

Meeting C++ 2017

# Concepts Driven Design

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**Kris Jusiak, Quantlab Financial**

# Overview

- Concepts
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- Type constraints (C++20)
  - Requirements
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  - Named concepts
    - Optional interfaces
- Concepts emulation (C++17)
- Concepts based design
  - Static polymorphism
  - Dynamic polymorphism
    - Virtual concepts (C++2?)
  - Dependency Injection
  - Mocking (testing)
- Future of concepts (C++2X)

# Disclaimer

This talk is from user perspective

See Andrew Sutton talks for more details about concepts!

Concepts, although, merged into C++20 draft, are still a subject for future changes

Compiler	Version	Notes
GCC	6.1+	Requires <code>-fconcepts</code> flag
MSVC	VS2017 15.5	-
Clang	In progress...	-

Examples in this talk were compiled using

```
g++7.2 -std=c++2a -fconcepts
```

# Motivation - Well specified interfaces

```
template<class T>
const T& min(const T& a, const T& b) {
    return b < a ? b : a;
}
```

## Precise documentation

- What's are the syntax requirements for `T` ?
  - compile-time / **concepts**
- What's are the semantics requirements for `min` ?
  - run-time / contracts, tests, manuals

# Motivation - Compiler diagnostics

```
int main() {  
    auto list = std::list{1, 2, 3};  
    std::sort(std::begin(list), std::end(list));  
}
```

<https://godbolt.org/g/RTRgg2>

# Motivation - Compiler diagnostics

## Without concepts

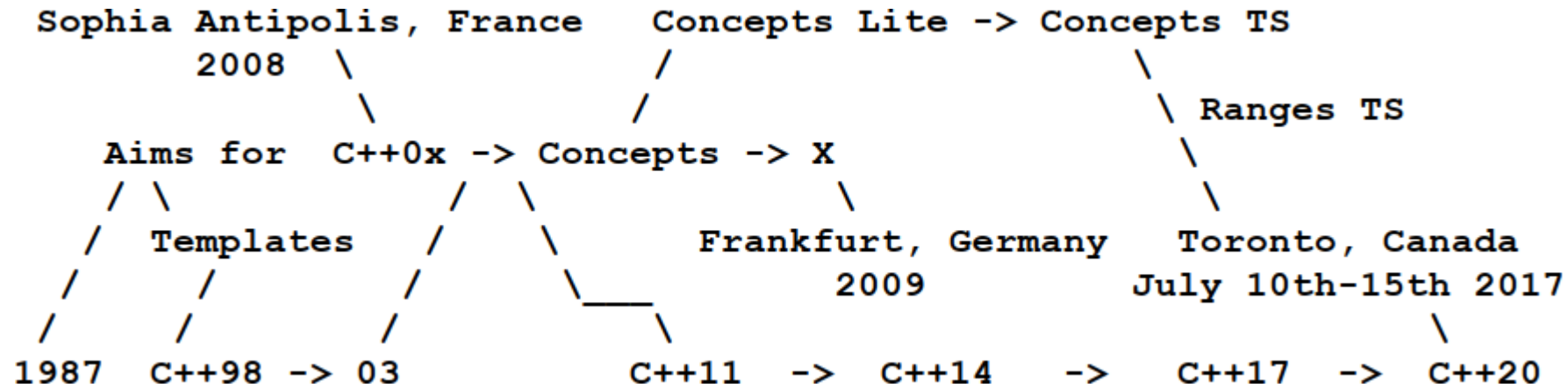
```
invalid operands to binary expression  
  ('std::_List_iterator<int>' and  
   'std::_List_iterator<int>')  
std::__lg(____last - ____first) * 2);  
          ~~~~~ ^ ~~~~~  
...many lines of templates instantiation call stack...
```

## With concepts

```
error: cannot call std::sort  
note: concept RandomAccessIterator was not satisfied  
since: expression (b-a) will be ill formed
```

Note: Constraints are checked at the point of use

# History



Requirements analysis	<a href="https://wg21.link/n3351">https://wg21.link/n3351</a>
Concepts Lite	<a href="https://wg21.link/n3701">https://wg21.link/n3701</a>
Concepts TS	<a href="https://wg21.link/P0734R0">https://wg21.link/P0734R0</a>

Bjarne Stroustrup, Andrew Sutton, Gabriel Dos Reis  
Alex Stepanow, Andrew Lumsdaine, Sean Parent, ...

