

Contract Use: Past, Present, and Future

Joshua Berne - jberne4@bloomberg.net

2019-09-18

Copyright Notice

©2019 Bloomberg L.P. Permission is granted to copy, distribute, and display this material, and to make derivative works and commercial use of it. The information in this material is provided “AS IS”, without warranty of any kind. Neither Bloomberg nor any employee guarantees the correctness or completeness of such information. Bloomberg, its employees, and its affiliated entities and persons shall not be liable, directly or indirectly, in any way, for any inaccuracies, errors or omissions in such information. Nothing herein should be interpreted as stating the opinions, policies, recommendations, or positions of Bloomberg.

Who am I?

- Software developer all century



- I have a purple house.
- First time presenting at CppCon
- First time presenting at a Conference

Who am I?

- Software developer all century



- I have a purple house.
- First time presenting at CppCon
- First time presenting at a Conference (Be gently please)

Who am I?

- Bloomberg LP since 2017
- Joined BDE team in 2018
- Contract checking and deployment with BSLS_REVIEW
- WG21 participation to make contracts better
- SG21 participation with same goal

- 1 Introduction
- 2 Basic Contracts
 - English Contracts
 - In Code Contracts
- 3 Doing Stuff With Contracts
- 4 SG21
- 5 Conclusion

English Contracts

Contracts are an agreement between two parties

English Contracts

Software contracts are an agreement between a library writer and client

English Contracts

Function contracts can be rendered in english

```
T* binsearch(T*begin, T*end, const T& val);  
  // Return a pointer to an element between the  
  // specified 'begin' and 'end' that is greater  
  // than or equal to the specified 'val', or 'end'  
  // if no such value exists. This function will  
  // perform no more than log(distance(begin,end))  
  // comparisons. The behavior is undefined  
  // unless '[begin,end)' is a contiguous sorted  
  // range.
```

English Contracts

Describe what a function will do

```
T* binsearch(T*begin, T*end, const T& val);  
  // Return a pointer to an element between the  
  // specified 'begin' and 'end' that is greater  
  // than or equal to the specified 'val', or 'end'  
  // if no such value exists. This function will  
  // perform no more than log(distance(begin,end))  
  // comparisons. The behavior is undefined  
  // unless '[begin,end)' is a contiguous sorted  
  // range.
```

English Contracts

Describe what behavior is not supported

```
T* binsearch(T*begin, T*end, const T& val);  
  // Return a pointer to an element between the  
  // specified 'begin' and 'end' that is greater  
  // than or equal to the specified 'val', or 'end'  
  // if no such value exists. This function will  
  // perform no more than log(distance(begin,end))  
  // comparisons. The behavior is undefined  
  // unless '[begin,end)' is a contiguous sorted  
  // range.
```

Undefined Behavior

undefined behavior

behavior for which this document imposes no requirements

N4830 - Working Draft, Standard for Programming Language C++

Undefined Behavior

undefined behavior

behavior for which this document imposes no requirements

N4830 - Working Draft, Standard for Programming Language C++

library undefined behavior

behavior for which a library contract provides no guarantees

John Lakos - CppCon 2014

Undefined Behavior

language undefined behavior

behavior for which this document imposes no requirements

N4830 - Working Draft, Standard for Programming Language C++

library undefined behavior

behavior for which a library contract provides no guarantees

John Lakos - CppCon 2014

English Contracts

Describe what behavior is not supported

```
T* binsearch(T*begin, T*end, const T& val);  
    // Return a pointer to an element between the  
    // specified 'begin' and 'end' that is greater  
    // than or equal to the specified 'val', or 'end'  
    // if no such value exists. This function will  
    // perform no more than log(distance(begin,end))  
    // comparisons. The behavior is undefined  
    // unless '[begin,end)' is a contiguous sorted  
    // range.
```

English Contracts

Preconditions

```
T* binsearch(T*begin, T*end, const T& val);  
    // Return a pointer to an element between the  
    // specified 'begin' and 'end' that is greater  
    // than or equal to the specified 'val', or 'end'  
    // if no such value exists. This function will  
    // perform no more than  $\log(\text{distance}(\text{begin}, \text{end}))$   
    // comparisons. The behavior is undefined  
    // unless '[begin, end)' is a contiguous sorted  
    // range.
```


