The Latest in the Deconstruction of DyninstAPI

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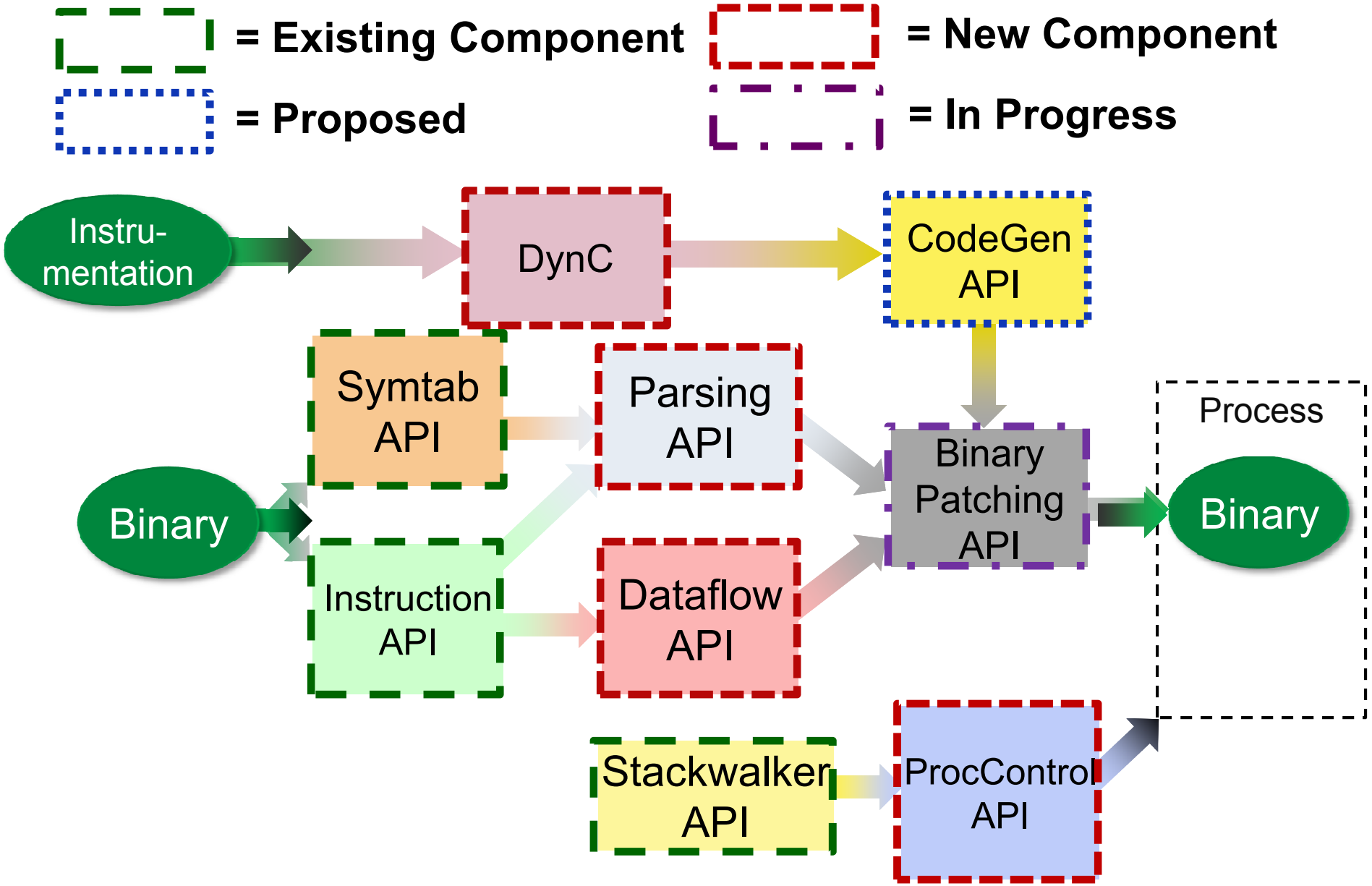
Paradyn