# C++20 draft



Requirements

Constraints

Named concepts

<http://eel.is/c++draft/temp.constr>



# Requirements

## Requires-clause

Specifies constraints on template arguments or on a function declaration

`std::enable_if` on steroids

```
template<bool Value>
void foo() requires Value {}
```

```
int main() {
    foo<true>(); // Okay
    foo<false>(); // Error: constraints not satisfied
}
```

Note: requires-clause is part of the function signature

# Requires-expression

Expression of type bool

```
requires ( [parameters] ) { requirements }
```

```
requires(T) { // type requirement  
  typename T::value_type; };
```

```
requires(T t) { // simple requirement  
  t[typename T::value_type{}]; };
```

```
requires(T t) { // compound requirement  
  { t.empty() } -> bool; }; // convertible to bool
```

```
requires(T t) { // nested requirement  
  requires std::is_enum_v<typename T::value_type>; };
```

Note: Parameters -> declvals

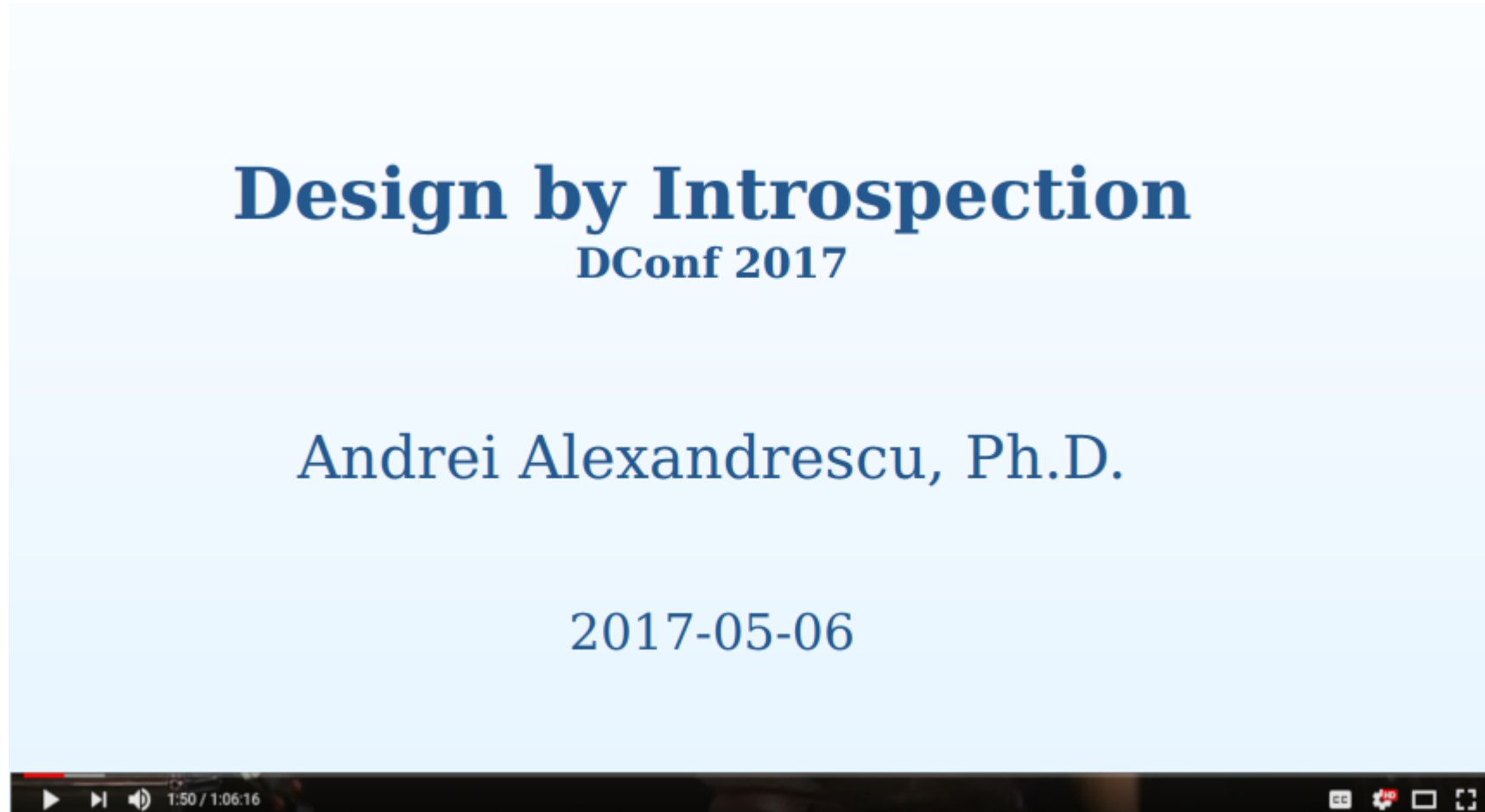
## Requires-clause/Requires-expression

```
template<class T>
constexpr auto foo(T&& x) // immediate context (SFINAE friendly)
    requires requires(T t) { t.bar(); }
{ return x.bar(); }
```

```
struct { void bar() {} } bar;
foo(bar); // Okay
foo(42);  // Error: constraints not satisfied
          // note: the required expression
          //       't.bar()' would be ill-formed
```

Note: `requires requires` -> `requires-clause` followed by `requires-expression`

# Design by introspection



<https://www.youtube.com/watch?v=29h6jGtZD-U>

# Design by introspection - D lang

<https://dlang.org/spec/traits.html>

```
auto foo(T)(T x) {  
    static if(__traits(hasMember, x, "bar")) {  
        return x.bar;  
    } else {  
        return 0;  
    }  
}  
  
void main() {  
    assert(0 == foo(42));  
  
    struct Bar { int bar = 42; }  
    Bar bar;  
    assert(42 == foo(bar));  
}
```

