

"Can you attach the type log?"

Bob

Alice

LLDB Bug Reports

Type log

Bob

Alice

LLDB Bug Reports

"How do I reproduce?"

Bob

Alice

LLDB Bug Reports

Steps to reproduce

Bob

Alice

LLDB Bug Reports

"It doesn't reproduce..."

Bob

Alice

Reproducers

- Automate the process
- Everything needed to reproduce
- Inspired by clang

Reproducers

"Hey this doesn't work..."

Bob

Alice

Reproducers

```
$ lldb ./a.out --capture
(lldb) target create "a.out"
(lldb) b main.cpp:12
...
(lldb) run
...
(lldb) expr @import Foo
(lldb) expr Bar
cannot materialize variable
(lldb) reproducer generate
```

```
$ lldb --replay reproducer
(lldb) target create "a.out"
(lldb) b main.cpp:12
...
(lldb) run
...
(lldb) expr @import Foo
(lldb) expr Bar
cannot materialize variable
```

LLDB Reproducers

Reconstruct the debugger's state

- How we get there is more important than the final result
- Capture data
- Debug during replay

Information

User interaction

- Commands typed in the command line interpreter
- Use of the public API

System interaction

- Data from the (file) system
- Data from the process being debugged

Minimize impact

- Don't hide or introduce bugs
- Reuse existing infrastructure
- Transparency and abstraction

Components

User Interaction

Command Line Interpreter

Public API (Scripting Bridge)

Files

GDB Remote Protocol

Command Interpreter

```
$ lldb ./a.out
(lldb) target create "a.out"
(lldb) b main.cpp:12
...
(lldb) run
...
(lldb) expr @import Foo
(lldb) expr Bar
```

User Interaction

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Stable C++ API

- Accessible through Python wrappers
- Used by IDEs such as Xcode, Eclipse, Visual Studio Code
- How the command line driver is implemented

Python Example

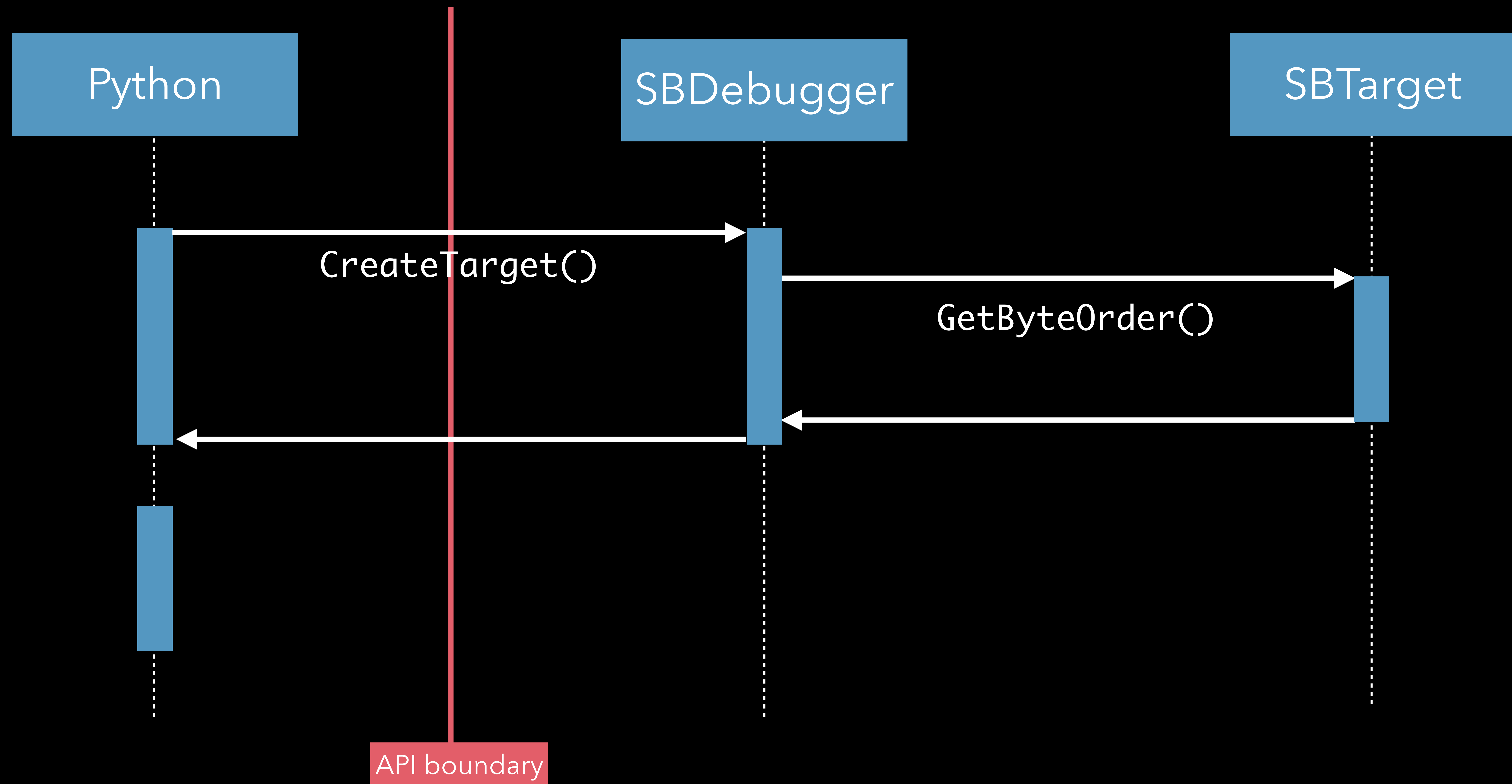
```python
import lldb

debugger = lldb.SBDebugger.Create()
target = debugger.CreateTarget("/path/to/a.out")
target.BreakpointCreateByName("foo")
process = target.LaunchSimple(...)
```