English Contracts

Postconditions

```
T* binsearch(T*begin, T*end, const T& val);  
  // Return a pointer to an element between the  
  // specified 'begin' and 'end' that is greater  
  // than or equal to the specified 'val', or 'end'  
  // if no such value exists. This function will  
  // perform no more than  $\log(\text{distance}(\text{begin}, \text{end}))$   
  // comparisons. The behavior is undefined  
  // unless '[begin, end)' is a contiguous sorted  
  // range.
```

English Contracts

Essential Behavior

```
T* binsearch(T*begin, T*end, const T& val);  
    // Return a pointer to an element between the  
    // specified 'begin' and 'end' that is greater  
    // than or equal to the specified 'val', or 'end'  
    // if no such value exists. This function will  
    // perform no more than log(distance(begin,end))  
    // comparisons. The behavior is undefined  
    // unless '[begin,end)' is a contiguous sorted  
    // range.
```

Violating a contract is a bug

Violating a contract is a bug

Bugs are contract violations

Violating a contract is a bug

Bugs are contract violations

Possibly a contract no one wrote down

What can be checked?

- Parts of the english contract might be checkable with standard C++ expressions.

What can be checked?

- Parts of the english contract might be checkable with standard C++ expressions.
- Parts might have readable representations that cannot be implemented

What can be checked?

- Parts of the english contract might be checkable with standard C++ expressions.
- Parts might have readable representations that cannot be implemented
- Parts might be statements beyond the scope of a single function execution

In code contracts

Some parts can be rendered with code

```
T* binsearch(T*begin, T*end, const T& val);  
    // Return a pointer to an element between the  
    // specified 'begin' and 'end' that is greater  
    // than or equal to the specified 'val', or 'end'  
    // if no such value exists. This function will  
    // perform no more than log(distance(begin,end))  
    // comparisons. The behavior is undefined  
    // unless '[begin,end)' is a contiguous sorted  
    // range.
```

In code contracts

Simple boolean predicates

```
begin != nullptr  
end != nullptr  
begin <= end
```

```
T* binsearch(T*begin, T*end, const T& val);  
    // Return a pointer to an element between the  
    // specified 'begin' and 'end' that is greater  
    // than or equal to the specified 'val', or 'end'  
    // if no such value exists. This function will  
    // perform no more than log(distance(begin,end))  
    // comparisons. The behavior is undefined  
    // unless '[begin,end)' is a contiguous sorted  
    // range.
```

In code contracts

Predicates about returned value

```
return_val >= begin  
return_val <= end  
return_val == end *return_val >= val
```

```
T* binsearch(T*begin, T*end, const T& val);  
    // Return a pointer to an element between the  
    // specified 'begin' and 'end' that is greater  
    // than or equal to the specified 'val', or 'end'  
    // if no such value exists. This function will  
    // perform no more than log(distance(begin,end))  
    // comparisons. The behavior is undefined  
    // unless '[begin,end)' is a contiguous sorted  
    // range.
```

In code contracts

Hard to check things

```
is_sorted(begin, end)
```

```
T* binsearch(T*begin, T*end, const T& val);  
    // Return a pointer to an element between the  
    // specified 'begin' and 'end' that is greater  
    // than or equal to the specified 'val', or 'end'  
    // if no such value exists. This function will  
    // perform no more than log(distance(begin, end))  
    // comparisons. The behavior is undefined  
    // unless '[begin, end)' is a contiguous sorted  
    // range.
```

In code contracts

Uncheckable things?

```
is_reachable_from(begin,end)
```

```
T* binsearch(T*begin, T*end, const T& val);  
    // Return a pointer to an element between the  
    // specified 'begin' and 'end' that is greater  
    // than or equal to the specified 'val', or 'end'  
    // if no such value exists. This function will  
    // perform no more than log(distance(begin,end))  
    // comparisons. The behavior is undefined  
    // unless '[begin,end)' is a contiguous sorted  
    // range.
```