Dyninst

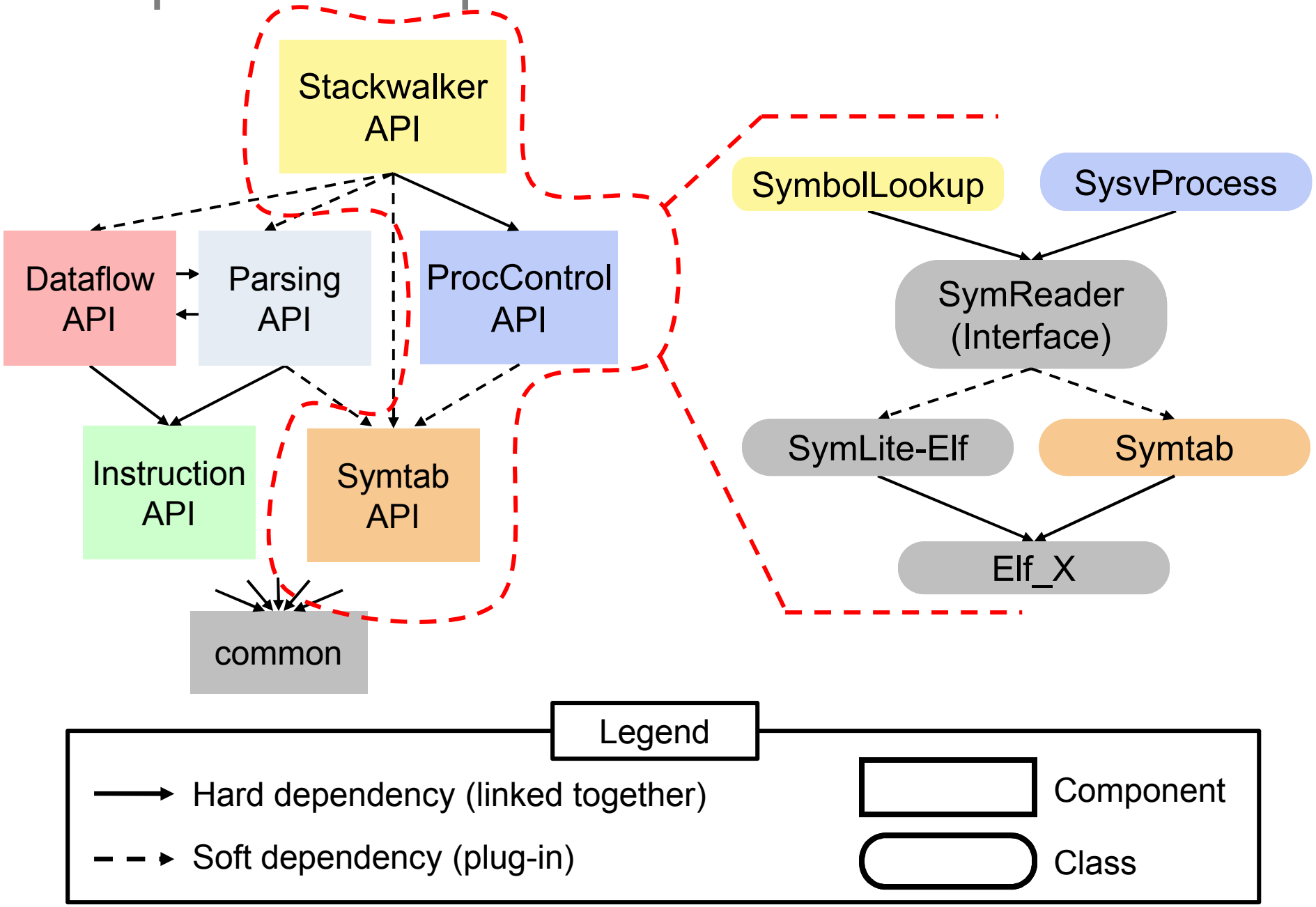
Dyninst and the Components



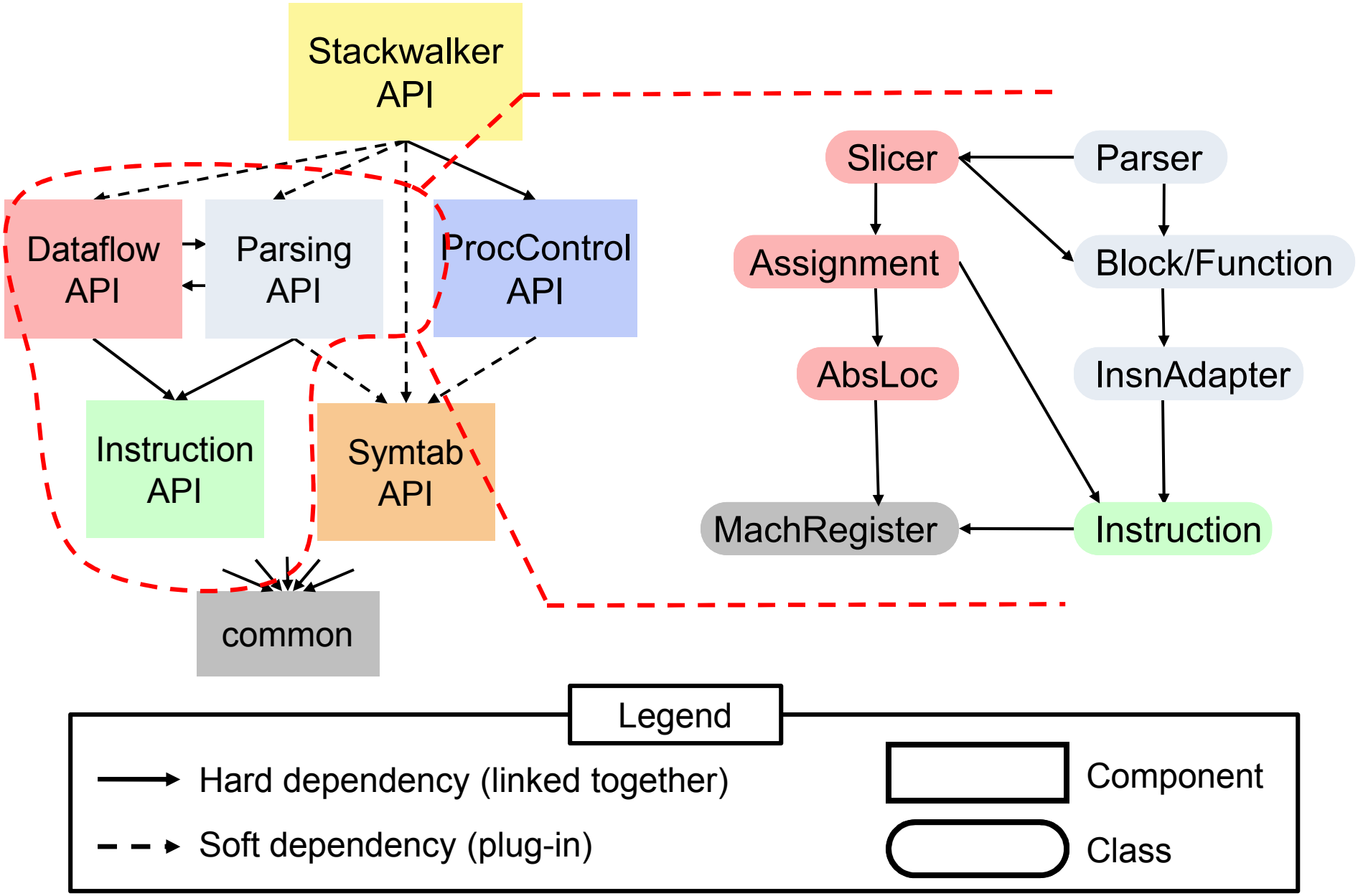
Talk Outline

- **Component Dependencies**
- **ProcControlAPI**
- **ParsingAPI**
- **DynC**
- **Wrapping C++ in C**
- **Other Components/Wrapup**