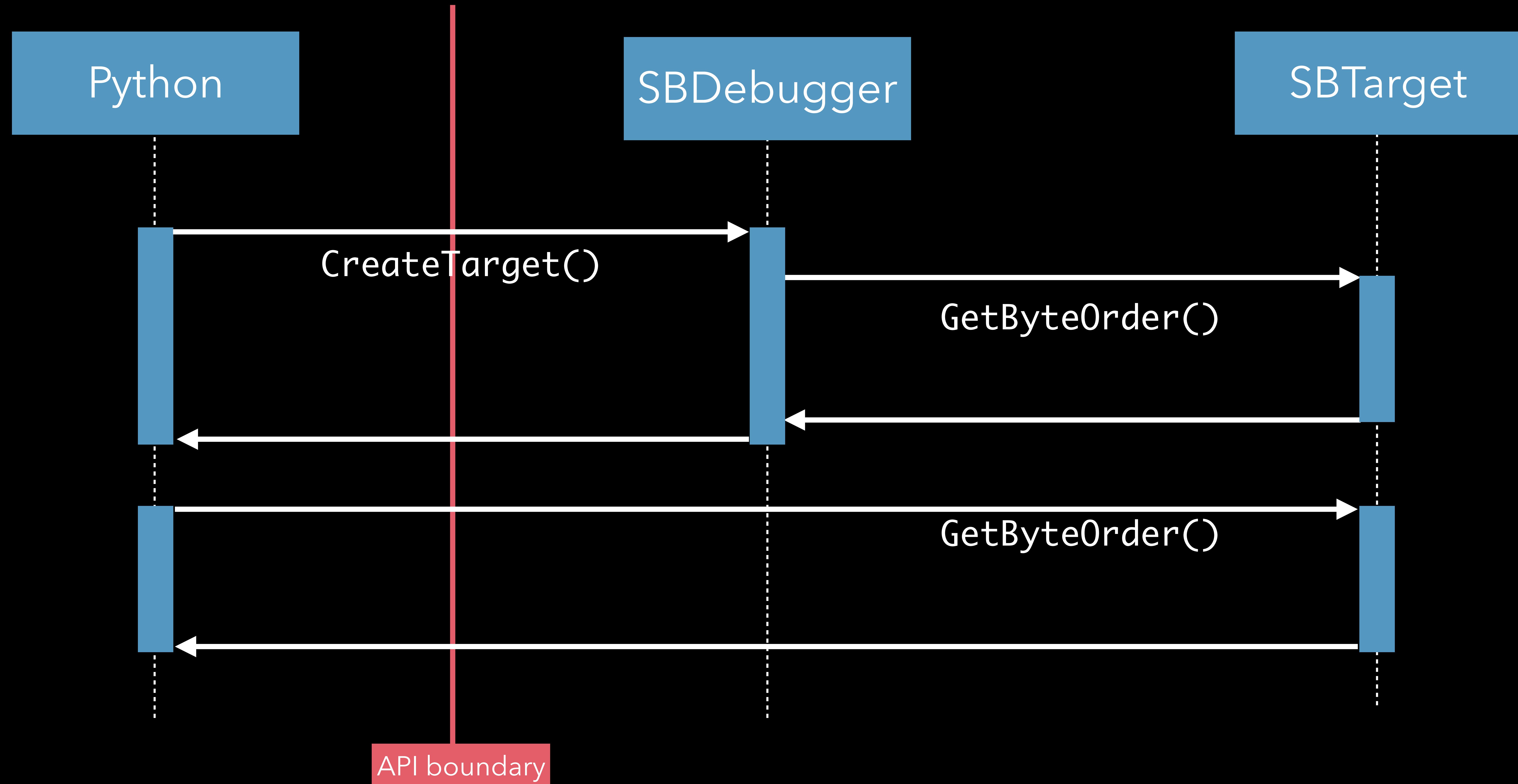
Capture and replay API calls

- Capture the call and its argument values
- Capture the return value

API Boundary



API Boundary



Detecting API Boundaries

- RAII object consisting of two booleans
- Static boolean toggles when crossing the API boundary
- Non-static boolean tracks if boundary needs to be reset

Capturing Calls

- Toggles the API boundary
- Captures the call and its arguments
- More than 2000 instances

```
lldb::SBThread SBValue::GetThread() {
  LLDB_RECORD_METHOD_NO_ARGS(lldb::SBThread, SBValue, GetThread);
  ...
  return LLDB_RECORD_RESULT(sb_thread);
}
```

Capturing Calls

- Maps functions to unique identifier
- Type safe
- Synthesizes deserialization logic

```
LLDB_REGISTER_METHOD(void, SBDebugger, SetAsync, (bool));
LLDB_REGISTER_METHOD(bool, SBDebugger, GetAsync, ());
LLDB_REGISTER_METHOD(void, SBDebugger, SkipAppInitFiles, (bool));
LLDB_REGISTER_METHOD(void, SBDebugger, SkipAppInitFiles,(bool));
```

lldb-instr

- Utility on top of libTooling
- Traverses the clang AST
- Inserts the record and register macros

Capturing Arguments

- Stream values to file
- Look at underlying value for pointers and references

Capturing Objects

- Index based on object address
- Table keeps mapping between object and index

```
SBDebugger debugger = SBDebugger::Create();
SBTarget target = debugger.createTarget();
SBLaunchInfo info("--arguments");
target.Launch(info);
```

Object	Index
debugger	1
target	2
info	3

Public API

Replay

```
while (deserializer.HasData(1)) {
  unsigned id = deserializer.Deserialize<unsigned>();
  GetReplayer(id)->operator()(deserializer);
}
```

Components

System Interaction

Command Line Interpreter

Public API (Scripting Bridge)

Files

GDB Remote Protocol

Files

```
$ lldb ./a.out
(lldb) target create "a.out"                    (binary)
(lldb) b main.cpp:12                 (debug information)
...
(lldb) run                            (shared libraries)
...
(lldb) expr @import Foo                        (headers)
(lldb) expr Bar
```

Virtual File System

- Use files from the reproducer
- YAML mapping between virtual and real paths
- Lifted from clang to LLVM
- Devirtualize to support `FILE*` and file descriptors

Filesystem Class

- Wrapper around the VFS
- All file system access must go through this class
- `FileCollector` used for recording files used by LLDB & clang

Components

System Interaction

Command Line Interpreter

Public API (Scripting Bridge)