In code contracts

Properties of repeated execution

????????????????

```
T* binsearch(T*begin, T*end, const T& val);  
    // Return a pointer to an element between the  
    // specified 'begin' and 'end' that is greater  
    // than or equal to the specified 'val', or 'end'  
    // if no such value exists. This function will  
    // perform no more than log(distance(begin,end))  
    // comparisons. The behavior is undefined  
    // unless '[begin,end)' is a contiguous sorted  
    // range.
```

- 1 Introduction
- 2 Basic Contracts
- 3 Doing Stuff With Contracts
 - A Dream
 - Less Bugs
 - Deploying it
 - Faster Code
- 4 SG21
- 5 Conclusion

Proven contracts

- Prove software correctness

Proven contracts

- Prove software correctness
- Encode contracts completely

Proven contracts

- Prove software correctness
- Encode contracts completely
 - All preconditions

Proven contracts

- Prove software correctness
- Encode contracts completely
 - All preconditions
 - All postconditions

Proven contracts

- Prove software correctness
- Encode contracts completely
 - All preconditions
 - All postconditions
 - All essential behavior

Proven contracts

- Prove software correctness
- Encode contracts completely
 - All preconditions
 - All postconditions
 - All essential behavior
- Statically prove everything

Proven contracts

- Prove software correctness
- Encode contracts completely
 - All preconditions
 - All postconditions
 - All essential behavior
- Statically prove everything
 - For each function, prove postconditions and essential behavior

Proven contracts

- Prove software correctness
- Encode contracts completely
 - All preconditions
 - All postconditions
 - All essential behavior
- Statically prove everything
 - For each function, prove postconditions and essential behavior
 - Use called functions contracts in proofs of larger functions

Proven contracts

- Prove software correctness
- Encode contracts completely
 - All preconditions
 - All postconditions
 - All essential behavior
- Statically prove everything
 - For each function, prove postconditions and essential behavior
 - Use called functions contracts in proofs of larger functions
- PROFIT

Dream Benefit #1 - Less Bugs

Dream Benefit #1 - Less Bugs

- Compiler identifies all violated contracts

Dream Benefit #1 - Less Bugs

- Compiler identifies all violated contracts
- Edge cases must be thought through

Dream Benefit #1 - Less Bugs

- Compiler identifies all violated contracts
- Edge cases must be thought through
- All assumptions are captured in compiled code

Dream Benefit #1 - Less Bugs

- Compiler identifies all violated contracts
- Edge cases must be thought through
- All assumptions are captured in compiled code
- Mostly, if it compiles, it doesn't have bugs (contract violations)

Dream Benefit #1 - Less Bugs

- Compiler identifies all violated contracts
- Edge cases must be thought through
- All assumptions are captured in compiled code
- Mostly, if it compiles, it doesn't have bugs (contract violations)
- If there is a bug, contracts just need to be elaborated

Dream Benefit #2 - Less Heat Generation

Dream Benefit #2 - Less Heat Generation

- No need for any checks

Dream Benefit #2 - Less Heat Generation

- No need for any checks
- More knowledge for the compiler

Dream Benefit #2 - Less Heat Generation

- No need for any checks
- More knowledge for the compiler
 - `__builtin_assume`

Dream Benefit #2 - Less Heat Generation

- No need for any checks
- More knowledge for the compiler
 - `__builtin_assume`
 - Removing excess branches

Dream Benefit #2 - Less Heat Generation

- No need for any checks
- More knowledge for the compiler
 - `__builtin_assume`
 - Removing excess branches
 - Vectorization/SIMD instructions

Dream Benefit #2 - Less Heat Generation

- No need for any checks
- More knowledge for the compiler
 - `__builtin_assume`
 - Removing excess branches
 - Vectorization/SIMD instructions
- Smaller code size

Realizing parts of the dream

- WARNING:

Realizing parts of the dream

- WARNING: MACROS INCOMING

Realizing parts of the dream

- WARNING: MACROS INCOMING
- How to leverage contracts without a language feature

