## Backporting to the Future

Andrew Paxie

Pacific++, 18-19 October 2018

"Ex Ignorantia Ad Sapientiam; Ex Luce Ad Tenebras"

#### Outline

```
Introduction
   Motivation
   Trompeloeil
   Backporting Goals
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Backporting to C++11
   Library
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   Issues
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Summary

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#### Motivation

Project needed more unit tests.

Catch was the unit testing framework.

What would be the mocking framework?

#### Motivation

Project needed more unit tests.

Catch was the unit testing framework.

What would be the mocking framework?

Requirements for a mock object framework:

- ► Integrates with Catch
- Header-only library
- Portable: desktop and embedded
- Thread-safe
- ► Supports C++11

#### **Alternatives**

- ► Google Mock
- ► Turtle
- HippoMocks
- ► Fakelt
- ► Mockator
- ► Trompeloeil
- ▶ Upgrade compiler to C++14
- Avoid mocking frameworks in unit tests

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A header only C++ mocking framework

## https://github.com/rollbear/trompeloeil



Björn Fahller (Code Owner)

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Andrew Paxie (Contributor)

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https://blog.andrew.paxie.org



(c) 2006, Lee Snider / Alamy Stock Photo

Paintings that create the illusion of a real object or scene...



(c) 2006, Lee Snider / Alamy Stock Photo

#### Main features:

- Mock functions
- Expectations
- Matchers
- Modifiers

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- Mock functions
- Expectations
- Matchers
- Modifiers

#### Other features:

- Sequencing expectations
- Object-lifetime monitoring
- Integration into test framework reporting
- Tracing

#### Mock classes and functions

## Interface

```
struct Interface
{
  virtual void setValue(int v) = 0;
  virtual int getValue() const = 0;
};
```

#### Mock classes and functions

# Interface struct Interface { virtual void setValue(int v) = 0; virtual int getValue() const = 0; };

#### Mock class

```
struct Mock: Interface
{
   MAKE_MOCK1(setValue, void(int), override);
   MAKE_CONST_MOCKO(getValue, int(), override);
};
```

#### Mock classes and functions

# Interface struct Interface { virtual void setValue(int v) = 0; virtual int getValue() const = 0; };

#### Mock class

```
TEST_CASE("Unit test", "[Sample]")
{ // Setup
 Mock obj;
 REQUIRE_CALL(obj, setValue(lt(7))
    .WITH(obj.getValue() == 3)
    .RETURN(_1 + 2);
```

```
TEST_CASE("Unit test", "[Sample]")
{ // Setup
 Mock obj;
 REQUIRE_CALL(obj, setValue(lt(7)) <- expectation</pre>
    .WITH(obj.getValue() == 3)
    .RETURN(_1 + 2);
```

```
TEST_CASE("Unit test", "[Sample]")
{ // Setup
                                        mock object
 Mock obj;
  REQUIRE_CALL(obj, setValue(lt(7)) <- expectation
    .WITH(obj.getValue() == 3)
    .RETURN(_1 + 2);
```

```
struct Interface
                                               struct Mock: Interface
 virtual void setValue(int v) = 0;
                                                 MAKE_MOCK1(setValue, void(int), override);
 virtual int getValue() const = 0;
                                                 MAKE CONST MOCKO(getValue, int(), override):
```

```
TEST_CASE("Unit test", "[Sample]")
{ // Setup
                                         mock object
                                         mock function
 Mock obj;
 REQUIRE_CALL(obj, setValue(lt(7)) <- expectation</pre>
    .WITH(obj.getValue() == 3)
    .RETURN(_1 + 2);
```

```
struct Interface
{
    virtual void setValue(int v) = 0;
    virtual int getValue() const = 0;
};

struct Mock: Interface
{
    MAKE_MOCK1(setValue, void(int), override);
    MAKE_CONST_MOCKO(getValue, int(), override);
};
```