<https://godbolt.org/g/wpLXzV>

# Design by introspection - C++20

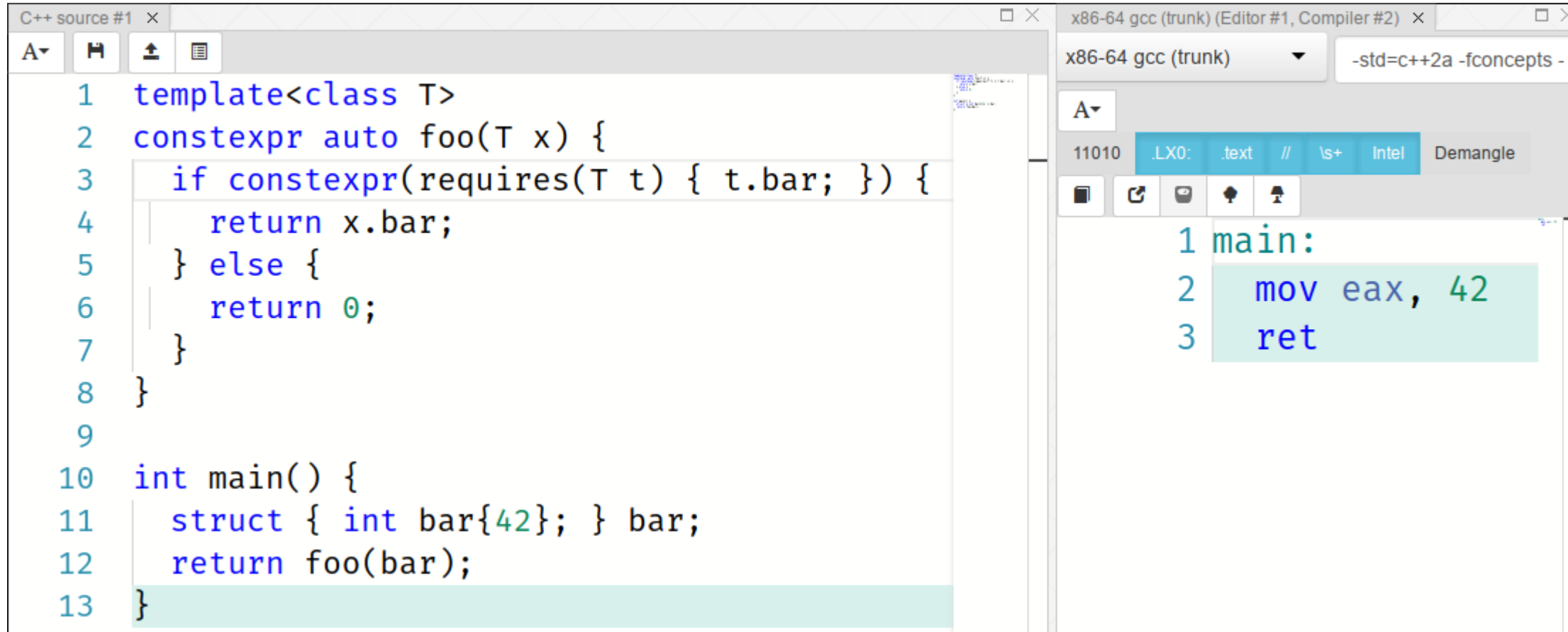
```
template<class T>
constexpr auto foo(T x) {
    if constexpr(requires(T t) { t.bar; }) { // immediate context
        return x.bar;
    } else {
        return 0;
    }
}

int main() {
    assert(0 == foo(42));

    struct { int bar{42}; } bar;
    assert(42 == foo(bar));
}
```

<https://godbolt.org/g/uot6Bv>

# Design by introspection - C++



The image shows a screenshot of a C++ IDE with two panes. The left pane, titled 'C++ source #1', contains the following C++ code:

```
1 template<class T>
2 constexpr auto foo(T x) {
3     if constexpr(requires(T t) { t.bar; }) {
4         return x.bar;
5     } else {
6         return 0;
7     }
8 }
9
10 int main() {
11     struct { int bar{42}; } bar;
12     return foo(bar);
13 }
```

The right pane, titled 'x86-64 gcc (trunk) (Editor #1, Compiler #2)', shows the assembly output for the same code. The assembly is for the 'main' function and shows the value 42 being moved into the 'eax' register.

```
11010 .LX0: .text // %s+ Intel Demangle
1 main:
2     mov     eax, 42
3     ret
```

<https://godbolt.org/g/MFxqWu>



# Requires

Readability?

```
template<class T>
auto bar(T& t)
    requires requires(T t) {
        typename T::type;
        { t.foo() } -> void;
        requires Movable<T> or Same<T, int>;
    } {
    return t.foo();
}
```

## **Named concepts**

## Named concepts

A collection of requirements on a type (variable template)

```
template<template-parameters>  
concept concept-name = constraint-expression;
```

