Curiously Recurring C++ Bugs at Facebook

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Facebook

C++ @ fb

- Second most used language at Facebook
- C++ in Infrastructure from very early on
- Now: C++, python, java, ...

my team

- Responsible for the C++ tooling and core libraries
- Tools: compilers, sanitizers, CI, build, etc.
- Core libraries: folly, "common", refactors
- Frequently involved in nasty bugs, escalations.

Agenda

- Bugs.
- Scary, common, concrete.
- Mitigation (welcome to the church of ASAN).
- Warning: gcc/clang bias from me.

Two audiences

- Audience #1. Show you a bug you've never seen before.
  - Save you from a really, really bad day.
- Audience #2. Show you a bug you've seen a hundred times
  - that you never, ever make yourself anymore...

Bug #1

`std::vector::operator[]`

Bug #1

```
std::vector::operator[]
array[]
*ptr
```

vector::operator[]

```
return vec[27];
```

- Crashing the Site 101.
- Eternal problem.
- ... and for our purposes, generally uninteresting.

mitigation

- Static analysis. Complicated, hard, expensive.
- Improved abstractions (range-based operations).
- Dynamic analysis.
  - Bounds checking
  - Address sanitizer (+fuzzing!)
  - `-fsanitize=address`

Bug #2

greatest C++ newbie bug

Bug #2

`std::map::operator[]`

std::map::operator[]

```
map<string, int> m;
m["hey"] = 12;
cout << m["hye"];
```

Weird, but useful

```
map<char, int> occ;
for (char c : str) {
    occ[c]++;
}
```

Won’t compile

const correctness

```
void Widget::configure(
    const map<string, string>& settings) {
    m_timeout = settings["timeout"];
    m_size = settings["max_items"];
}
```

Noooooo!

```
void Widget::configure(
            map<string, string>& settings) {
    m_timeout = settings["timeout"];
    m_size = settings["max_items"];
}
```

error message

```
error: passing 'const std::map<std::string<char>,
                                std::string<char> >'
as 'this' argument discards qualifiers
```

"error passing const"

```
error: passing 'const std::map<std::string<char>,
                                std::string<char> >'
as 'this' argument discards qualifiers
```

Twice

```
Widget::Widget(
   const map<string, int>& settings) :
     m_settings (settings) {

}
```

Twice

```
Widget::Widget(
   const map<string, int>& settings) :
     m_settings (settings) {
   std::cout << "initializing with ... \n"
             << "timeout: "
             << m_settings["timeout"];
             << std::endl;
}
```

Helpfully set timeout to 0

```
Widget::Widget(
  const map<string, string>& settings) :
    m_settings (settings) {
  std::cout << "initializing with ... \n"
            << "timeout: "
            << m_settings["timeout"];
            << std::endl;
}
```

mitigation

- none
- const correctness?
- ban it?

Bug #3

`mapGetDefault()`

some haskell!

```
findWithDefault def k m
  = case lookup k m of
      Nothing -> def
      Just x  -> x
```

folly::get_default

```
template <class Map, typename Key>
typename Map::mapped_type get_default(
    const Map& map,
    const Key& key,
    const typename Map::mapped_type& dflt ) {
  auto pos = map.find(key);
  return (pos != map.end() ? pos->second : dflt);
}
```

string-version

```
string get_default(
      const map<string,string>& map,
      const string& key,
      const string& dflt) {
    auto pos = map.find(key);
    return (pos != map.end() ?
                  pos->second : dflt);
}
```

fixed!

```
const string& get_default(
      const map<string,string>& map,
      const string& key,
      const string& dflt) {
    auto pos = map.find(key);
    return (pos != map.end() ?
                  pos->second : dflt);
}
```

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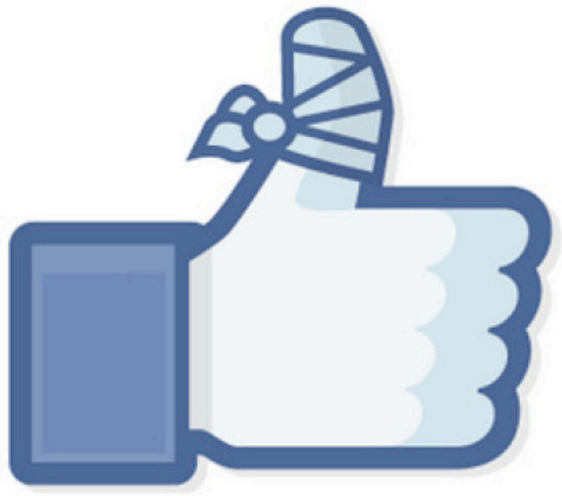


People love temporary default values.