```
TEST_CASE("Unit test", "[Sample]")
{ // Setup
                                         mock object
                                         mock function
                                         matcher
 Mock obj;
 REQUIRE_CALL(obj, setValue(lt(7)) <- expectation</pre>
    .WITH(obj.getValue() == 3)
    .RETURN(_1 + 2);
```

```
struct Interface
                                               struct Mock: Interface
 virtual void setValue(int v) = 0;
                                                 MAKE_MOCK1(setValue, void(int), override);
 virtual int getValue() const = 0;
                                                 MAKE CONST MOCKO(getValue, int(), override):
```

```
TEST_CASE("Unit test", "[Sample]")
{ // Setup
                                         mock object
                                         mock function
                                        matcher
 Mock obj;
 REQUIRE_CALL(obj, setValue(lt(7)) <- expectation</pre>
    .WITH(obj.getValue() == 3) <- modifier</pre>
    .RETURN(_1 + 2);
```

```
struct Interface
{
     virtual void setValue(int v) = 0;
     virtual int getValue() const = 0;
};

struct Mock: Interface
{
     MAKE_MOCK1(setValue, void(int), override);
     MAKE_CONST_MOCKO(getValue, int(), override);
};
```

```
TEST_CASE("Unit test", "[Sample]")
{ // Setup
                                        mock object
                                        mock function
                                       matcher
 Mock obj;
 REQUIRE_CALL(obj, setValue(lt(7)) <- expectation</pre>
    .WITH(obj.getValue() == 3)
                                 <- modifier
    .RETURN(_1 + 2);
                                    <- modifier
```

#### Expectations

- REQUIRE\_CALL(obj, func(params))
- ALLOW\_CALL(obj, func(params))
- ► FORBID\_CALL(obj, func(params))

```
TEST_CASE("Unit test", "[Sample]")
{
    // Setup
    Mock obj;

    REQUIRE_CALL(obj, setValue(ANY(int));
    FORBID_CALL(obj, getValue());

    // :::
}
```

Also: Named variants of the above

#### Matchers

Matchers		Notes
_	ANY(type)	wildcards
eq(mark)	ne(mark)	equal, not equal
ge(mark)	le(mark)	[greater or less] than or equal
gt(mark)	<pre>lt(mark)</pre>	greater than, less than
re(mark,)		regular expression
·!		negating matcher
*		pointer dereference

#### Modifiers

- ► WITH(condition)
- ► SIDE\_EFFECT(statement)
- ► RETURN(expression)
- ► THROW(expression)

Parameters named using \_1 ... \_15 placeholder variables

Also: local reference (LR\_) versions of the above

```
Interface class
struct IDb
f virtual int
  lookup(const char*) = 0;
 / Production class
struct Db: IDb
{ int.
  lookup(const char*)
  override;
struct MockDb final: IDb
  MAKE MOCK1(
```

```
System Under Test (SUT)
struct Engine
  explicit
  Engine(IDb& db_)
    : db(db_)
  int
  compute(
    const char* key)
    return
      3 * db.lookup(key);
private:
  IDb& db;
```

```
const char* key = "k";
MockDb db:
  lookup(eq(key)))
Engine sut(db);
int ret =
  sut.compute(key);
REQUIRE(ret == 6);
```

```
Interface class
struct IDb
f virtual int
  lookup(const char*) = 0;
  Mock class
struct MockDb final: IDb
{ // Mock function
  MAKE MOCK1(
    lookup,
    int(const char*),
    final):
```

```
System Under Test (SUT)
struct Engine
  explicit
  Engine(IDb& db_)
    : db(db_)
  int
  compute(
    const char* key)
    return
      3 * db.lookup(key);
private:
  IDb& db;
```