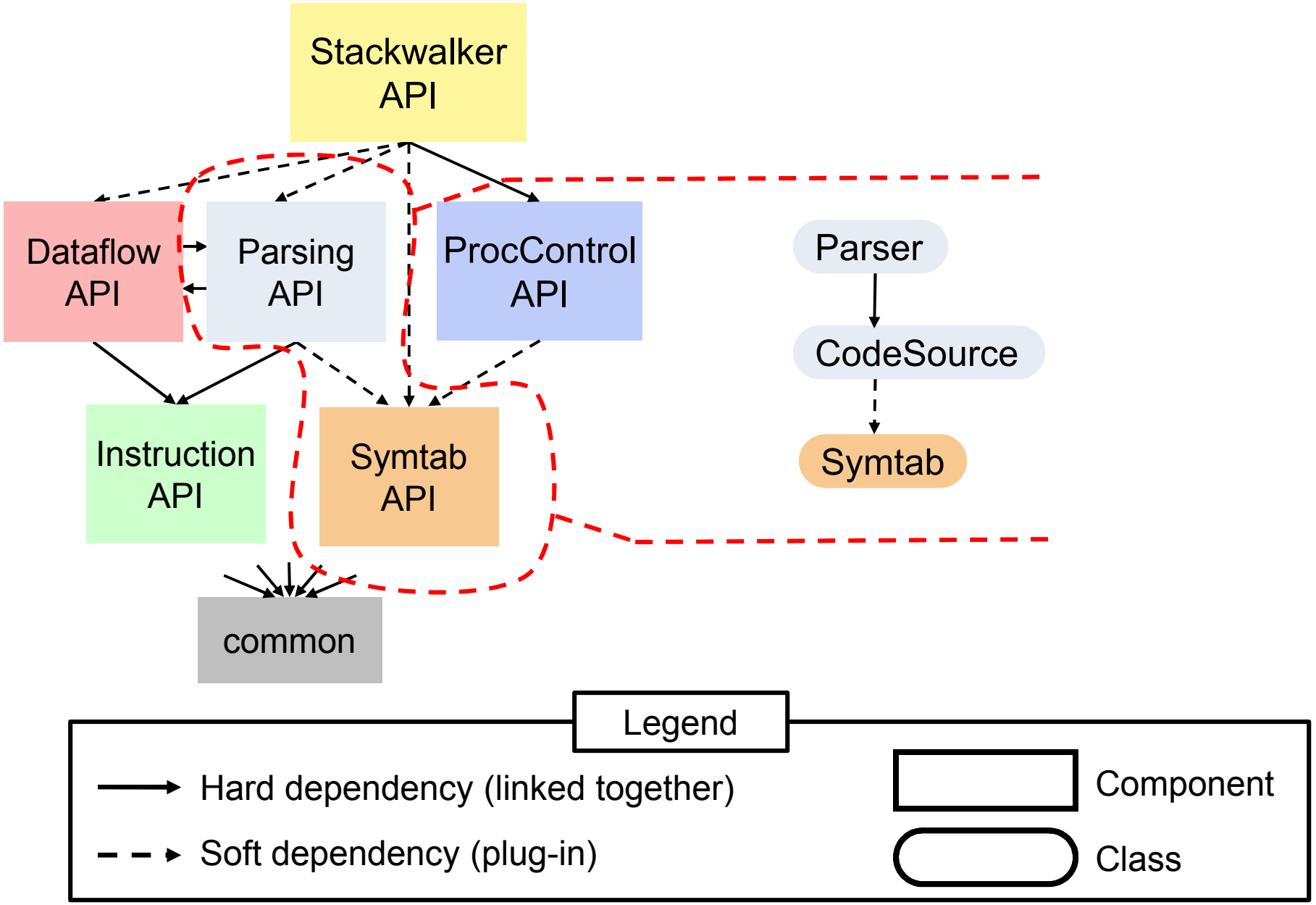
Component Dependencies



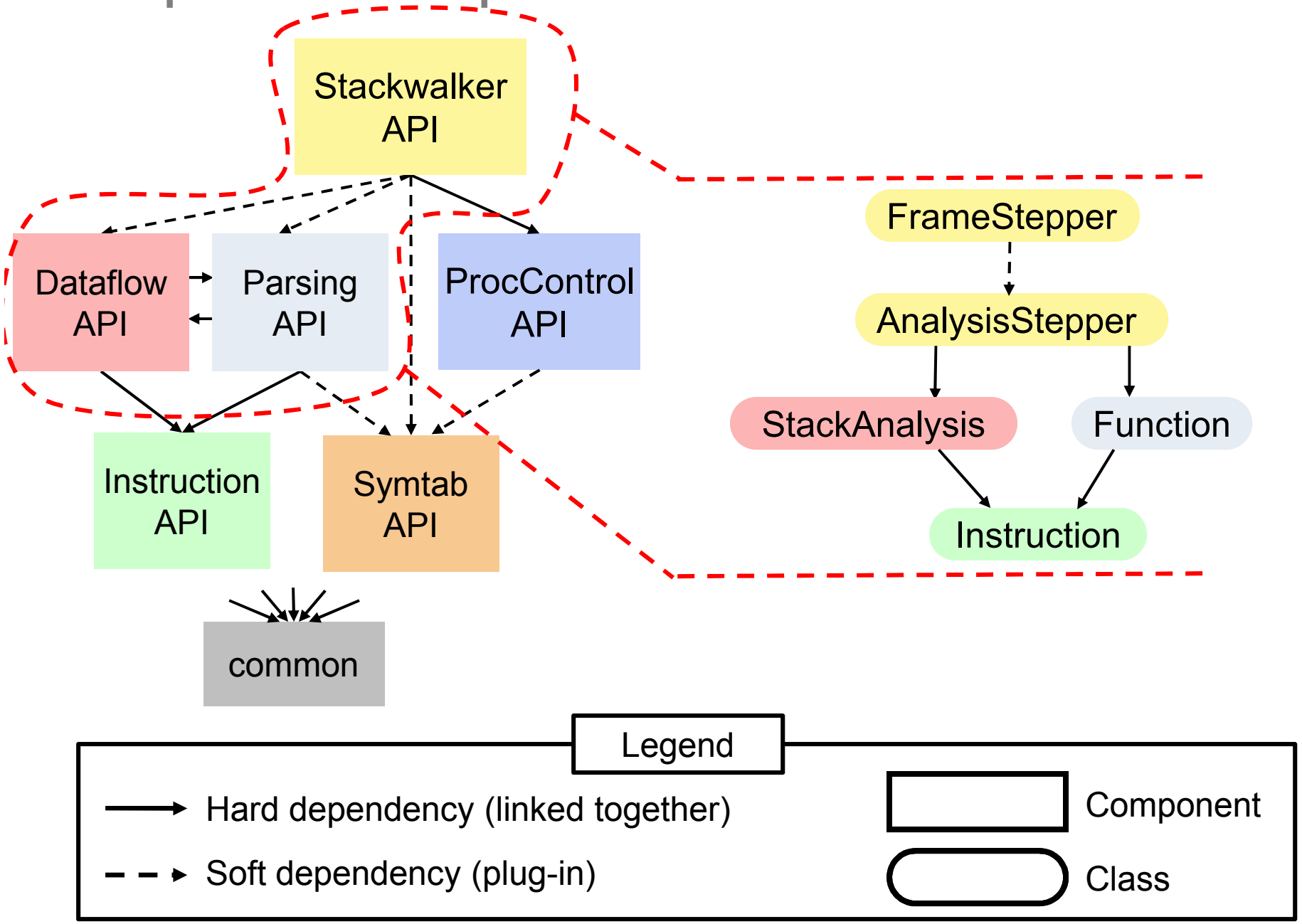
Component Dependencies



Component Dependencies



Component Dependencies



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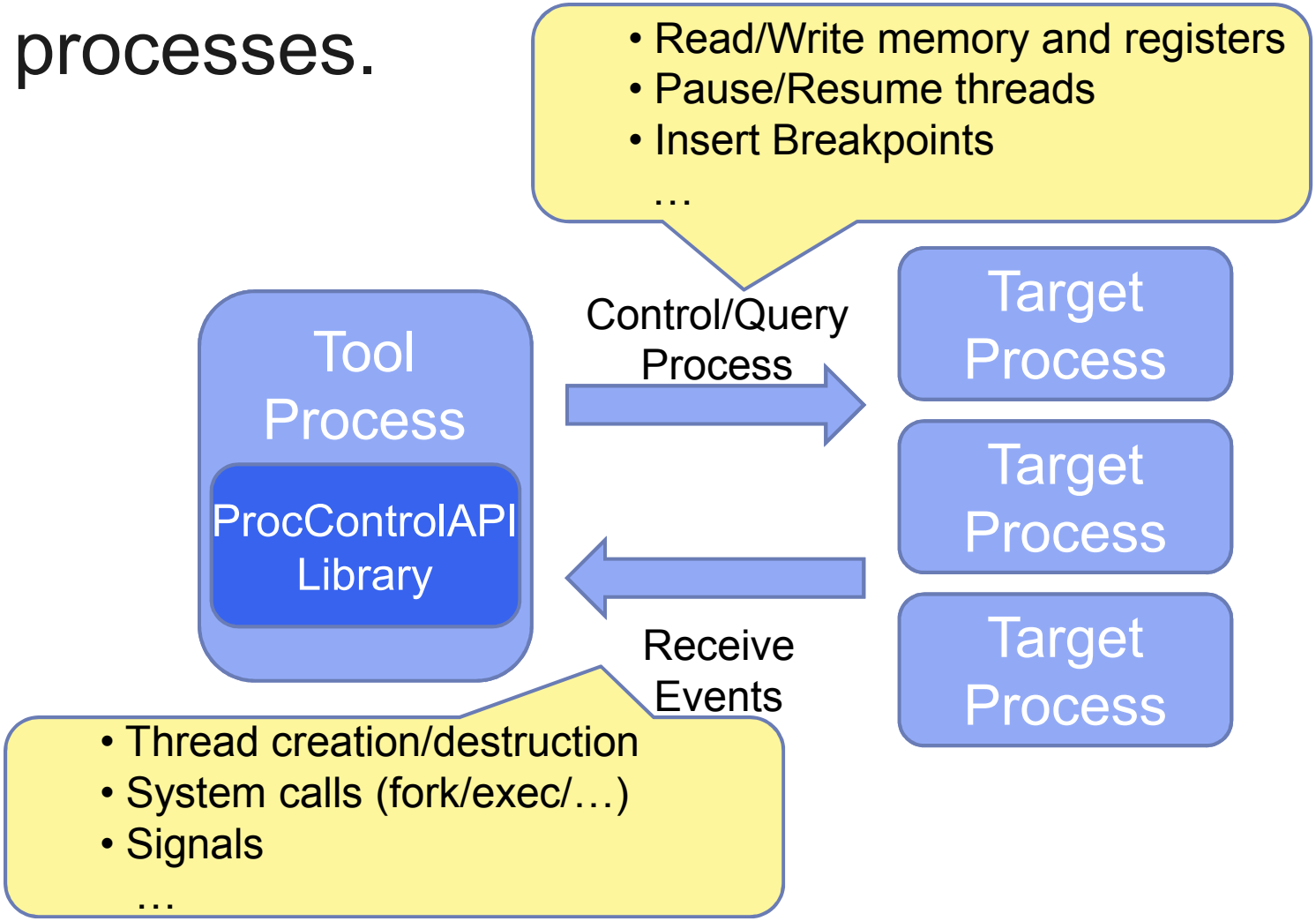
ProcControlAPI

- A library for controlling and monitoring processes.