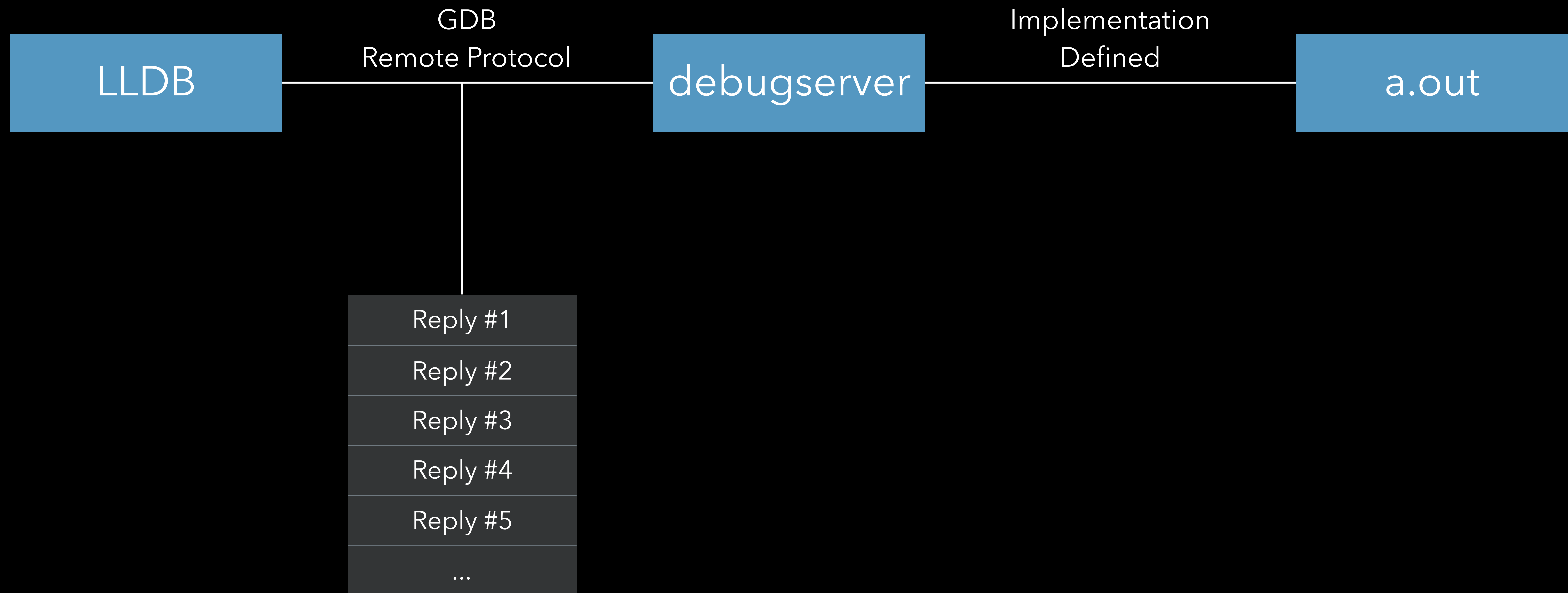
Files

GDB Remote Protocol

GDB Remote Protocol

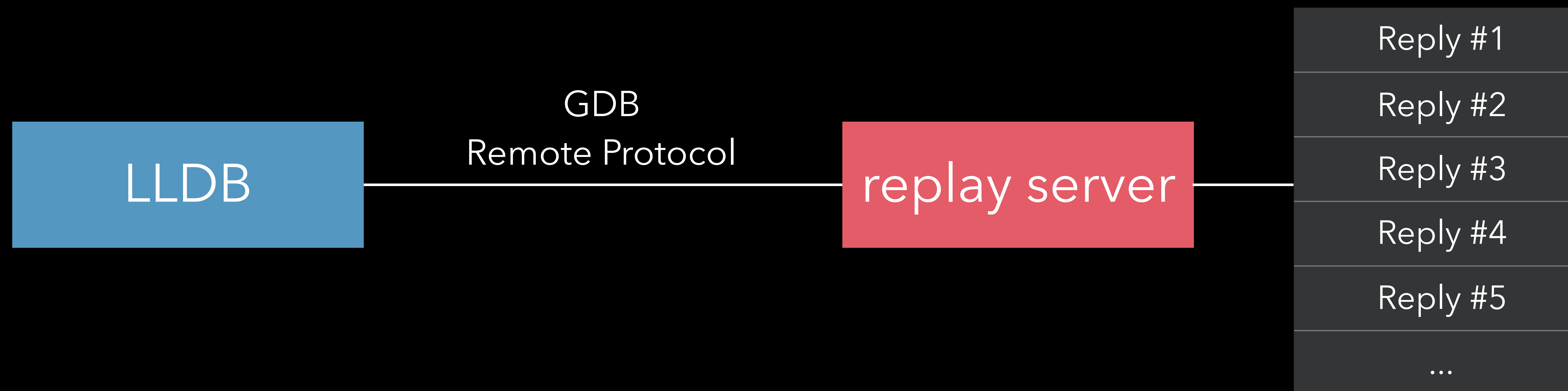
- Simple command and response protocol
- Read and write memory, registers and to start/stop the process
- Designed for remote debugging but also used locally

Capture



Replay

- Responds with recorded reply (in order)
- Fully transparent to the debugger
- Replay remote debug sessions



Limitations and future work

API Arguments

- Function pointers
- Void & data pointers

```
void Foo(char* data, size_t length);
```

ID 10	Data 0xFF ... 0x00	Length 56

Memory Management

- No lifetime tracking for now
- Pointer addresses can be reused
- Objects created during replay are never deallocated

Swift

- Virtual File System
- FileCollector callback

Reproducer Size

- Large files
- Many files
- Do we need all of them?

Crashes

- No guarantees in the signal handler
- Do something smart like clang

Privacy

- Reproducers contain a lot of potentially sensitive information
- Need to be clear and upfront about this to the user

Please try it out!

bugs.llvm.org

Questions?