"If you like it then you should have put a name on it", Beyonce rule

# Named concepts

## Predicate constraints

```
template<class>  
concept Always = true; // always satisfied
```

```
template<class T>  
concept Size32 = sizeof(T) == 4;
```

## Conjunctions, Disjunctions

```
template<class T>  
concept SignedIntegral = std::is_integral_v<T> and std::is_signed_v<T>;
```

# Named concepts

## Requirements

```
template<class T>
concept Fooable =           // named concept
    requires(T t) {         // collection of
        typename T::type;   // type requirement
        { t.foo() } -> void; // compound requirement
        requires Movable<T> or // nested requirement
            Same<T, int>;
    };
```

Note: Concepts are never instantiated  
(therefore the `concept` keyword)

# Named concepts

Unconstrained class definition

```
template<class> class Bar {};
```

Requires expression (long form)

```
template<class T> requires Fooable<T>;  
class Bar { };
```

Abbreviated templates

```
template<Fooable T>  
class Bar {};
```

Note: C++17 - Non-type template arguments

```
template<auto T> class Bar {};
```

*// For values -> Bar<42>*

# Named concepts

## Example

```
struct tcp_socket { void send(std::string_view); };  
struct udp_socket { void send(std::string_view); };  
struct file       { void write(std::string_view); };
```

## Everything Cpp

<https://www.youtube.com/watch?v=xsSYPD0v5Mg>

# Named concepts

## Concept definition

```
template<class T> concept Socket =  
    requires(T t, std::string_view data) {  
        { t.send(data) } -> void; // compound requirement  
    };
```

```
template<class T> concept File =  
    requires(T t, std::string_view data) {  
        { t.write(data) } -> void; // compound requirement  
    };
```



# Named concepts

## Concept overloading

```
template<Socket T> // requires Socket<T>  
/*1*/ void forward(T& t, std::string_view data) { t.send(data); }  
  
template<File T> // requires File<T>  
/*2*/ void forward(T& t, std::string_view data) { t.write(data); }
```

```
int main() {  
    tcp_socket tcp; forward(tcp, "tcp data"sv); // calls 1  
    udp_socket udp; forward(udp, "udp data"sv); // calls 1  
    file file; forward(file, "file data"sv); // calls 2  
}
```

Note: If multiple are satisfied the most constrained is chosen

# Named concepts

Concepts overloading

`if constexpr` (C++17)

```
template<class T>
void forward(T& t, std::string_view data) {
    if constexpr(Socket<T>) { // compile-time
        t.send(data);
    } else if constexpr(File<T>) {
        t.write(data);
    }
}
```

Note: Branch which is not taken is discarded

----- Statement may not compile but syntax has to be valid

# Named concepts

## Lambdas

```
constexpr auto forward =  
    [](auto& t, std::string_view data) {  
        using type = std::decay_t<decltype(t)>;  
        if constexpr(Socket<type>) { t.send(data); } else  
        if constexpr(File<type>) { t.write(data); }  
    };
```

## Generic lambdas (C++17) - <https://wg21.link/P0428r2>

```
constexpr auto forward =  
    [<class T>(T& t, std::string_view data) {  
        if constexpr(Socket<T>) { t.send(data); } else  
        if constexpr(File<T>) { t.write(data); }  
    };
```

# Named concepts

Optional interfaces

Example -> `Stream<T>`

- Copy constructible
- Callable member function `write` which takes type `T&`
- Callable member function `read` which returns type `T`
- Callable **optional** member function `read_complete`
- Printable

# Named concepts

Optional interfaces : Inheritance / virtual functions (not expressive enough)

```
/**
 * Implementation requires to be printable and
 * copy constructible
 */
template<class T>
class istream {
public:
    virtual ~istream() noexcept = default;
    virtual void write(T&) = 0;
    virtual T read() = 0;

    // ??? [[optional]] ???
    virtual void read_complete() = 0;
};
```

# Named concepts

## Optional interfaces : Concepts

```
template<class T, class TData>
concept Streamable =
    CopyConstructible<T> and          // CopyConstructible
    requires(T t, std::ostream& out, TData& data) {
        out << t;                     // Printable
        t.write(data);                // Writable
        { t.read() } -> TData          // Readable
    } or requires(T t, std::ostream& out, TData& data) {
        out << t;                     // Printable
        t.write(data);                // Writable
        { t.read() } -> TData          // Readable 1/2
        t.read_complete();             // Readable 2/2
    }
};
```

# Named concepts

## Optional interfaces : Usage

```
using data_t = std::array<std::byte, 1024>;
```

```
class FileStream {  
public:  
    void write(data_t&);  
    data_t read();  
    void read_complete();  
};
```

```
int main() {  
    Streamable<data_t> stream = FileStream{};  
    const auto data = stream.read();  
    ...  
    stream.read_complete();  
}
```

# Placeholders

Placeholder	Synopsis
Unconstrained	<code>auto</code>
Constrained	<code>concept-name&lt;[template-argument-list]&gt;</code>

```
template<class T> class Foo {};  
template<class T> concept Fooable = true;
```

```
// auto - least constrained concept  
auto    foo1 = Foo<int>{};  
// C++17 - Constructor Template Argument Deduction  
Foo     foo2 = Foo<int>{};  
// C++20 - placeholder  
Fooable foo3 = Foo<int>{};
```