(understandably)

```
auto& v = get_default(m, k, "127.0.0.1");
```

Broader class of problems

- "smuggling" a reference to a temporary through a function.
- One of many, many examples.
- C++ standards

mitigation

- Address sanitizer will catch this!
- Maybe with extra flags. Depends on clang version. I think.
- `-fsanitize-address-use-after-scope`

Bug #4

a success story

volatile

volatile lint warning

'volatile' does not make your code thread-safe. If multiple threads are sharing data, use std::atomic or locks. In addition, 'volatile' may force the compiler to generate worse code than it could otherwise.

we had so many arguments

wild success

- std::atomics
- higher level abstractions
- Solved a very hard, social problem.
- expectations == reality?

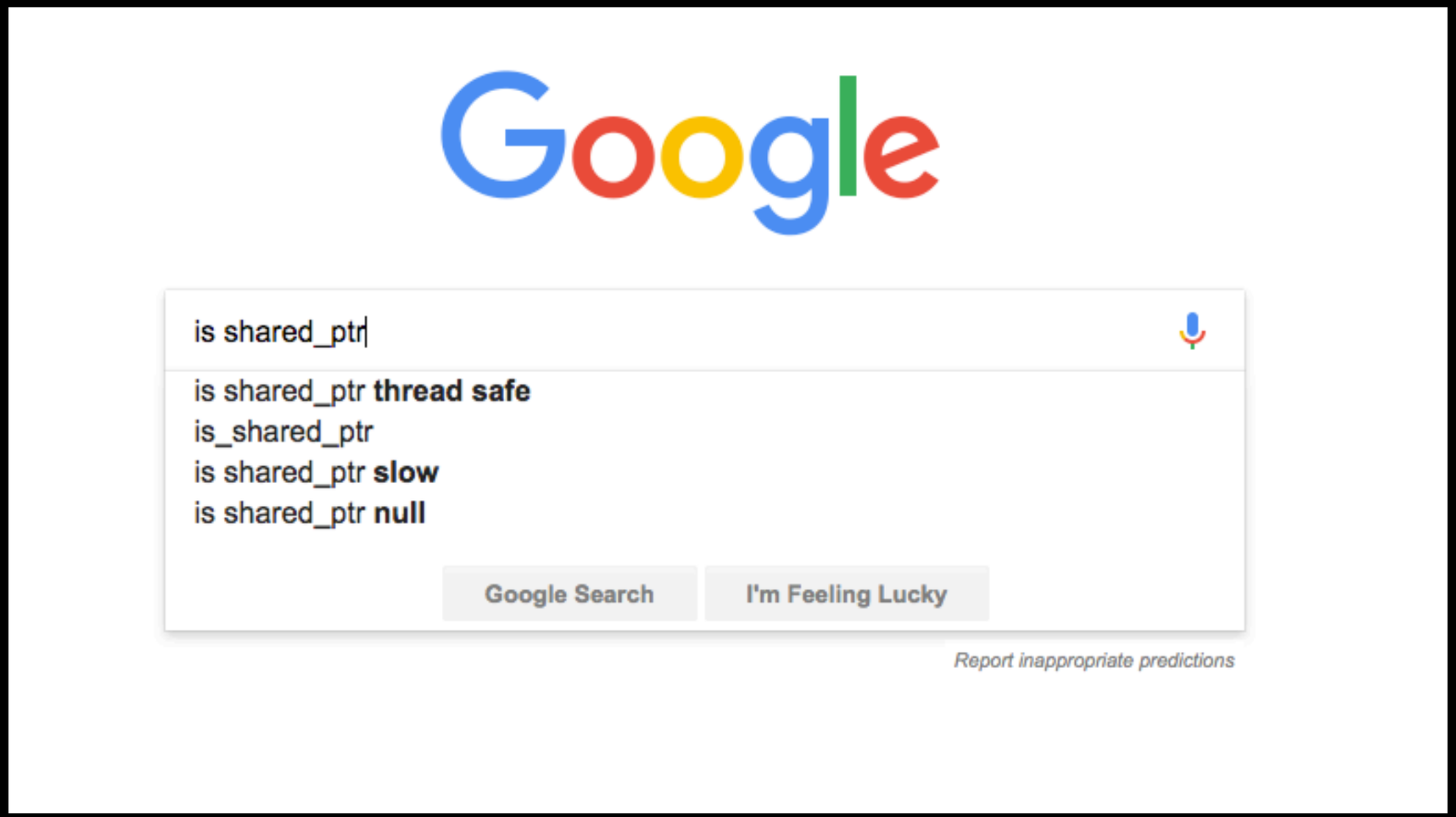
Bug #5

the worst question in all of C++

ls

Is shared_ptr

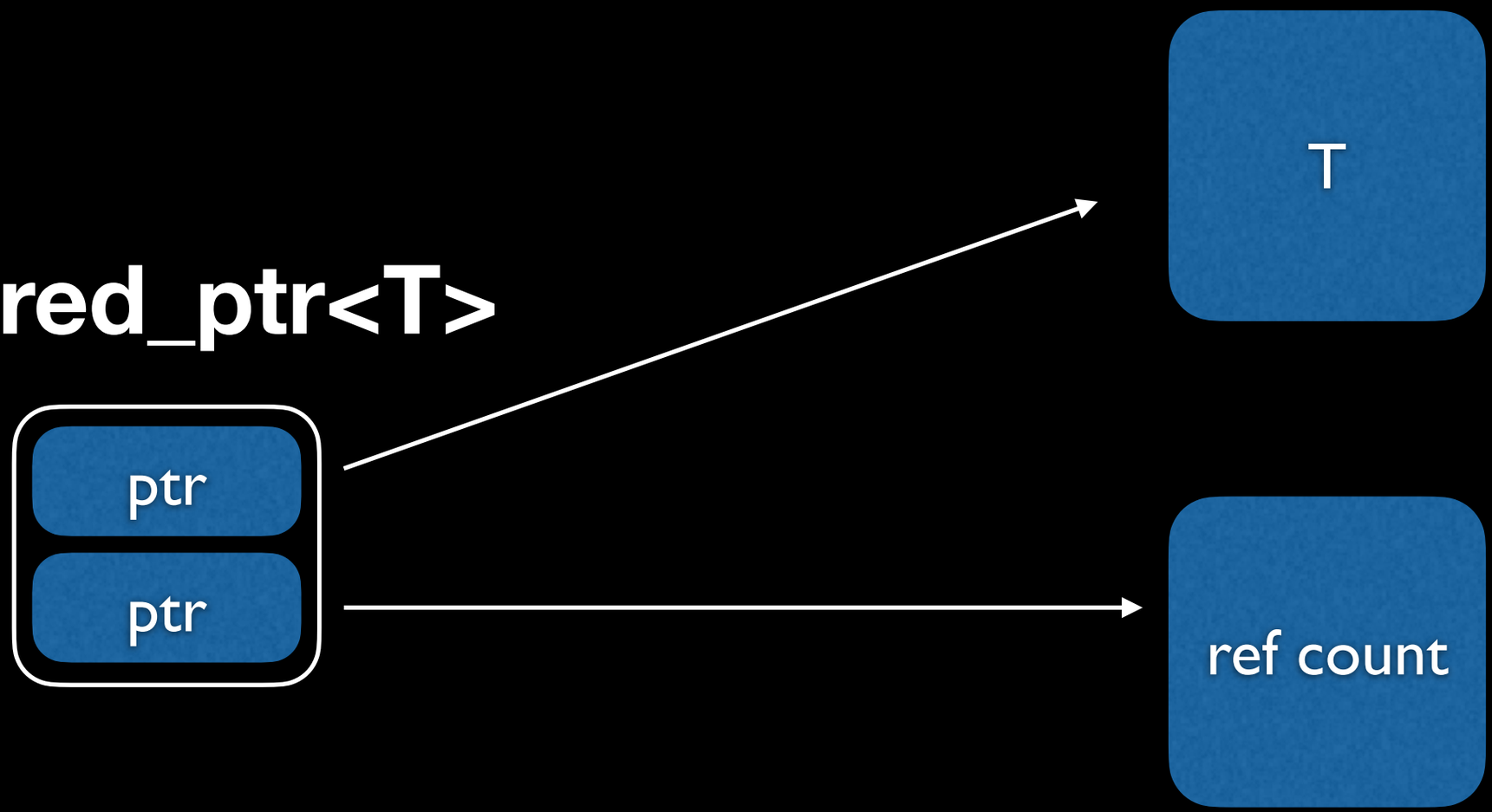
Is shared_ptr thread-safe?