Realizing parts of the dream

- WARNING: MACROS INCOMING
- How to leverage contracts without a language feature
- Bloomberg has been doing this for 15 years

Realizing parts of the dream

- WARNING: MACROS INCOMING
- How to leverage contracts without a language feature
- Bloomberg has been doing this for 15 years
- See the BDE open source repostory for the real implementation
 - https://github.com/bloomberg/bde/blob/master/groups/bsl/bsls/bsls_assert.h
 - https://github.com/bloomberg/bde/blob/master/groups/bsl/bsls/bsls_review.h

What do you do if you can't prove a contract is being followed?

What do you do if you can't prove a contract is being followed?

Experiment

- 1 Introduction
- 2 Basic Contracts
- 3 Doing Stuff With Contracts**
 - A Dream
 - **Less Bugs**
 - Deploying it
 - Faster Code
- 4 SG21
- 5 Conclusion

Documenting expectations

- Initial benefit of contracts in code

Documenting expectations

- Initial benefit of contracts in code

```
#define ASSERT(X)
```

Documenting expectations

- Initial benefit of contracts in code
- Bloomberg specific naming

```
#define BSLS_ASSERT(X)
```


Documenting expectations

- Initial benefit of contracts in code
- Bloomberg specific naming
- Avoid code rot

```
#define BSLS_ASSERT(X) sizeof( (X)?true:false )
```

Documenting expectations

- Initial benefit of contracts in code
- Bloomberg specific naming
- Avoid code rot
- ... wish we had done that originally

```
#ifndef BSLS_ASSERT_VALIDATE_DISABLED_MACROS  
#define BSLS_ASSERT(X) sizeof( (X)?true:false )  
#else  
#define BSLS_ASSERT(X)  
#endif
```

Documenting expectations

- Initial benefit of contracts in code
- Bloomberg specific naming
- Avoid code rot
- ... wish we had done that originally
- ... or at least this to require a ;

```
#define BSLS_ASSERT(X) ((void)0)
```

Documenting expectations

- Initial benefit of contracts in code
- Bloomberg specific naming
- Avoid code rot
- ... wish we had done that originally
- ... or at least this to require a ;
- For simplicity

```
#define ASSERT(X)
```

Aborting on bugs

- Identifying violations would be nice

Aborting on bugs

- Identifying violations would be nice
- The safest thing to do is stop immediately

```
#define ASSERT(X) if (!(X)) { std::abort(); }
```

Aborting on bugs

- Identifying violations would be nice
- The safest thing to do is stop immediately
- Nice if ASSERT(X) needs a semicolon

```
#define ASSERT(X) do { if (!(X)) { std::abort(); } } while (false)
```

Aborting on bugs

- Identifying violations would be nice
- The safest thing to do is stop immediately
- Nice if `ASSERT(X)` needs a semicolon
- For simplicity

```
#define ASSERT(X) if (!(X)) { std::abort(); }
```


... only in some builds

- Checks of contracts are redundant if they're not broken

... only in some builds

- Checks of contracts are redundant if they're not broken
- NDEBUG might be a way to control enablement

```
#ifdef NDEBUG  
#define ASSERT(X)  
else  
#define ASSERT(X) if (!(X)) { std::abort(); }  
#endif
```

... only in some builds

- Checks of contracts are redundant if they're not broken
- NDEBUG might be a way to control enablement
- This reminds me of something

```
#include <cassert>  
#define ASSERT(X) assert(X)
```

... only in some builds

- Checks of contracts are redundant if they're not broken
- NDEBUG might be a way to control enablement
- This reminds me of something
- Separating out controls from behavior helps

```
#define ASSERT_IMP(X)          if (!(X)) { std::abort(); }
```

... only in some builds

- Checks of contracts are redundant if they're not broken
- NDEBUG might be a way to control enablement
- This reminds me of something
- Separating out controls from behavior helps

```
#define ASSERT_IMP(X)          if (!(X)) { std::abort(); }  
#define ASSERT_DISABLED_IMP(X)
```

... only in some builds

- Checks of contracts are redundant if they're not broken
- NDEBUG might be a way to control enablement
- This reminds me of something
- Separating out controls from behavior helps

```
#define ASSERT_IMP(X)          if (!(X)) { std::abort(); }  
#define ASSERT_DISABLED_IMP(X)  
  
#ifdef ASSERT_LEVEL_ASSERT  
#define ASSERT(X) ASSERT_IMP(X)  
#else  
#define ASSERT(X) ASSERT_DISABLED_IMP(X)  
#endif
```

... but what happened?