Note: Placeholders can be used for functions `void f(auto);`



# Concepts in the C++ ISO standard

18	EqualityComparable requirements . . . . .	467
19	LessThanComparable requirements . . . . .	467
20	DefaultConstructible requirements . . . . .	467
21	MoveConstructible requirements . . . . .	468
22	CopyConstructible requirements (in addition to MoveConstructible) . . . . .	468
23	MoveAssignable requirements . . . . .	468
24	CopyAssignable requirements (in addition to MoveAssignable) . . . . .	468
25	Destructible requirements . . . . .	468
26	NullablePointer requirements . . . . .	470
27	Hash requirements . . . . .	471
28	Descriptive variable definitions . . . . .	471
29	Allocator requirements . . . . .	472

Note: More concepts to come with Ranges TS

# Concepts and the C++ ISO standard

Table 18 — EqualityComparable requirements [equalitycomparable]

Expression	Return type	Requirement
<code>a == b</code>	convertible to <code>bool</code>	<code>==</code> is an equivalence relation, that is, it has the following properties: <ul style="list-style-type: none"><li>— For all <code>a</code>, <code>a == a</code>.</li><li>— If <code>a == b</code>, then <code>b == a</code>.</li><li>— If <code>a == b</code> and <code>b == c</code>, then <code>a == c</code>.</li></ul>

```
template<class T> // C++20 concepts
concept EqualityComparable = requires(T a, T b) {
    { a == b } -> bool;
};
```

```
class EqualityComparable a where // Haskell typeclasses
    (==) :: a -> a -> Bool
```

# Concepts - Ranges TS

```
template <class I>
concept InputIterator =
    Iterator<I> &&
    Readable<I> &&
    requires(I& i, const I& ci) {
        typename iterator_category_t<I>;
        DerivedFrom<
            iterator_category_t<I>, input_iterator_tag>;
        i++;
    };
```

<https://github.com/CaseyCarter/cmcstl2>

# Concepts emulation (C++17)

# Concepts emulation (C++17)

Substitution Failure Is Not An Error (SFINAE)

```
template<bool, class = void>
struct enable_if {}; // no type alias

template<class T>
struct enable_if<true, T> { using type = T; };
```

- `false` predicates lead to ill-formed code that's discarded

# Concepts emulation (C++17)

Deduction idiom (C++20)

```
template<class T>
using Fooable = decltype(std::declval<T&>().foo());
```

```
struct Foo { void foo(); };
struct Bar { };
```

```
static_assert(not std::is_detected<Fooable, Bar>{});
static_assert( std::is_detected<Fooable, Foo>{});
```

Note: Under the hood, it uses

```
template<class...> using void_t = void;
```

<https://wg21.link/n4436>

# Concepts emulation (C++17)

Does the Concepts TS Improve on C++17?

```
template <class F, class... Args, class = decltype(
    std::declval<F&&>()(std::declval<Args&&>()...))>
constexpr auto requires_impl(int) { return true; }

template <class F, class... Args>
constexpr auto requires_impl(...) { return false; }

template <class... Args, class F>
constexpr auto requires(F&&) {
    return requires_impl<F&&, Args&&...>(int{});
}
```

<https://wg21.link/P0726R0>

# Concepts emulation (C++17)

requires-clause

```
struct Foo { void foo(); };  
struct Bar {};
```

```
static_assert(  
    requires<Foo>([](auto&& t) -> decltype(t.foo()) {})  
);  
  
static_assert(  
    !requires<Bar>([](auto&& t) -> decltype(t.foo()) {})  
);
```



# Concepts emulation (C++17)

Design by introspection - C++17

```
template<class T> constexpr auto foo(T x) {  
    if constexpr(requires<T>( // compile-time if  
        [](auto&& t) -> decltype(t.bar) {})) {  
        return x.bar;  
    } else {  
        return 0;  
    }  
}
```

Note: Workaround for expression is not a constant expression

```
if constexpr(  
    auto bar = [](auto&& t) -> decltype(t.bar) {};  
    requires<T>(bar)  
)
```

# Concepts emulation (C++17)

Named concept

```
template<class T> constexpr auto Socket =  
    requires<T>([](auto&& t, std::string_view data)->  
        decltype(t.send(data)) {}  
    );
```

```
template<class T> constexpr auto File =  
    requires<T>([](auto&& t, std::string_view data) ->  
        decltype(t.write(data)) {}  
    );
```

# Concepts emulation (C++17)

## Error message

```
template<class T, class = std::enable_if_t<Socket<T>>>
void forward(T& t, std::string_view data) {
    t.send(data);
}
```

```
int main() {
    tcp_socket tcp; forward(tcp, "tcp data"sv); // Okay
    file file; forward(file, "file data"sv);
    // error: no matching function for call to 'forward'
    // possibly many lines of output <- library side
}
```