Google
is shared_ptr
is shared_ptr thread safe
is_shared_ptr
is shared_ptr slow
is shared_ptr null
Google Search
I'm Feeling Lucky
Report inappropriate predictions

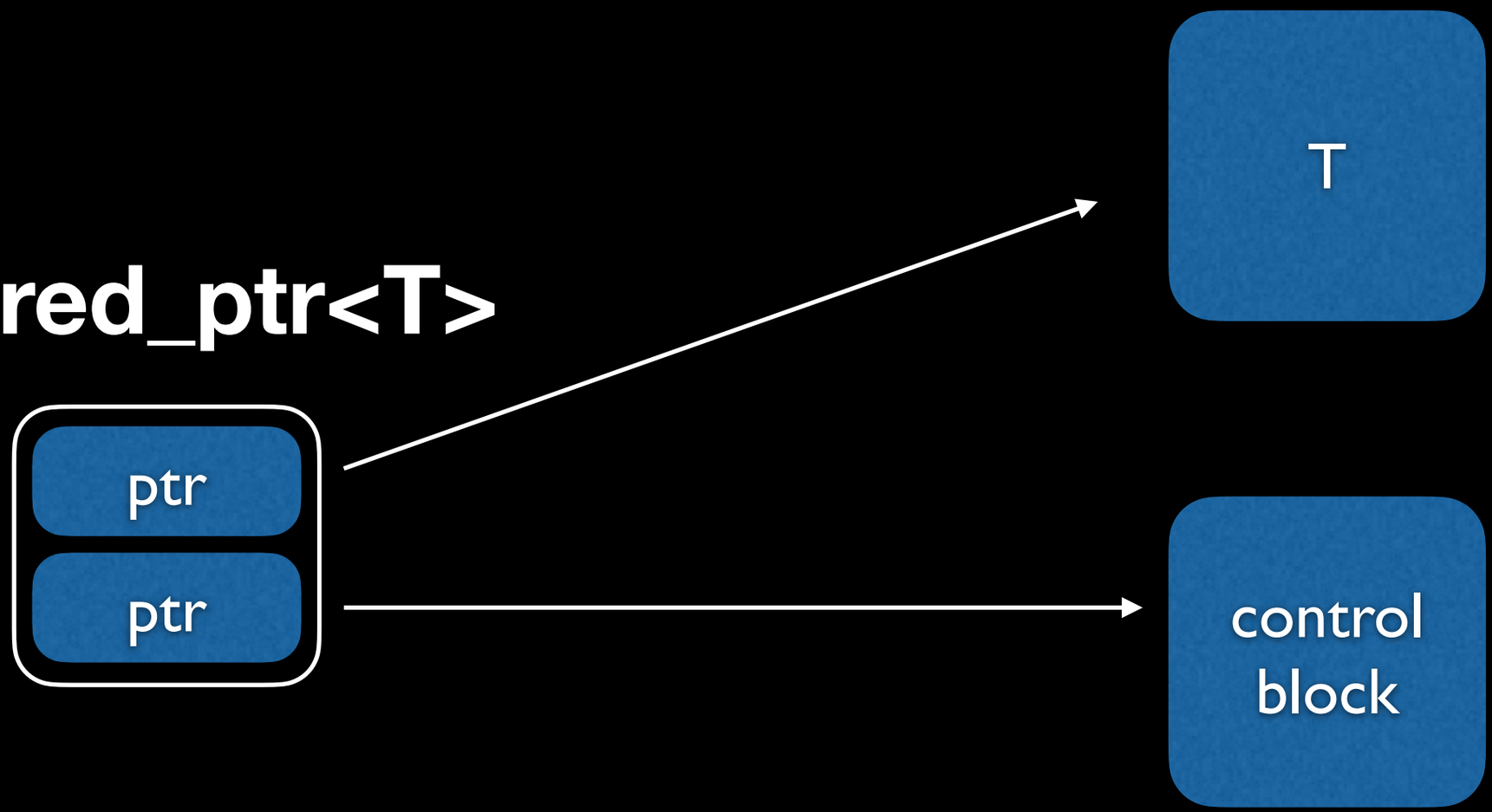
Correct answer

- Is shared_ptr thread-safe?
- If you need to ask...
- Let's go with "No!"