- Aborting with no information sucks

```
#define ASSERT_IMP(X) if (!(X)) {  
    /*POOF*/;  
    std::abort();  
}
```

... but what happened?

- Aborting with no information sucks
- Logging something helps

```
#define ASSERT_IMP(X) if (!(X)) {                                \
    printf("ASSERTION FAILED!\n");                               \
                                                                    \
    std::abort();                                                \
}
```


... but what happened?

- Aborting with no information sucks
- Logging something helps
- The preprocessor can give us more help

```
#define ASSERT_IMP(X) if (!(X)) { \
    printf("ASSERTION FAILED (" __FILE__ ":%d): %s\n", \
        __LINE__, #X); \
    std::abort(); \
}
```

What about this guy?

⚠ ERROR

IF YOU'RE SEEING THIS, THE CODE IS IN WHAT I THOUGHT WAS AN UNREACHABLE STATE.

I COULD GIVE YOU ADVICE FOR WHAT TO DO. BUT HONESTLY, WHY SHOULD YOU TRUST ME? I CLEARLY SCREWED THIS UP. I'M WRITING A MESSAGE THAT SHOULD NEVER APPEAR, YET I KNOW IT WILL PROBABLY APPEAR SOMEDAY.

ON A DEEP LEVEL, I KNOW I'M NOT UP TO THIS TASK. I'M SO SORRY.



NEVER WRITE ERROR MESSAGES TIRED.

... but what happened?

- Aborting with no information sucks
- Logging something helps
- The preprocessor can give us more help
- Delegating to a pluggable function helps that

```
#define ASSERT_IMP(X) if (!(X)) { \
    bb::Assert::invoke_violation_handler(__FILE__, __LINE__, #X); \
    \
    std::abort(); \
}
```

... but what happened?

- Aborting with no information sucks
- Logging something helps
- The preprocessor can give us more help
- Delegating to a pluggable function helps that

```
#define ASSERT_IMP(X) if (!(X)) { \
    bb::assert_violation violation(__FILE__, __LINE__, #X); \
    bb::Assert::invoke_violation_handler(violation); \
    std::abort(); \
}
```

... but what happened?

- Aborting with no information sucks
- Logging something helps
- The preprocessor can give us more help
- Delegating to a pluggable function helps that
- Leave all behavior up to the violation handler

```
#define ASSERT_IMP(X) if (!(X)) { \
    bb::assert_violation violation(__FILE__, __LINE__, #X); \
    bb::Assert::invoke_violation_handler(violation); \
}
```

... but what happened?

- Aborting with no information sucks
- Logging something helps
- The preprocessor can give us more help
- Delegating to a pluggable function helps that
- Leave all behavior up to the violation handler

```
void bb::Assert::invoke_violation_handler(  
    const bb::assert_violation &violation) {  
    getViolationHandler()(violation);  
}
```

... but what happened?

- Aborting with no information sucks
- Logging something helps
- The preprocessor can give us more help
- Delegating to a pluggable function helps that
- Leave all behavior up to the violation handler

```
void xkcd::violationHandler(const bb::assert_violation &violation) {  
    printf("Error\n");  
    printf("If you're seeing this, the code is in what\n");  
    printf("I thought was an unreachable state.");  
    //...  
}
```

... but what happened?

- Aborting with no information sucks
- Logging something helps
- The preprocessor can give us more help
- Delegating to a pluggable function helps that
- Leave all behavior up to the violation handler

```
int main() {  
    bb::Assert::setViolationHandler(&xkcd::violationHandler);  
    //..  
}
```


... that doesn't work everywhere!