Note: No details why function couldn't be called

# Concepts emulation (C++17)

## Concepts overloading

```
template<class T, std::enable_if_t<Socket<T>, int> = 0>
/*1*/ void forward(T& t, std::string_view data) { t.send(data); }

template<class T std::enable_if_t<File<T>, int> = 0>
/*2*/ void forward(T& t, std::string_view data) { t.write(data); }
```

```
int main() {
    tcp_socket tcp; forward(tcp, "tcp data"sv); // calls 1
    udp_socket udp; forward(udp, "udp data"sv); // calls 1
    file file; forward(file, "file data"sv); // calls 2
}
```

Note: Default template parameters aren't part of the function signature (no SFINAE)

# Concepts emulation (C++17)

Concept overloading

`if constexpr` (C++17)

```
template<class T>
void forward(T& t, std::string_view data) {
    if constexpr(Socket<T>) { // compile-time
        t.send(data);
    } else if constexpr(File<T>) {
        t.write(data);
    }
}
```

Note: Exactly the same way as with C++20 concepts

# Concepts based design

# Concepts based design

## Goals

Expressiveness	Type constraints for better error messages
Loosely coupleled design	Inject all the things! (Policy Design)
Performance	Static dispatch by default (based on concepts)
Flexiblity	Dynamic dispatch using type erasure (based on the same concepts)
Testability	Automatic mocks injection (based on the same concepts)

# Concepts based design

## Static polymorphism

```
template<class T> concept Drawable = requires  
(T t, std::ostream& out) { { t.draw(out) } -> void; };
```

```
struct Square {  
    void draw(std::ostream& out) { out << "Square"; } };  
  
struct Circle {  
    void draw(std::ostream& out) { out << "Circle"; } };  
  
template<Drawable T>  
void f(T& d) { d.draw(std::cout); }  
  
int main() {  
    f(Square{}); // prints Square  
    f(Circle{}); // prints Circle  
}
```