a naive mental model



thread safety



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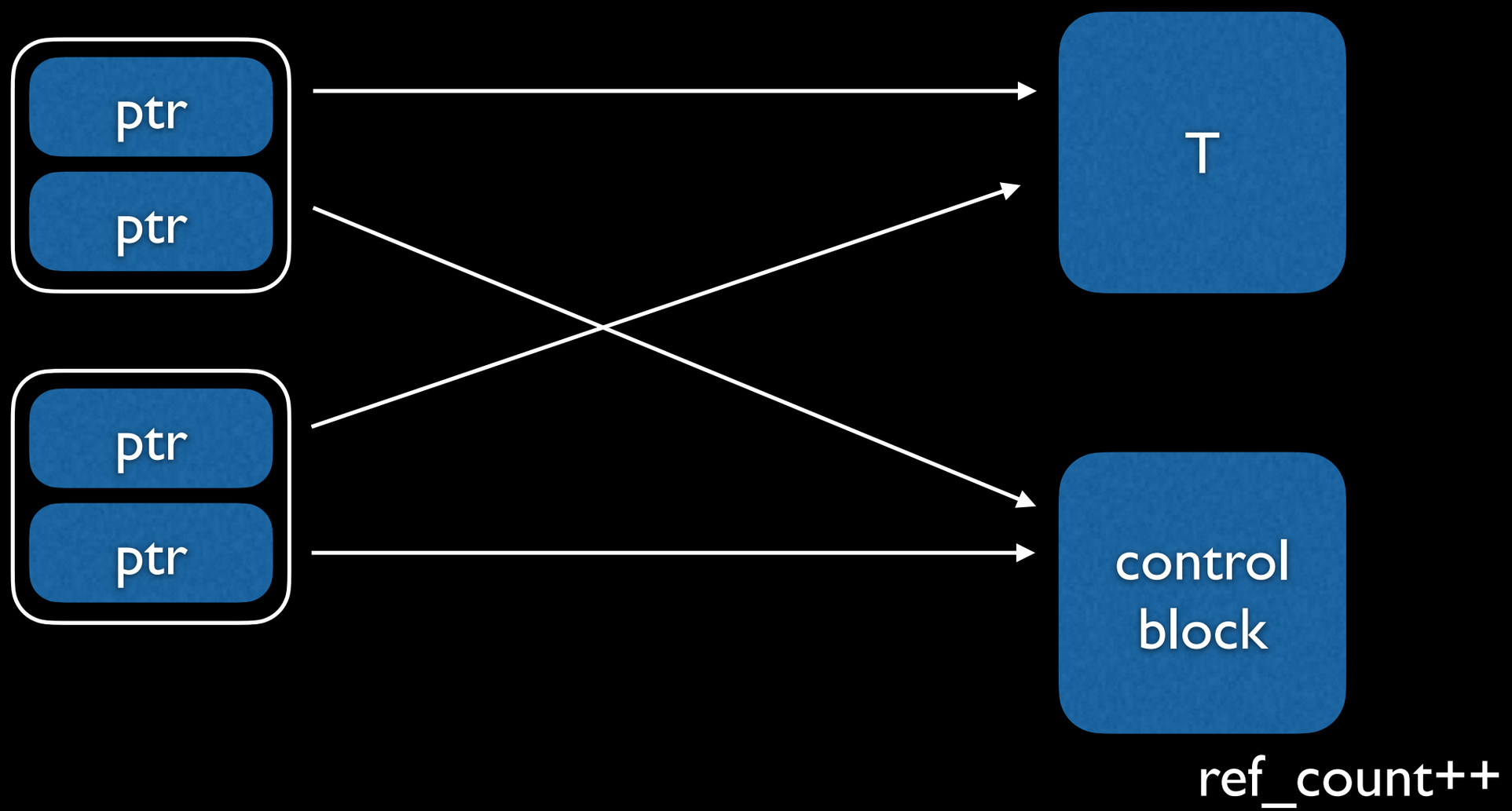
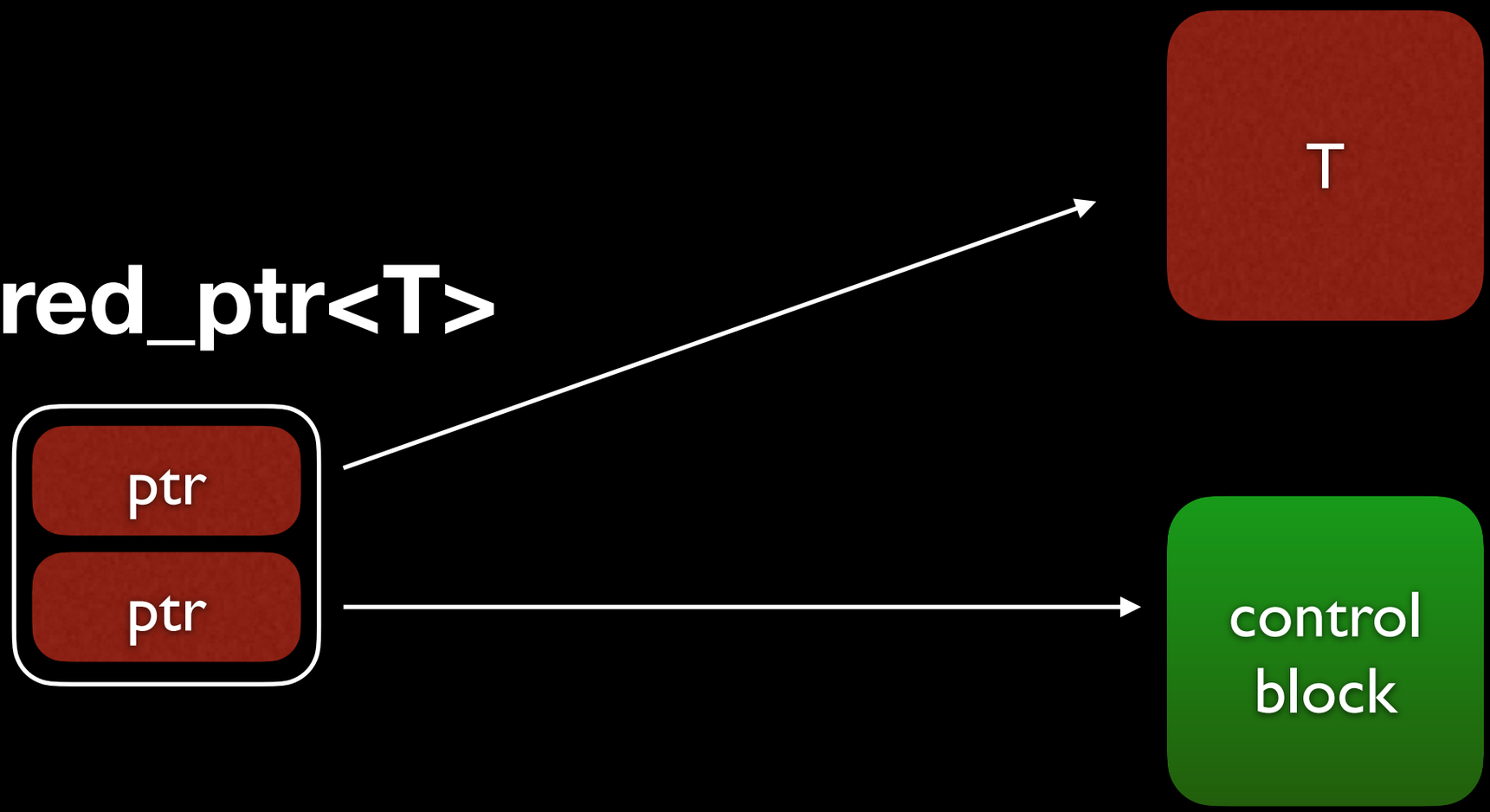