ProcControlAPI Goals

- Platform Independent Interface
  - Implemented on: Linux, FreeBSD, CrayXT, BlueGene, AIX, Solaris, VXWorks, Windows
- Simple and Powerful
  - High-level abstractions in interface. E.g.,
    - Breakpoints
    - Inferior RPCs
    - Process Control
    - Events

Example: Single Step Threads

```
void singlestep_proc(int pid) {
  Process::ptr proc = Process::attachProcess(pid);
  Process::registerEventCallback(EventType::SingleStep,
                                 singlestep);
  ThreadPool::iterator i = proc->threads().begin();
  for (; i != proc->threads().end(); i++)
    (*i)->setSingleStepMode(true);

  proc->continueProc();
  while (!proc->isTerminated())
    Process::handleEvents(true);
}
```

Attach to a
Register a

For each thread running in the process
Enable single-stepping

Run the process
Block until process terminates

Example: Single Step Threads

```
Process::cb_ret_t on_singlestep(Event::ptr event)
{
  unsigned long cur_pc, thread_id;
  event->getThread()->getRegister(MachRegister::getPC(),
                                  cur_pc);
  thread_id = event->getThread()->getLWP();

  printf("Singlestep to %lx on thread %lx\n",
         cur_pc, thread_id);

  return Process::cbThreadContinue;
}
```

Called each time a thread executes an instruction

Get the thread's PC and LWP.

Tell ProcControlAPI to continue the thread

Process Class

- Handle for target process
- Typical operations
  - Create and attach to processes
  - Access process memory
  - Insert breakpoints
  - Track library loads/unloads
  - Track thread creation and destruction
  - Stop/Continue all threads
  - Detach from/terminate target process

Thread Class

- Handle for thread in target process
- Typical Operations
  - Stop/Continue individual thread
  - Get/Set registers
  - Single step

- Assuming 1:1 threading/LWP model
  - Thread object represents OS's LWP
  - Thread object represents user space thread

Inferior RPCs

- Insert and run code in target process
  - User provides machine code to run
  - ProcControlAPI allocates memory, saves registers, runs code, restores registers and memory
  - Returns result of iRPC

- gdb supports a subset of this

```
(gdb) call getpid()
$1 = 14218
(gdb)
```

Events

- Can register callbacks for process events:
  - Fork
  - Pre-Exec
  - Post-Exec
  - Pre-Exit
  - Post-Exit
  - Crash
  - Signal
  - Thread Create
  - Thread Destroy
  - Library Load
  - Library Unload
  - Breakpoint
  - RPC Completion
  - Single Step

Callbacks

- Events are delivered via callbacks
  - User registers callbacks for interesting events

- Restrictions on callback functions
  - Can not call anything that would recursively trigger more callbacks.
  - This prevents races

ProcControlAPI Status

- Currently on Linux/x86, Linux/x86_64, FreeBSD,Cray/XT
- Next platforms are Linux/ppc, BlueGene.
- Windows and AIX support to follow.

- Beta release available upon request.

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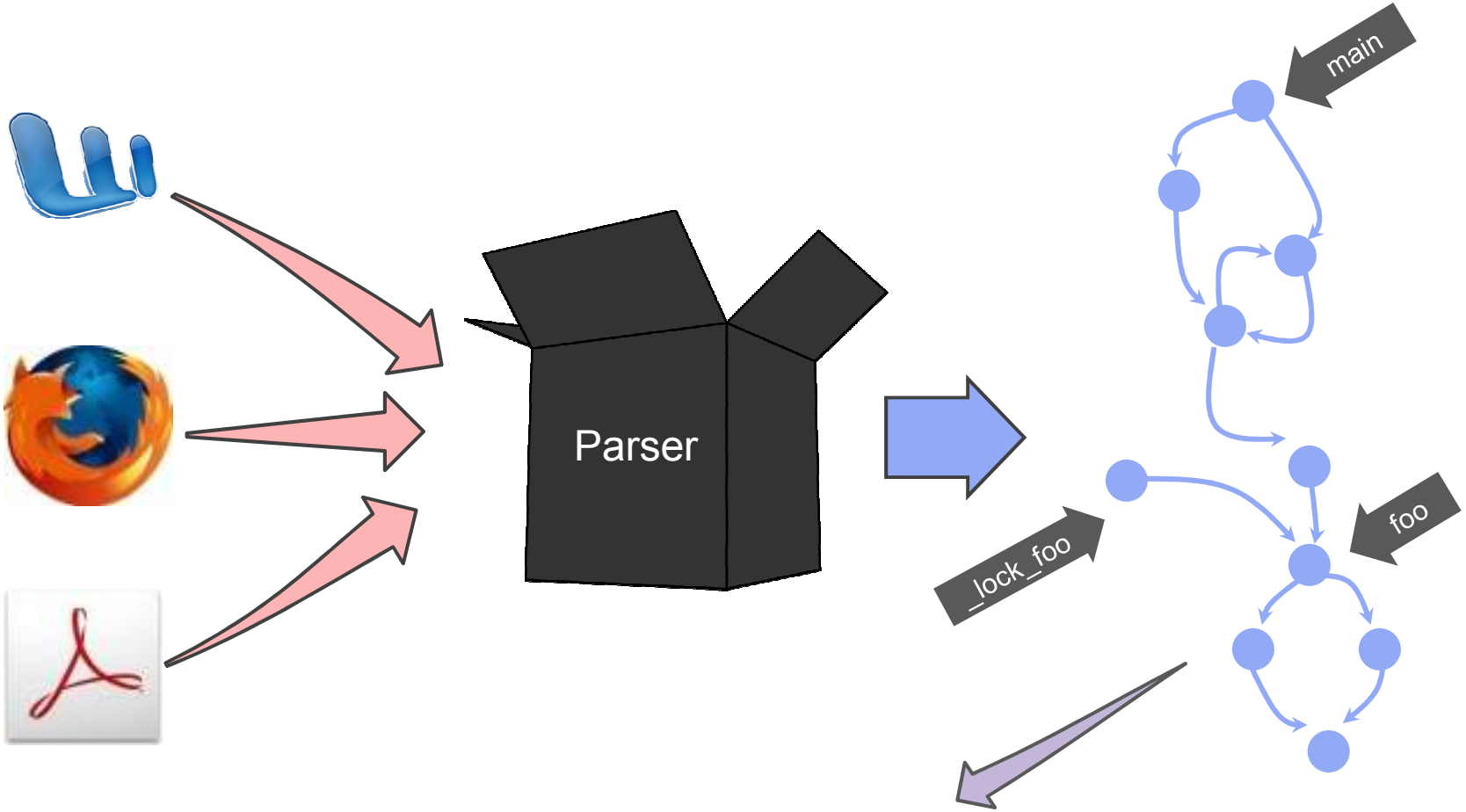
Binary parsing



dynamic instrumentation, debugger, static binary analysis tools, malware analysis, binary editor/rewriter, …