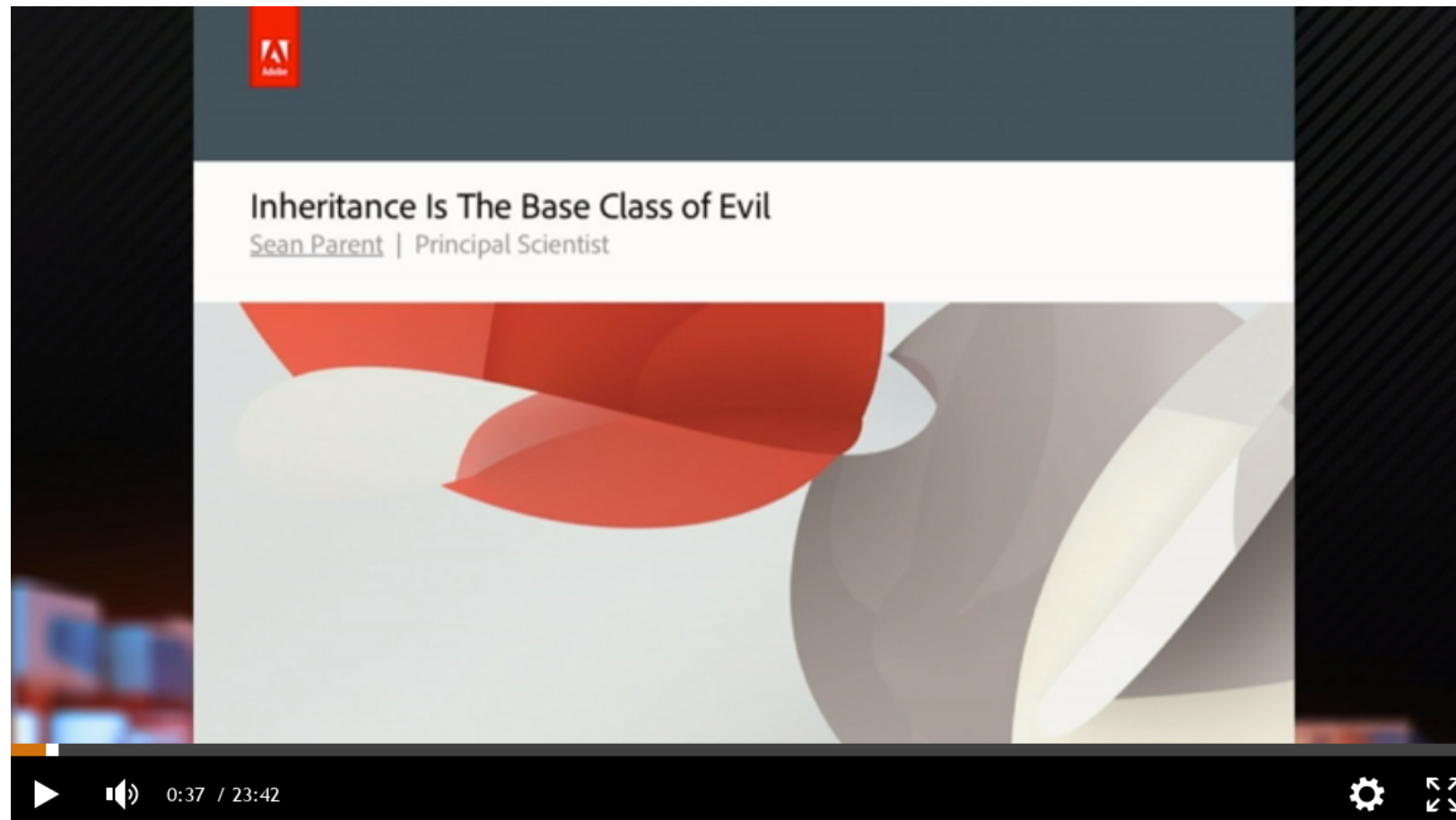
# Concepts based design

## Static polymorphism

```
std::vector v1 = { Square{}, Circle{} };  
// ERROR: class template argument deduction failed  
  
std::vector<auto> v2 = { Square{}, Circle{} };  
// ERROR: couldn't deduce template parameter  
  
std::vector<Drawable> v3 = { Square{}, Circle{} };  
// ERROR: couldn't deduce template parameter
```

# Concepts based design

Concepts based polymorphism / Dynamic polymorphism



Inheritance-Is-The-Base-Class-of-Evil

# Concepts based design

Dynamic polymorphism / type erasure

```
class Drawable {  
    void* ptr_{}; // ??? Small Buffer Optimization (SBO)  
    struct {  
        void (*draw)(std::ostream&);  
        void (*delete_ptr)(void*);  
    } const* const vptr_{};  
  
public:  
    template<class T> Drawable(T t) // non explicit  
        : ptr_{new T{t}}, vptr_{  
            [](void* self) { static_cast<T*>(self)->draw(); },  
            [](void* self) { delete static_cast<T*>(self); } }  
        { }  
    ~Drawable() { vptr_->delete_ptr(ptr_); }  
  
    void draw(std::ostream& os) { vptr_->draw(os); }  
};
```

# Concepts based design

Dynamic polymorphism / Virtual concepts (C++2?)

```
template<class T> concept Drawable =  
    requires() { auto T::draw(std::ostream&) -> void; };  
    // Signature requirement
```

```
struct Square {  
    void draw(std::ostream& out) { out << "Square"; } };  
  
struct Circle {  
    void draw(std::ostream& out) { out << "Circle"; } };  
  
void f(virtual Drawable& d) { d.draw(std::cout); }  
    // Type erasure  
  
int main() {  
    f(Square{}); // prints Square  
    f(Circle{}); // prints Circle  
}
```

# Concepts based design

Dynamic polymorphism / Virtual concepts (C++2?)

Signature requirement

```
template<class T>
concept Fooable = requires() {
    auto T::foo() -> void; // NOT C++20!
};
```

## Dynamic Generic Programming with Virtual Concepts

Note: Virtual concepts aren't part of C++20

# Concepts based design

Dynamic polymorphism / Virtual concepts (C++2?)

```
std::vector<virtual Drawable> v; // okay (type erasure)
v.push_back(Square{});           // okay
v.push_back(Circle{});           // okay
```

100% value semantics / Stack based / Small buffer optimization (SBO)

Note: Might be also generated with Metaclasses (C++2?)

<pre>template&lt;class T&gt; any Foo     auto foo() -&gt; void; };</pre>	<pre>template&lt;class T&gt; \$any { // metaclass     constexpr { ... } };</pre>
--	--

<https://wg21.link/p0707r0>

# Concepts based design

Dynamic polymorphism / Virtual concepts emulation (C++17)

```
template<class T> constexpr auto Drawable =  
    Callable<void(T::*)(std::ostream&)>( $(draw) );
```

```
struct Square {  
    void draw(std::ostream& out) { out << "Square"; } };  
  
struct Circle {  
    void draw(std::ostream& out) { out << "Circle"; } };  
  
void f(any<$(Drawable)>& d) { d.draw(std::cout); }  
  
int main() {  
    f(Square{}); // prints Square  
    f(Circle{}); // prints Circle  
}
```

# Concepts based design

## Virtual concepts emulation (C++17)

```
Callable<void(T::*)(std::ostream&)>( $((draw)) ]
    \_      \_____      \_____      \____-> name
    \      /      /      /
$((name)) [](auto&& r, auto&& t, auto&&... args) {
    struct { // base class
        auto name(decltype(args)... args) ->
            decltype(self.name(args...)){ } {
            // static polymorphism (CRTP)
            return static_cast<decltype(t) *>(this)->template
                call<name, typename decltype(r)::type>(args...);
        }
    }; return _;
}
```

```
$(type) decltype(type<...>)
```



# Concepts based design

Dependency Injection ( policy design ) / concepts

```
template<class T>
concept ErrorPolicy =
    requires(T t, std::string_view msg) {
        requires CopyConstructible<T>;
        { t.onError(msg) } -> void;
    };
```

```
struct ThrowPolicy {
    void onError(std::string_view msg) { throw T{msg}; }
};

struct LogPolicy {
    void onError(std::string_view msg) { std::clog << T{msg} << '\n'; }
};
```