- The violation handler can notify in different ways

... that doesn't work everywhere!

- The violation handler can notify in different ways
 - Custom logging frameworks

... that doesn't work everywhere!

- The violation handler can notify in different ways
 - Custom logging frameworks
 - GUI messages (abort, retry, fail?)

... that doesn't work everywhere!

- The violation handler can notify in different ways
 - Custom logging frameworks
 - GUI messages (abort, retry, fail?)
 - Hardware notifications

... that doesn't work everywhere!

- The violation handler can notify in different ways
 - Custom logging frameworks
 - GUI messages (abort, retry, fail?)
 - Hardware notifications
- ... do different things

... that doesn't work everywhere!

- The violation handler can notify in different ways
 - Custom logging frameworks
 - GUI messages (abort, retry, fail?)
 - Hardware notifications
- ... do different things
 - `std::abort()`

... that doesn't work everywhere!

- The violation handler can notify in different ways
 - Custom logging frameworks
 - GUI messages (abort, retry, fail?)
 - Hardware notifications
- ... do different things
 - `std::abort()`
 - `while (true) {std::this_thread::sleep_for(std::chrono::years(1));}`

... that doesn't work everywhere!

- The violation handler can notify in different ways
 - Custom logging frameworks
 - GUI messages (abort, retry, fail?)
 - Hardware notifications
- ... do different things
 - `std::abort()`
 - `while (true) {std::this_thread::sleep_for(std::chrono::years(1));}`
 - `throw std::exception("Oops?");`

... that doesn't work everywhere!

- The violation handler can notify in different ways
 - Custom logging frameworks
 - GUI messages (abort, retry, fail?)
 - Hardware notifications
- ... do different things
 - `std::abort()`
 - `while (true) {std::this_thread::sleep_for(std::chrono::years(1));}`
 - `throw std::exception("Oops?");`
- ... or try to recover?

... that doesn't work everywhere!

- The violation handler can notify in different ways
 - Custom logging frameworks
 - GUI messages (abort, retry, fail?)
 - Hardware notifications
- ... do different things
 - `std::abort()`
 - `while (true) {std::this_thread::sleep_for(std::chrono::years(1));}`
 - `throw std::exception("Oops?");`
- ... or try to recover?
- main gets to decide

Checking is slow!

- Checks use state already in cache, are often very fast

```
T* binsearch(T*begin, T*end, const T& val) {  
    ASSERT(begin);  
    ASSERT(end);  
    ASSERT(begin < end)  
    //..  
}
```

Checking is slow!

- Checks use state already in cache, are often very fast
- Algorithmic complexity can still ruin that

```
T* binsearch(T*begin, T*end, const T& val) {  
    ASSERT(is_sorted_range(begin,end));  
    //..  
}
```

Checking is slow!

- Checks use state already in cache, are often very fast
- Algorithmic complexity can still ruin that
- 3 levels of complexity

```
#define ASSERT_OPT(X) ...  
#define ASSERT(X) ...  
#define ASSERT_SAFE(X) ...
```

Checking is slow!

- Checks use state already in cache, are often very fast
- Algorithmic complexity can still ruin that
- 3 levels of complexity
- ... 2 levels probably sufficient

```
[[ assert default : X ]];  
[[ assert audit : X ]];
```

Checking is slow!

- Checks use state already in cache, are often very fast
- Algorithmic complexity can still ruin that
- 3 levels of complexity
- ... 2 levels probably sufficient
- Linear scale of enablement

```
#if defined(ASSERT_LEVEL_NONE)    ? 1 : 0 \  
  + defined(ASSERT_LEVEL_OPT)    ? 1 : 0 \  
  + defined(ASSERT_LEVEL_ASSERT) ? 1 : 0 \  
  + defined(ASSERT_LEVEL_SAFE)   ? 1 : 0 \  
  > 1  
#error Multiple ASSERT_LEVEL macros defined  
#endif
```

Checking is slow!