We've been down this road…

the Dyninst binary parser

recursive traversal parsing

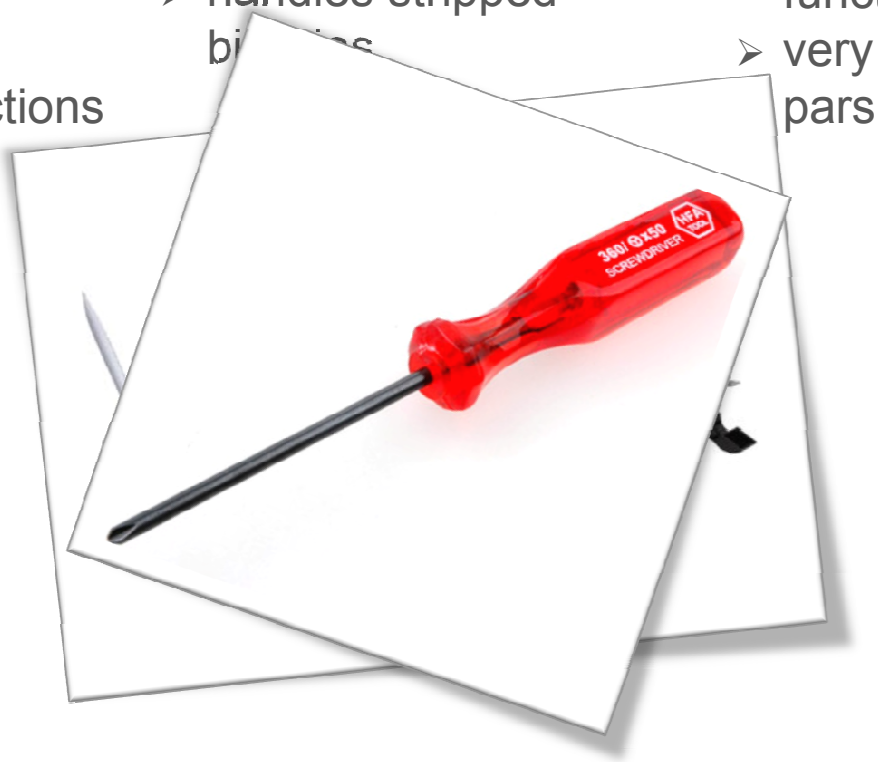
- non-contiguous functions
- code sharing
- non-returning functions

"gap" parsing heuristics

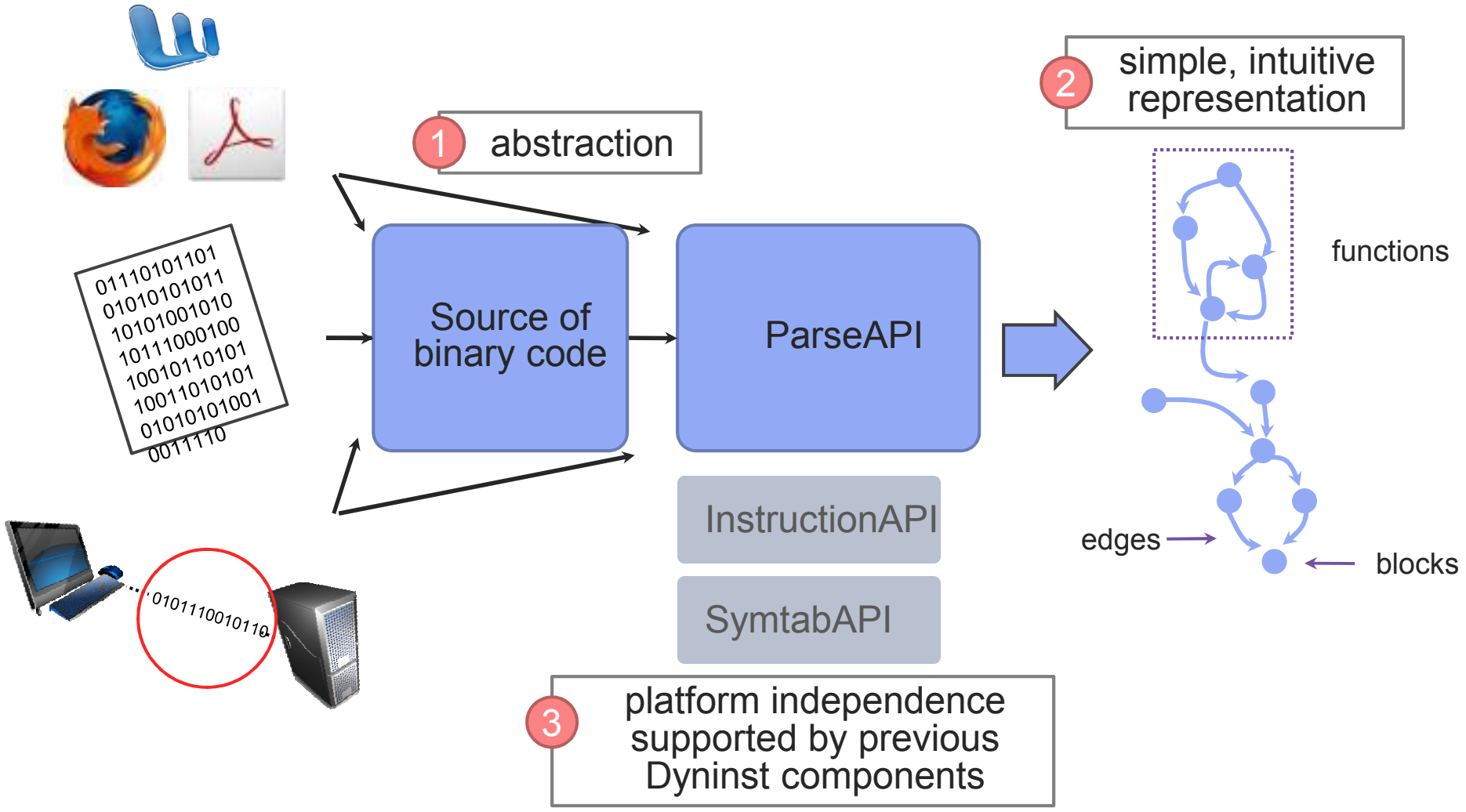
- preamble scanning
- handles stripped bi…