# Concepts based design

Dependency Injection ( policy design ) / concepts

```
template<ErrorPolicy TPolicy = class Policy> // inject
struct App {
    TPolicy policy{};
    void run() { if (...) { policy.onError("error!"); } }
};
```

Bindings / Injection

```
Creatable injector = di::injector{
    di::bind<class Policy>.to<ThrowPolicy>()
};
injector.create<App>().run();
```

Same as...

```
App{ThrowPolicy{}}.run();
```

# Concepts based design

Dependency Injection ( policy design ) / virtual concepts (C++2?)

```
class App {  
public:  
    explicit App(virtual ErrorPolicy policy)  
        : policy{policy}  
    { }  
  
    void run() {  
        if (...) { policy.onError("error!"); }  
    }  
  
private:  
    virtual ErrorPolicy policy{};  
};
```

# Concepts based design

Dependency Injection ( policy design ) / virtual concepts (C++2?)

```
Creatable injector = di::make_injector(  
    di::bind<virtual ErrorPolicy>.to<LogPolicy>()  
);  
injector.create<App>().run();
```

Same as...

```
App{LogPolicy{}}.run();
```

<https://github.com/boost-experimental/di>

# Concepts based design

Dependency Injection ( `policy design` ) / `virtual concepts emulation (C++17)`

```
template<class T>
constexpr auto ErrorPolicy =
    CopyConstructible<T> and Callable<void(T::*)()>( $((onError)) ); // expose
```

```
struct App {
    any<$(ErrorPolicy)> policy{};
    void run() { if (...) { policy.onError("error!"); } }
};
```

# Concepts based design

Dependency Injection ( policy design ) / virtual concepts emulation (C++17)

```
Creatable injector = di::make_injector(  
    di::bind<$(ErrorPolicy)>.to<LogPolicy>()  
);  
injector.create<App>().run();
```

Same as...

```
App{LogPolicy{}}.run();
```

Note: Same wiring for static/dynamic polymorphism

# Concepts based design

Mocking (testing)

Interface based mocking

```
struct ErrorPolicy {  
    virtual ~ErrorPolicy() = default;  
    virtual void onError(std::string_view) = 0;  
};  
GMock<ErrorPolicy> mock{};  
EXPECT_CALL(mock, onError("interface!")).Times(1);  
mock.onError("interface!");
```

Concepts based mocking

```
GMock<$(ErrorPolicy)> mock{};  
EXPECT_CALL(mock, onError("concept!")).Times(1);  
object(mock).onError("concept!");
```

# Concepts based design

Mocking (testing)

automatic mocks injection

```
"should print read text"_test = [] {  
  auto [app, mocks] = testing::make<App>();  
  
  EXPECT_CALL(mocks<$(ErrorPolicy)>, onError("error!"));  
  
  app.run();  
};
```

Note: `make` creates mocks based on concepts requirements (reflection)

<https://github.com/cpp-testing/gunit>



# Future of concepts (C++2X)

# Future of concepts (C++2X)

Terse template syntax

```
void forward(Socket& socket, std::string_view data);
```

long form

```
template<Socket T>  
void forward(T& socket, std::string_view data);
```

longer form

```
template<class T> requires Socket<T>  
void forward(T& socket, std::string_view data);
```

# Future of concepts (C++2X)

Terse template syntax - <https://wg21.link/p0696r1>

```
void forward(Socket, Socket);
```

long form

```
template<class T>  
void forward(T, T);
```

vs

```
void forward(auto, auto);
```

long form

```
template<class T, class U>  
void forward(T, U);
```

# Future of concepts (C++2X)

Template-introduction syntax

```
Socket{T} void forward(T, auto);
```

or

```
template<Socket [T]> void forward(T, auto);
```

long form

```
template<class T, class U>  
void forward(T, U) requires Socket<T>;
```

# Future of concepts (C++2X)

```
template<class T>
struct tcp_socket {
    static_assert(Socket<tcp_socket>); // always fail, tcp_socket is incomplete
};
```

Metaclasses syntax

```
template<class T>
Socket tcp_socket { };
```

<https://wg21.link/p0707r0>

# Summary

Provides better diagnostics

Simplify usage of SFINAE / `enable_if`

- Introspection by design / Optional interfaces

Well specified interfaces (precised documentation)

Can be emulated in C++14/C++17

- `variable templates` / `constexpr` / `constexpr if`

C++20 is just the beginning

- `syntax improvements` / `requirements improvements`
- `virtual concepts` / `metaclasses` / `static reflection`

# Questions?

<b>C++20 draft</b>	<a href="http://eel.is/c++draft/temp.constr">http://eel.is/c++draft/temp.constr</a>
<b>Concepts</b>	<a href="https://wg21.link/P0734R0">https://wg21.link/P0734R0</a>
<b>Virtual Concepts</b>	<a href="https://github.com/andyprowl/virtual-concepts/blob/master/draft/Dynamic%20Generic%20Programming%20with%20Virtual%20Concepts.pdf">https://github.com/andyprowl/virtual-concepts/blob/master/draft/Dynamic Generic Programming with Virtual Concepts.pdf</a>