```
Unit test
TEST CASE(
  "Compute, key exists",
  "[Engine]")
{ // Setup
  const char* key = "k";
  MockDb db;
  REQUIRE_CALL (
    db.
    lookup(eq(key)))
    .RETURN(2);
  Engine sut(db);
  // Exercise
  int ret =
    sut.compute(key);
  // Verify
  REQUIRE(ret == 6);
  // Teardown
```

#### Outline

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**Backporting Goals** 

C++14 Features Used Library Language

Backporting to C++11 Library Language

Summary



#### Goals

- ▶ Provide existing API in C++11 mode
  - Expectations
  - Matchers
  - Modifiers
- Support same compilers, versions
- ► Preserve C++14 capability

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## C++14 Features Used Library

Language

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Backporting to C++11
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```

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# C++14 Features Used: Library

constexpr for <tuple></tuple>	[N3471]
User-defined literals for <chrono> and <string></string></chrono>	[N3642]
TransformationTraits Redux, v2	[N3655]
std::make_unique	[N3656]
std::integer_sequence	[N3658]
std::exchange	[N3668]
Dual-range std::equal	[N3671]

# C++14 Features Used: Library

constexpr for <tuple></tuple>	[N34/1]
User-defined literals for <chrono> and <string></string></chrono>	[N3642]
TransformationTraits Redux, v2	[N3655]
std::make_unique	[N3656]
std::integer_sequence	[N3658]
std::exchange	[N3668]
Dual-range std::equal,	[N3671]

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```

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# C++14 Features Used: Language

decitype(auto)	[N3638]
Return type deduction for normal functions	[N3638]
Generalized lambda captures	[N3648]
Generic lambda expressions	[N3649]

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# Backporting: Library

Approach

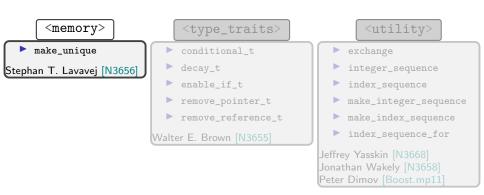
- ▶ Define a namespace detail
  - ▶ Define C++11 versions of the C++14 API.

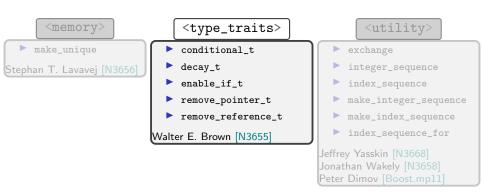
Approach

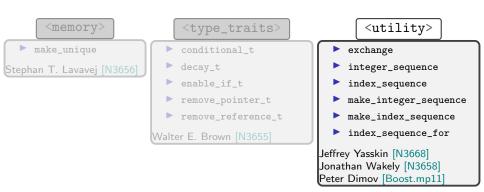
- ▶ Define a namespace detail
  - ightharpoonup Define C++11 versions of the C++14 API.
- Call the namespace detail entities.
  - std::make\_unique becomes detail::make\_unique.

#### Approach

- ▶ Define a namespace detail
  - ▶ Define C++11 versions of the C++14 API.
- ► Call the namespace detail entities.
  - std::make\_unique becomes detail::make\_unique.
- ► For C++14 and later, make std:: entities accessible in namespace detail.
  - Maybe a namespace alias: namespace detail = std;
  - Maybe using declarations in namespace detail
  - Maybe alias templates in namespace detail







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### Backporting: Language

- Generic lambda expressions
- Generalized lambda captures
- Return type deduction for normal functions
- decltype(auto)

# Generic Lambda Expressions

Definition

▶ Lambdas that use auto in their parameter specifications

```
[](auto x)
{
   return x + x;
}
```

#### Generic Lambda Expressions

#### Definition

- Lambdas that use auto in their parameter specifications
- ▶ In C++14, lambdas may also be variadic

```
[](auto x)
{
  return x + x;
}
```

```
[](auto&&... xs)
{
   return sum(
      std::forward<
       decltype(xs)
       >(xs)...);
}
```

Approach

- Replace generic lambda with lambda
- Use a functor (FunctionObject) with function call operator member template (generic functor)
- Replace functions returning generic lambda with generic functor

#### Example