probabilistic code models

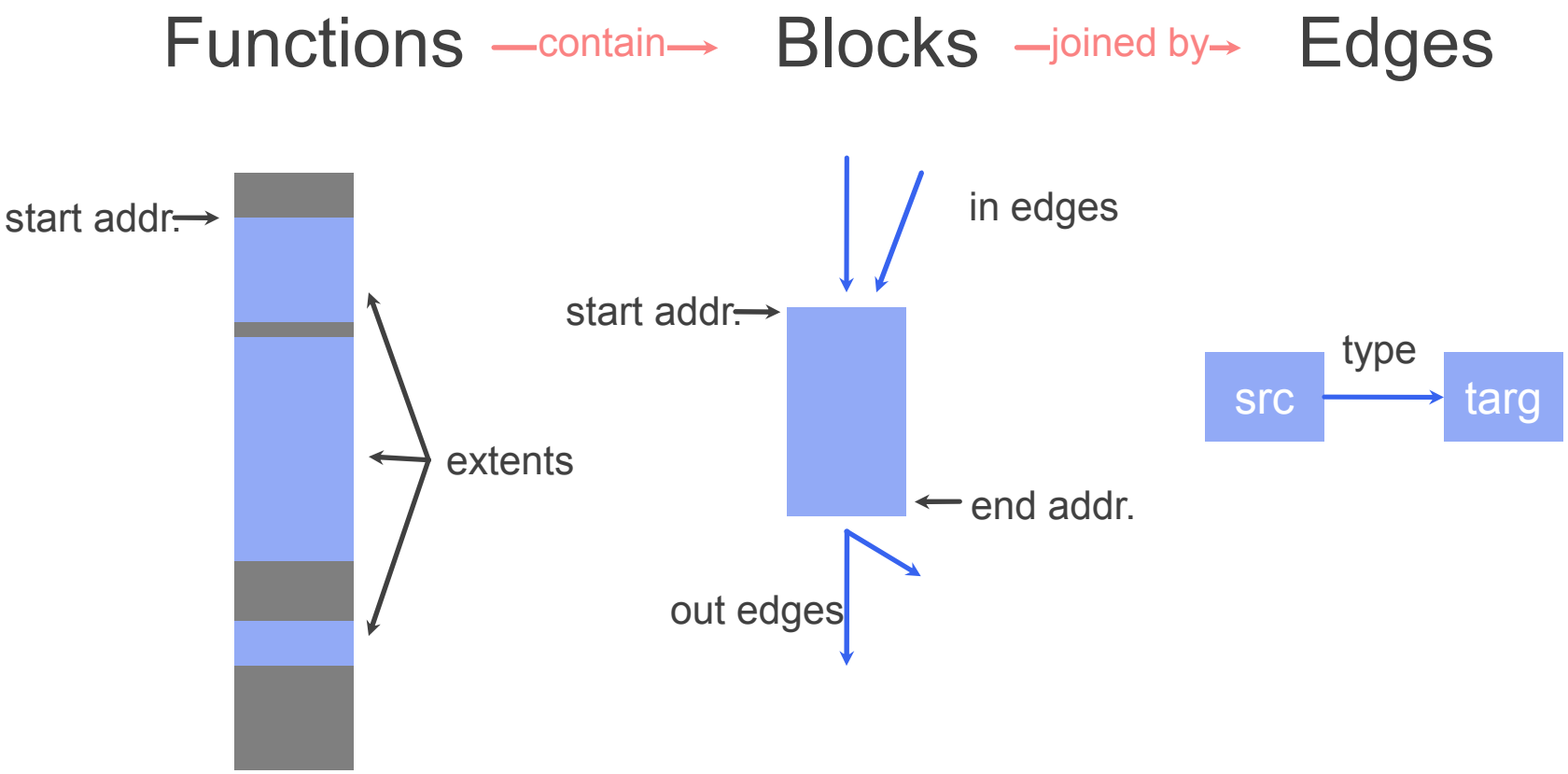
- learn to recognize function entry points
- very accurate gap parsing



What makes a parsing component?



Simple control flow interface



Parsing Interface

```
SymtabCodeSource s("/lib/libc.so.6");
CodeObject libc(&s);
Address entry_addr = ...;

// Find and parse the function @ entry_addr
libc.parse(entry_addr, NO_RECURSE);

// Parse the entire object
libc.parse ();

// Find "printf"
Function *printf_func = libc.findFuncByName("printf");

// Find the function starting at entry_addr
Function *other = libc.findFuncByEntry(entry_addr);
```

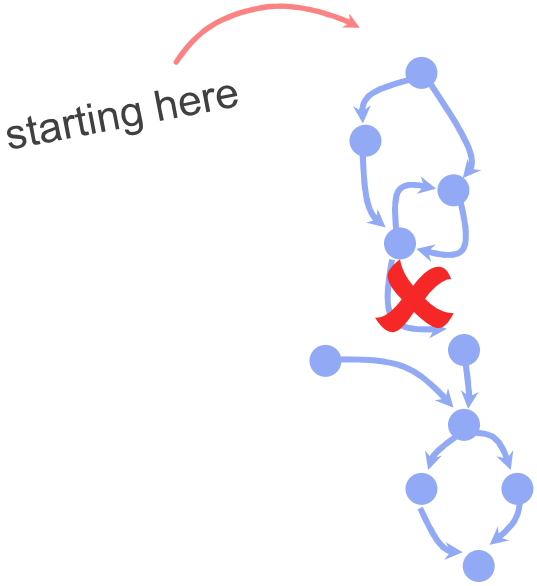
Views of control flow

*Walking an **intra**procedural control flow graph*

```
blocks.push_back(printf_func->entry());
while(!blocks.empty()) {
  Block *b = blocks.pop();

  /* do something with b */


  edgeiter eit = b->out().begin();
  while(eit != b->out().end()) {
    blocks.push(*eit++);
  }
}
```



What if we only want intraprocedural edges?

Edge predicates

*Walking an **intraprocedural** control flow graph*

```
blocks.push_back(printf_func->entry());
while(!blocks.empty()) {
  Block *b = blocks.pop();

  /* do something with b */

  IntraProc pred;
  edgeiter eit = b->out().begin(&pred);
  while(eit != b->out().end()) {
    blocks.push(*eit++);
  }
}
```

Edge Predicates

Tell iterator whether Edge argument should be returned
Composable (and, or)

Examples:

- Intraprocedural
- Single function context

What's in the box?* box to be released soon

Binary Parser

- recursive descent parsing
- speculative gap parsing
- cross platform: x86, x86-64, PPC, SPARC

SymtabAPI-based Code Source

- cross-platform
- supports ELF, PE, XCOFF formats

Control Flow Graph Representation

- graph interface
- extensible objects for easy tool integration

Dataflow Analysis

?

Dataflow applications

Inside parsing:

- Improved jump table parsing
- Virtual function identification
- Detecting return address modifications
- Identifying library functions via syscall patterns

Other:

- Relocating code safely
- Stack walking

Interface Questions

Low level concepts

- Abstract location
- Abstract region

Graph representation

- Data dependence
- Control dependence
- Slicing

Symbolic Evaluation

- Translate instructions to functions via semantics

Analysis Algorithms

- Stack analysis
- …?