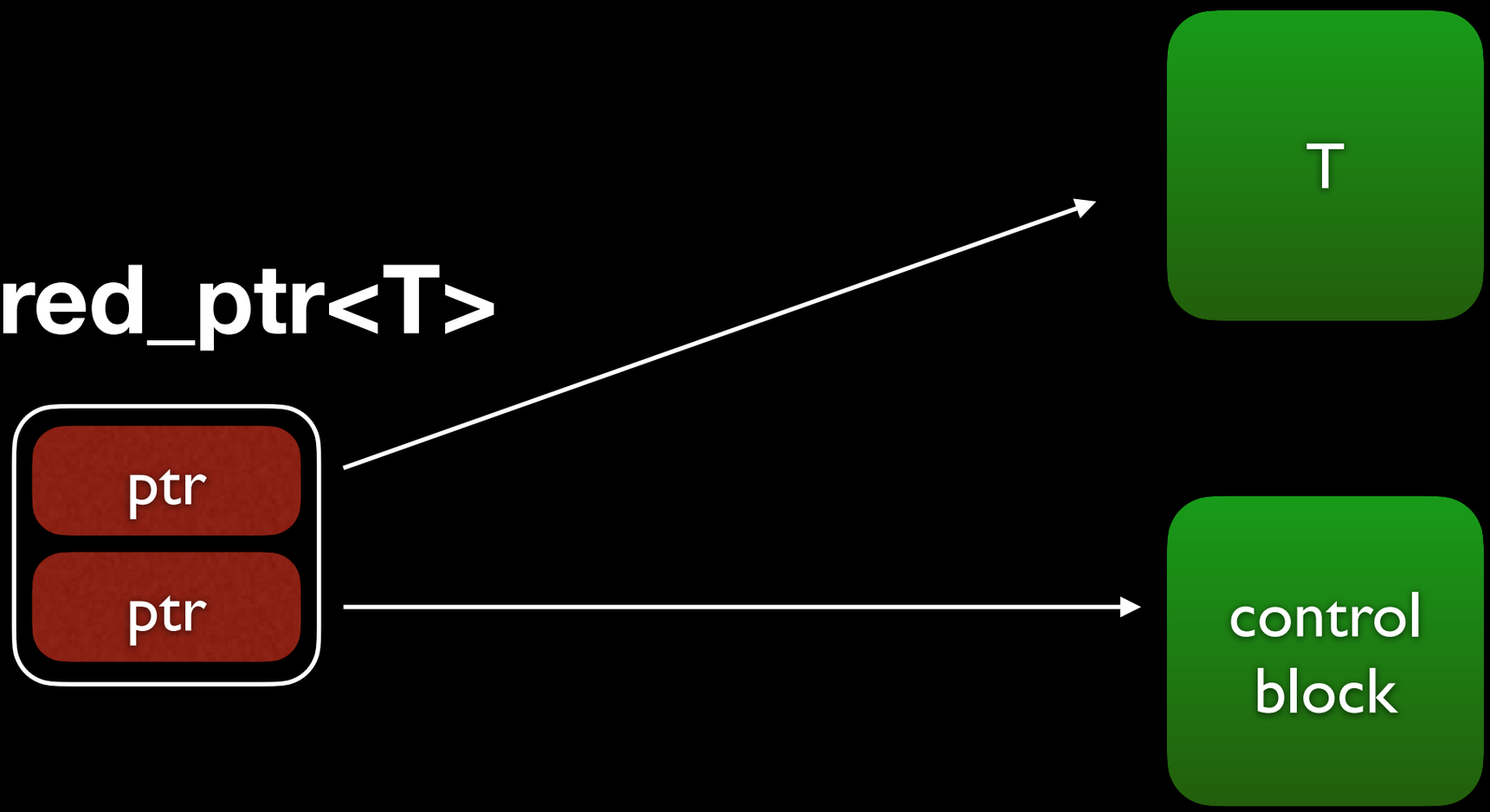
thread safety



Thread safe

NOT thread safe

Our intuition



Expected

Not so expected

buggy RCU

- Read-Copy-Update
- One thread is writing (updating) to some one-true-shared-ptr
- Many threads are reading (copying) the shared_ptr.
- Use a lock on the shared_ptr at the center.

mitigation

- Thread sanitizer.
- Address Sanitizer often too, though incidentally.
- Library!
  - C++11: `atomic<shared_ptr>`
  - Concurrency TS: `atomic_shared_ptr`
  - Maybe back? `atomic<shared_ptr>`

bonus bug

```
auto& ref = *returns_a_shared_ptr();
ref.boom();
```

Sanitizers will catch this too.

Bug #6

code review

does this compile?

```
#include <string>
void f() {
    std::string(foo);
}
```

does this compile?

```
#include <string>
void f() {
    std::string(foo);
}
```

✔ YES

Same.

```
std::string(foo);
```

```
std::string foo;
```

x86-64 gcc 7.1 (Editor #1, Compiler #1) ×

x86-64 gcc 7.1 ▾ | -std=c++11

11010 | .LX0: | .text | // | \s+ | Intel | A▾

```
1  f():
2          push    rbp
3          mov     rbp, rsp
4          sub     rsp, 32
5          lea     rax, [rbp-32]
6          mov     rdi, rax
7          call    std::__cxx11::basic_string<char, std::char_traits<char>, std::allocator<char> >::basic_string()
8          lea     rax, [rbp-32]
9          mov     rdi, rax
10         call    std::__cxx11::basic_string<char, std::char_traits<char>, std::allocator<char> >::~basic_string()
11         nop
12         leave
13         ret
```

Ok, but so what?

```
std::string(foo);
```

```
std::string foo;
```

See the problem?

```
void Obj::update() noexcept {
}
```

See the problem?

```
void Obj::update() noexcept {
    unique_lock<mutex>(m_mutex);
    do_the_mutation();
}
```

Fixed

```
void Obj::update() noexcept {
    unique_lock<mutex> g(m_mutex);
    do the mutation();
}
```

Do a code search.