```
[](auto x)
{
   return x + x;
}
```

Example

```
[](auto x)
{
   return x + x;
}
```

```
C++11/14
class ClosureType
public:
  template <typename T>
  auto
  operator()(T x) const
   return x + x;
```

#### Trompeloeil

```
[](
std::ostream& os,
auto const& value)
{
  os << " == ";
  print(os, value);
}</pre>
```

#### Trompeloeil

```
[](
  std::ostream& os,
  auto const& value)
{
   os << " == ";
   print(os, value);
}</pre>
```

```
C++11/14
struct equal_printer
 template <typename T>
 void
 operator()(
   std::ostream& os,
   T const& value)
  const
   os << " == ":
   print(os, value);
```

# Generalized Lambda Capture Definition

An init-capture may specify

- A name of the data member in the closure type
- An expression to initialize that data member

# Generalized Lambda Capture

#### Definition

#### An init-capture may specify

- A name of the data member in the closure type
- An expression to initialize that data member

```
auto p = std::make_unique<std::vector<int>>();

[ptr = std::move(p)]
{
   return ptr->empty();
}
```

Approaches

#### Create a functor like ClosureType

- Declare member variables
- Define constructor to initialize members

**Approaches** 

#### Create a functor like ClosureType

- Declare member variables
- Define constructor to initialize members

#### Use std::bind [Meyers[2], Item 32]

- Move object to be captured into a function object produced by std::bind
- Give the lambda a reference to the captured object

#### Example

```
auto p =
   std::make_unique<
     std::vector<int>>>();

[ptr = std::move(p)]
{
   return ptr->empty();
}
```

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#### Example

```
auto p =
  std::make_unique<
    std::vector<int>>>();

[ptr = std::move(p)]
{
  return ptr->empty();
}
```

```
C++11/14
struct ClosureType
 using T = std::unique_ptr<
    std::vector<int>>;
 explicit ClosureType(T&& p)
    : ptr(std::move(p))
 {}
 bool operator()() const
 { return ptr->empty(); }
private:
 T ptr;
```

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```
C + +14
inline auto
regex_check(std::regex&& re)
 return [re = std::move(re)](
   /* args */)
 -> decltype(std::regex_search(
     /* args */,
     re))
   return std::regex_search(
     /* args */,
     re);
```

Trompeloeil

```
C + +14
inline auto
regex_check(std::regex&& re)
 return [re = std::move(re)](
   /* args */)
 -> decltype(std::regex_search(
     /* args */.
     re))
   return std::regex_search(
     /* args */,
     re);
```

```
C++11/14
struct regex_check
 regex_check(std::regex&& re_)
  : re(std::move(re_))
 {}
 template <typename T>
 bool
 operator()(/* args */) const
   return std::regex_search(
     /* args */.
     re):
 std::regex_check re;
```

#### Return Type Deduction

#### Definition

Jason Merrill, [N3638]:

Write auto on your function declaration and have the return type deduced

```
C++14
auto foo(int var)
 if (var)
   return 0;
 else
   return var + 1;
```

Approach

Use trailing return type

Example

```
C + +14
auto
foo(int var)
  if (var)
    return 0;
  else
    return var + 1;
```

Example

```
C + +14
auto
foo(int var)
  if (var)
    return 0;
  else
    return var + 1;
```

```
C++11/14
auto
foo(int var)
-> int
  if (var)
    return 0;
  else
    return var + 1;
```

#### Trompeloeil

```
C++14
template <
  typename Kind = wildcard
lauto
lre(
  std::string s,
  match_flag_type match_type)
  return make matcher<Kind>(
    lambdas::regex_check(
      std::regex(s), match_type),
    lambdas::regex_printer(),
    std::move(s));
```

C++14

#### Trompeloeil

```
template <
    typename Kind = wildcard
>
auto
re(
    std::string s,
    match_flag_type match_type)
{
    return make_matcher<Kind>(
        lambdas::regex_check(
        std::regex(s), match_type),
```

lambdas::regex\_printer(),

#### C++11/14

```
template <
  typename Kind = wildcard,
  typename R = /* omitted */
auto
re(
  std::string s,
  match_flag_type match_type)
 > decltype(R)
  return make_matcher<Kind>(
    lambdas::regex_check(
      std::regex(s), match_type),
    lambdas::regex_printer(),
    std::move(s));
```

std::move(s)):

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# decltype(auto)

Use the rules of decltype() to deduce a type.