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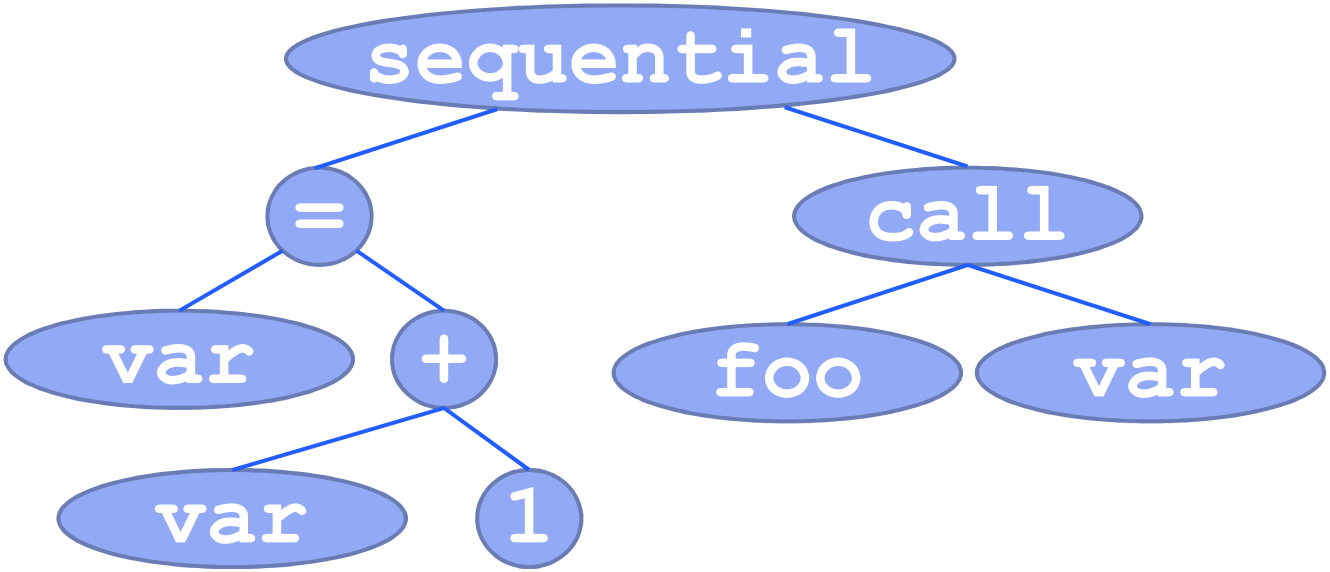
DynC – An Instrumentation Language

- Old ASTs



- DynC Language

```
`foo(++`var);
```

DynC Domains

- Reference symbols with domains (backtick operator):

```
global`printf("Open called on %s\n"
                param`pathname);
```

- Lone backticks have Dyninst search:

```
`printf("Loop index is %d\n"
        local`i);
```

- Idea from Cinquecento language

DynC Instrumentation Support

- Use $ operator to access built-in instrumentation functions

```
if ($thread_index == 0) {
   `printf("Entering function %s\n",
            $function_name);
}
```

- Declare variables in instrumentation

```
int i;
i++;
```

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C++ in First-Party Tools

Good

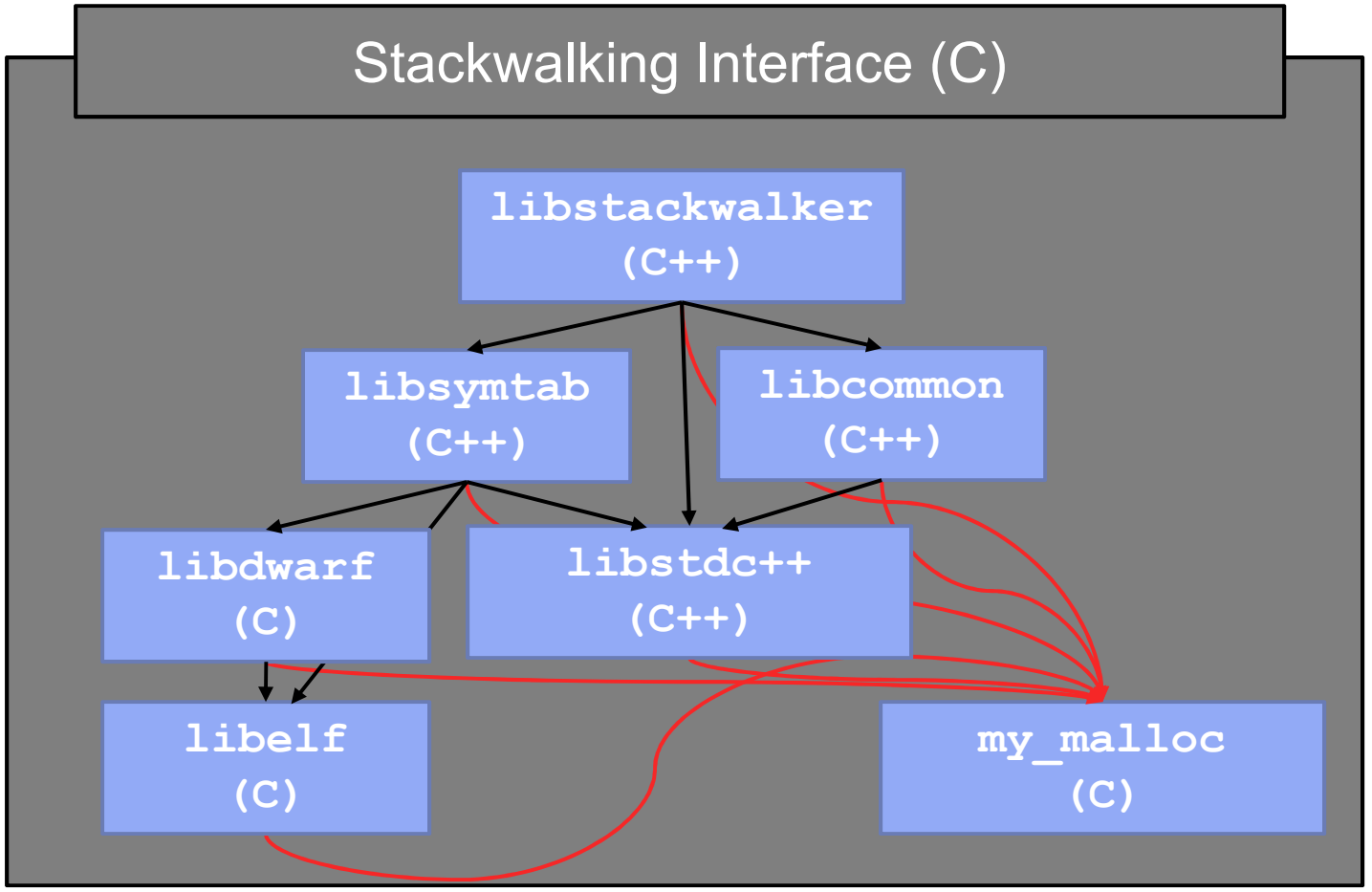
- A high-level language, good for large applications
- Large suite of support libraries (STL, Boost)
- Good performance

Bad

- Incompatibilities between libstdc++ versions
- Implicit dynamic memory allocations from STL
- Poor interoperability with other languages

- DyninstAPI and components are about ~460,000 lines of C++

Goal: Hide the C++



- Wrap collection of libraries into “wrapper” library
  - Only export minimal C interface