- Checks use state already in cache, are often very fast
- Algorithmic complexity can still ruin that
- 3 levels of complexity
- ... 2 levels probably sufficient
- Linear scale of enablement

```
#if !defined(ASSERT_LEVEL_NONE) \
    && !defined(ASSERT_LEVEL_OPT) \
    && !defined(ASSERT_LEVEL_ASSERT) \
    && !defined(ASSERT_LEVEL_SAFE)
#define ASSERT_LEVEL_ASSERT
#endif
```


Checking is slow!

- Checks use state already in cache, are often very fast
- Algorithmic complexity can still ruin that
- 3 levels of complexity
- ... 2 levels probably sufficient
- Linear scale of enablement

```
#if defined(ASSERT_LEVEL_NONE)  
#define ASSERT_OPT(X)  ASSERT_DISABLED_IMP(X)  
#define ASSERT(X)      ASSERT_DISABLED_IMP(X)  
#define ASSERT_SAFE(X) ASSERT_DISABLED_IMP(X)  
//..
```

Checking is slow!

- Checks use state already in cache, are often very fast
- Algorithmic complexity can still ruin that
- 3 levels of complexity
- ... 2 levels probably sufficient
- Linear scale of enablement

```
//..  
#elif defined(ASSERT_LEVEL_OPT)  
#define ASSERT_OPT(X)  ASSERT_IMP(X)  
#define ASSERT(X)      ASSERT_DISABLED_IMP(X)  
#define ASSERT_SAFE(X) ASSERT_DISABLED_IMP(X)  
//..
```

Checking is slow!

- Checks use state already in cache, are often very fast
- Algorithmic complexity can still ruin that
- 3 levels of complexity
- ... 2 levels probably sufficient
- Linear scale of enablement

```
//..  
#elif defined(ASSERT_LEVEL_ASSERT)  
#define ASSERT_OPT(X)  ASSERT_IMP(X)  
#define ASSERT(X)      ASSERT_IMP(X)  
#define ASSERT_SAFE(X) ASSERT_DISABLED_IMP(X)  
//..
```

Checking is slow!

- Checks use state already in cache, are often very fast
- Algorithmic complexity can still ruin that
- 3 levels of complexity
- ... 2 levels probably sufficient
- Linear scale of enablement

```
//..  
#elif defined(ASSERT_LEVEL_SAFE)  
#define ASSERT_OPT(X)  ASSERT_IMP(X)  
#define ASSERT(X)      ASSERT_IMP(X)  
#define ASSERT_SAFE(X) ASSERT_IMP(X)  
#endif
```

Checking is slow!

- Checks use state already in cache, are often very fast
- Algorithmic complexity can still ruin that
- 3 levels of complexity
- ... 2 levels probably sufficient
- Linear scale of enablement

```
#if defined(ASSERT_LEVEL_OPT) \
    defined(ASSERT_LEVEL_ASSERT) \
    defined(ASSERT_LEVEL_SAFE)
#define ASSERT_OPT(X) ASSERT_IMP(X)
#else
    // defined(ASSERT_LEVEL_NONE)
#define ASSERT_OPT(X) ASSERT_DISABLED_IMP(X)
#endif
```

Checking is slow!

- Checks use state already in cache, are often very fast
- Algorithmic complexity can still ruin that
- 3 levels of complexity
- ... 2 levels probably sufficient
- Linear scale of enablement

```
#if defined(ASSERT_LEVEL_ASSERT) \  
    defined(ASSERT_LEVEL_SAFE)  
#define ASSERT(X) ASSERT_IMP(X)  
#else  
    // defined(ASSERT_LEVEL_OPT)  
    // defined(ASSERT_LEVEL_NONE)  
#define ASSERT(X) ASSERT_DISABLED_IMP(X)  
#endif
```

Checking is slow!