Jason Merrill, [N3638]:

Plain auto never deduces to a reference, and auto & always deduces to a reference. [...] forwarding functions can't use auto.

#### Replace decltype (auto)

Approach

- Replace decltype(auto) with explicit type
- Use auto and trailing return type

#### Replace decltype(auto)

Example: Use explicit type

From macro RETURN(...):

```
handle_return(

[&](auto& x)
-> decltype(auto)
{

// Define placeholders
// _1 ... _15 from x

return __VA_ARGS__;
})
```

#### Replace decltype(auto)

Example: Use explicit type

From macro RETURN(...):

```
C++14
handle_return(
  [\&](auto\& x)
  -> decltype(auto)
    // Define placeholders
    // _1 ... _15 from x
    return __VA_ARGS__;
```

```
C++11/14
handle_return(
  [\&](/* ::: */\& x)
  -> return_of_t
    // Define placeholders
    // _1 ... _15 from x
    return __VA_ARGS__:
```

# Replace decltype (auto)

Example: Use auto and trailing return type

From placeholder naming code (simplified):

```
template <
  int N,
  typename T
constexpr
decltype(auto)
arg(
  T*t,
  std::true_type)
  return std::get<N-1>(*t);
```

### Replace decltype (auto)

Example: Use auto and trailing return type

From placeholder naming code (simplified):

```
C + + 14
template <
  int N,
  typename T
constexpr
decltype(auto)
arg(
  T*t,
  std::true_type)
  return std::get<N-1>(*t);
```

```
C++11/14
template <
  int N,
 typename T
constexpr
auto
arg(
 T*t
  std::true_type)
-> decltype(
  std::get<N-1>(*t))
 return std::get<N-1>(*t);
```

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#### Backporting to C++11

Library Language Issues

#### Issue: Expectation API Changed

Consider the definition of an expectation:

```
REQUIRE_CALL(...)
```

RETURN(...)

Consider the definition of an expectation:

```
REQUIRE_CALL(...) an expression yielding an object
```

```
RETURN(...)
```

Consider the definition of an expectation:

```
REQUIRE_CALL(...) an expression yielding an object
```

is the member access operator (cannot overload)

```
RETURN(...)
```

Consider the definition of an expectation:

```
REQUIRE_CALL(...) an expression yielding an object

is the member access operator (cannot overload)

RETURN(...) yields a member function call invoked with an argument
```

Consider the definition of an expectation:

```
REQUIRE_CALL(...) an expression yielding an object

is the member access operator (cannot overload)

RETURN(...) yields a member function call invoked with an argument
```

The result is still an expression, for more modifiers to be added.

**Issue**: Have not found a way, so far, to transmit type information between expectation macros and modifiers.

Changed API to allow access to type. A subtle change:

```
REQUIRE_CALL(obj, foo(_))
   .WITH(_1 == 42);
   .WITH(_1 == 42));

_V is for 'variadic'
```

Changed API to allow access to type. A subtle change:

- API didn't change once but three times.
- ► Two APIs are available in C++14 mode or later.
- ► Can incrementally transform from C++11 API to C++14 API in unit tests.

## Issue: RETURN(...) Macro doesn't Quite Work

- ► C++14 API provides type check of expression and gives helpful error messages, via static\_assert.
- ► C++11 API performs implicit conversion of \_\_VA\_ARGS\_\_ to return\_of\_t **before** type checking.