Recipe for Wrapper Library

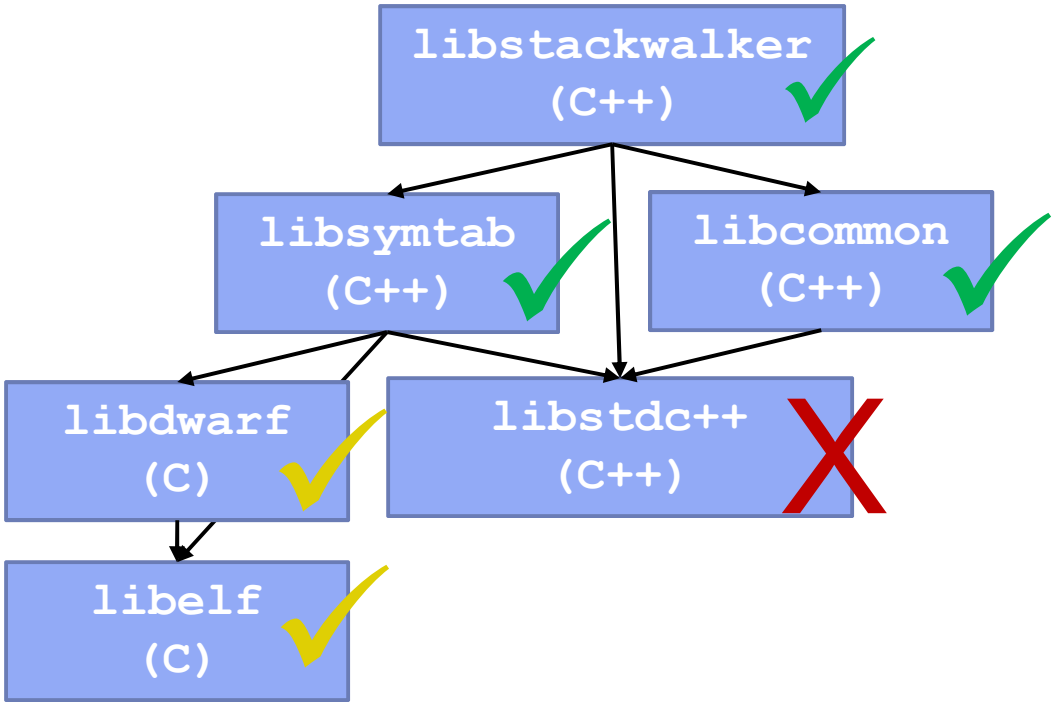
For each sub-library

- Build object files with –fPIC
- Link into static archive

Link sub-libraries into wrapper shared library

- Include custom malloc
- Include “C” interface
- Use GNU ld’s --exclude-libs option to hide exports from sub-libraries

The Catch: Building archives with -fPIC



✓ Written by us—easy to change

✓ Simple tool—not too difficult to change

X Part of gcc—hard to change

Building fPIC libstdc++.a

- GCC comes with:
  - libstdc++.so, built with –fPIC
  - libstdc++.a, built without –fPIC
- Build custom gcc with fPIC and libstdc++.a
  - Modify libstdc++ Makefile, add –fPIC to CFLAGS
- Distribute modified libstdc++ with tool
  - Or distribute wrapper library as binary code

Current Status

- StackwalkerAPI into wrapper library
  - No visible C++
  - Does not touch application heap
  - ~3MB on disk

- "C" interface to StackwalkerAPI partially completed.

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StackwalkerAPI

- Current:
  - Linux/x86, Linux/x64, Linux/PPC32, Linux/PPC64, BlueGene/L, BlueGene/P, CrayXT
  - DWARF based stack walking
- Future:
  - Analysis based stack walking
  - No file access stack walking
  - ProcControlAPI for third-party

InstructionAPI and SymtabAPI

- InstructionAPI:
  - x86, x86_64, PPC32, PPC64 instruction decoding
  - Significant performance improvements over previous versions
- SymtabAPI
  - Object file and debug parsing for ELF, PE, XCOFF
  - Shared libraries, static libraries, executables, static binaries, object files
  - Rewriting interface

DyninstAPI

- Static and dynamic binary instrumentation
- Binary analysis framework

- New features:
  - LGPL licensed
  - Rewriting statically linked binaries
  - FreeBSD/x86_64 support
  - Linux/PPC static rewriting
  - BlueGene static rewriting

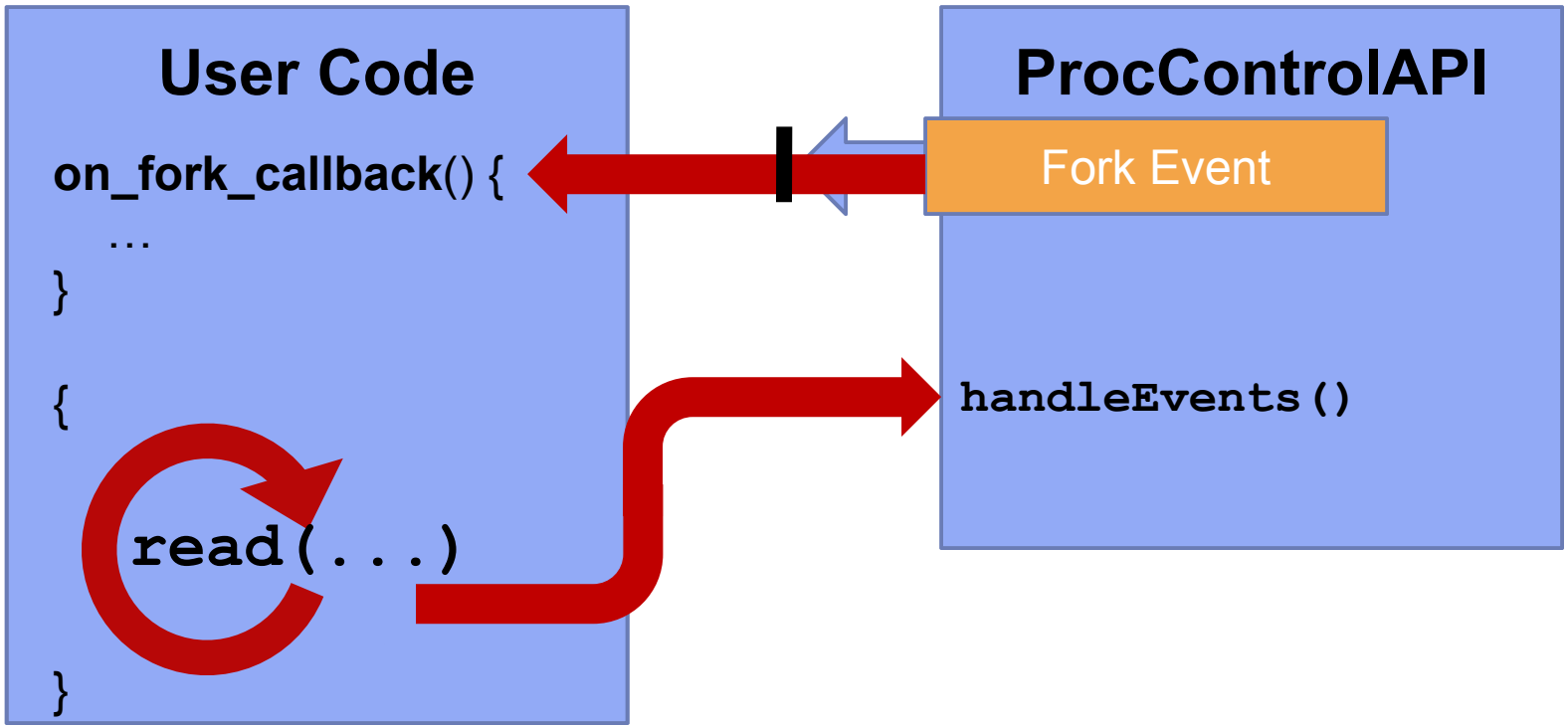
New MRNet features

- Cray XT support
- Lightweight MRNet back end (C-based)
- Per-stream data arrival notification
- Optimizations to startup efficiency
- Beta: topology information available at filters
- Timeout filters (finally!)

Questions?

Callback Notification

- Want to deliver callback on user thread
  - User thread may be busy or blocked



- ***Notify*** user that event is pending via Callback or FD

ProcControlAPI Use Cases

- StackwalkerAPI
  - Read stack memory
  - Access registers
  - Stop/Continue process
  - Track dynamic libraries
- DyninstAPI
  - Write instrumentation
  - Receive events
  - Track threads
  - Walk call stack
  - Stop/Continue process
  - OneTimeCode
  - Launch/Attach processes
  - Track dynamic libraries
  - Read/Set variable values
- Debugger
  - Receive Events
  - Track threads
  - Walk call stack
  - Stop/Continue process
  - Insert breakpoints
  - Track dynamic libraries
  - Read/Set variable values
  - Single step