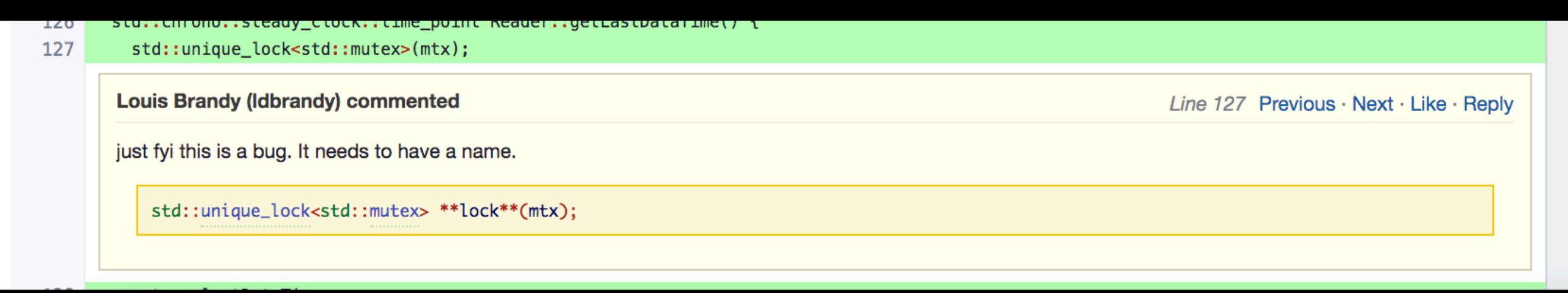
You'll find em.

Do a code search.

While prepping these slides...

I found a bug.

```
std::unique_lock<std::mutex>(mtx);
```



I found two bugs.

```
unique_lock<mutex>(m_);
```

```
11  shared_ptr<Client> ChronosJobUtil::getClient(
12      const std::string& clusterName) {
13    unique_lock<mutex>(m_);
```

Louis Brandy (ldbrandy) commented *Line 13* Previous · Next · Like · Reply

just fyi, this is a bug... the local variable needs a name....

```
unique_lock<mutex> lock(m_);
```

the worst C++ quiz
does it compile?

Remember?

```
#include <string>

void f() {
    std::string(foo);
}
```

✔ YES

does this compile?

```
#include <string>

void f() {
    std::string(foo);
    std::string("wow");
}
```

✔ YES

does this compile?

```
#include <string>

void f() {
    std::string(foo);
    std::string(foo);
}
```

does this compile?

```
#include <string>

void f() {
    std::string(foo);
    std::string{foo};
}
```

✔ YES

does this compile?

```
#include <string>

void f() {
    std::string(foo);
    {std::string(foo);}
}
```

✔ YES

Some important notes

```
unique_lock<mutex>(m_mutex);
```

- RAII-like types are especially affected because you won't otherwise "use" them.
- Only works because of the default constructor.
  - `std::unique_lock` is affected.
  - `std::lock_guard` is not.
- RAII types + default constructors -> DANGER.

Mitigation

- This is a shadowing bug. `-Wshadow` finds this.
- `-Wshadow` tends to be noisy and isn't used often.
- `-Wshadow-compatible` and `-Wshadow-compatible-local` do not find these.

```
<source>: In function 'void f()':
10 : <source>:10:41: warning: declaration of 'm_mutex' shadows a global declaration [-Wshadow]
     std::unique_lock<std::mutex>(m_mutex);
                                  ^
5 : <source>:5:12: note: shadowed declaration is here
 std::mutex m_mutex;
            ^~~~~~
Compiler exited with result code 0
```

Easily detectable

- ... but not widely detected.
- Our clang based linter finds these, now.
- Warn on extraneous parenthesis in declarations?
- Perhaps a `[[nodiscard]]` attribute for constructors?

Some conclusions

- C++ is hard.
- Tools are our best teaching weapons.
- Invest in a good, extendable linter (e.g. clang-tidy)
- ASAN is life.

Questions?