**Result**: Less helpful compiler error messages in C++11 mode.

## Issue: Compilers Have Defects Too

Other limitations because of compiler defects:

- <regex> partial implementation (PR61582)
- Ambiguous conversion operator error
  - negating matcher (!)
  - wildcard matcher (\_)
- <tuple> broken (PR61947)

These just for GCC 4.8.3.

- ▶ Provide existing API in C++11 mode
  - Expectations
  - Matchers
  - Modifiers
- Support same compilers, versions
- ► Preserve C++14 capability

- ▶ Provide existing API in C++11 mode
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- ▶ Provide existing API in C++11 mode
  - Expectations X
  - ► Matchers ✓/X
  - Modifiers
- Support same compilers, versions
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- ▶ Provide existing API in C++11 mode
  - Expectations X
  - ► Matchers ✓/X
    - Modifiers √/X
- Support same compilers, versions
- ► Preserve C++14 capability

- ▶ Provide existing API in C++11 mode
  - Expectations X
  - ► Matchers ✓/X
  - ► Modifiers ✓/X
- Support same compilers, versions
- ► Preserve C++14 capability

- ▶ Provide existing API in C++11 mode
  - Expectations X
  - ▶ Matchers ✓/X
  - ► Modifiers ✓/X
- Support same compilers, versions
- ▶ Preserve C++14 capability ✓

# Backporting to the Future

How do I port a C++11 program to C++14?

## Backporting to the Future

How do I port a C++11 program to C++14?

Reverse the direction of these code transformations and Use library and and language features that are also part of C++14(see Appendix)

### Trompeloeil

### https://github.com/rollbear/trompeloeil



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https://playfulprogramming.blogspot.com



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https://github.com/AndrewPaxie

https://blog.andrew.paxie.org

Library (1)

constexpr for <complex></complex>	[N3302]
Making operator functors greater<>	[N3421]
std::result_of and SFINAE	[N3462]
<pre>constexpr for <chrono></chrono></pre>	[N3469]
constexpr for <array></array>	[N3470]
<pre>Improved std::integral_constant</pre>	[N3545]

Library (2)

Null forward iterators	[N3044]
std::quoted	[N3654]
Heterogeneous associative lookup	N3657
Shared locking in $C++$	N3659
Fixing constexpr member functions without const	N3669
std::get <t></t>	[N3670]

Language

Binary literals	[N3472]
Variable templates	[N3651]
Extended constexpr	[N3652]
Member initializers and aggregates	[N3653]
[[deprecated]] attribute	[N3760]
Single quote as digit separator	[N3781]

Miscellaneous

Tweak to certain contextual conversions	[N3323]	
Clarifying memory allocation Sized deallocation	[N3664]	
	[N3778]	

Motivation



Available: https://github.com/catchorg/catch2

Accessed: 13 October 2018

#### Alternatives (1)

Google Mock

Available: https://github.com/google/googletest

Accessed: 10 October 2018

Turtle

Available: https://github.com/mat007/turtle

Accessed: 10 October 2018

HippoMocks

Available: http://hippomocks.com/Main\_Page

Available: https://github.com/dascandy/hippomocks

Accessed: 10 October 2018

#### Alternatives (2)

Fakelt

Available: https://github.com/eranpeer/FakeIt

Accessed: 10 October 2018

Mockator

Available: https://www.cevelop.com/

Accessed: 10 October 2018

Trompeloeil

Available: https://github.com/rollbear/trompeloeil

Accessed: 15 October 2018

Trompe l'oeil



Trompe l'oeil definition

Available: https:

//www.tate.org.uk/art/art-terms/t/trompe-loeil

Accessed: 13 October 2018

C++14 Features Used: Library (1)

Benjamin Kosnik and Daniel Krügler, "Constexpr Library Additions: utilities, v3," N3471, 18 October 2012.

Available: http://wg21.link/n3471

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Peter Sommerlad,

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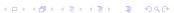
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