- Checks use state already in cache, are often very fast
- Algorithmic complexity can still ruin that
- 3 levels of complexity
- ... 2 levels probably sufficient
- Linear scale of enablement
- Bloomberg 2005-2018

```
#if defined(ASSERT_LEVEL_SAFE)
#define ASSERT_SAFE(X) ASSERT_IMP(X)
#else
    // defined(ASSERT_LEVEL_OPT)
    // defined(ASSERT_LEVEL_ASSERT)
    // defined(ASSERT_LEVEL_NONE)
#define ASSERT_SAFE(X) ASSERT_DISABLED_IMP(X)
#endif
```

- 1 Introduction
- 2 Basic Contracts
- 3 Doing Stuff With Contracts
 - A Dream
 - Less Bugs
 - Deploying it
 - Faster Code
- 4 SG21
- 5 Conclusion

Choosing Levels in code

- Original Suggestion:

Choosing Levels in code

- Original Suggestion:
 - OPT: 5% most critical tests

Choosing Levels in code

- Original Suggestion:
 - OPT: 5% most critical tests
 - ASSERT: 90% tests $< 2\times$ performance hit

Choosing Levels in code

- Original Suggestion:
 - OPT: 5% most critical tests
 - ASSERT: 90% tests $< 2\times$ performance hit
 - SAFE: 5% anything slower

Choosing Levels in code

- Original Suggestion:
 - OPT: 5% most critical tests
 - ASSERT: 90% tests $< 2\times$ performance hit
 - SAFE: 5% anything slower
- Current Suggestion:

Choosing Levels in code

- Original Suggestion:
 - OPT: 5% most critical tests
 - ASSERT: 90% tests $< 2\times$ performance hit
 - SAFE: 5% anything slower
- Current Suggestion:
 - OPT: 0-0.5% absolutely critical and 0-impact

Choosing Levels in code

- Original Suggestion:
 - OPT: 5% most critical tests
 - ASSERT: 90% tests $< 2\times$ performance hit
 - SAFE: 5% anything slower
- Current Suggestion:
 - OPT: 0-0.5% absolutely critical and 0-impact
 - ASSERT: 99% non $O(n)$ -impacting

Choosing Levels in code

- Original Suggestion:
 - OPT: 5% most critical tests
 - ASSERT: 90% tests $< 2\times$ performance hit
 - SAFE: 5% anything slower
- Current Suggestion:
 - OPT: 0-0.5% absolutely critical and 0-impact
 - ASSERT: 99% non $O(n)$ -impacting
 - SAFE: 0.5-1% algorithmically slow

Choosing Levels in code

- Original Suggestion:
 - OPT: 5% most critical tests
 - ASSERT: 90% tests $< 2\times$ performance hit
 - SAFE: 5% anything slower
- Current Suggestion:
 - OPT: 0-0.5% absolutely critical and 0-impact
 - ASSERT: 99% non $O(n)$ -impacting
 - SAFE: 0.5-1% algorithmically slow
- Changing is hard

Choosing Levels in builds

- What we did

Choosing Levels in builds

- What we did
 - Developement - `ASSERT_LEVEL_ASSERT`

Choosing Levels in builds

- What we did
 - Developement - `ASSERT_LEVEL_ASSERT`
 - Unit tests - `ASSERT_LEVEL_ASSERT` hopefully

Choosing Levels in builds

- What we did
 - Developement - `ASSERT_LEVEL_ASSERT`
 - Unit tests - `ASSERT_LEVEL_ASSERT` hopefully
 - Beta testing - `ASSERT_LEVEL_ASSERT_OPT`

Choosing Levels in builds

- What we did
 - Developement - `ASSERT_LEVEL_ASSERT`
 - Unit tests - `ASSERT_LEVEL_ASSERT` hopefully
 - Beta testing - `ASSERT_LEVEL_ASSERT_OPT`
 - Production - `ASSERT_LEVEL_ASSERT_OPT`

Choosing Levels in builds

- What we did
 - Developement - `ASSERT_LEVEL_ASSERT`
 - Unit tests - `ASSERT_LEVEL_ASSERT` hopefully
 - Beta testing - `ASSERT_LEVEL_ASSERT_OPT`
 - Production - `ASSERT_LEVEL_ASSERT_OPT`
- What we wanted

Choosing Levels in builds

- What we did
 - Developement - `ASSERT_LEVEL_ASSERT`
 - Unit tests - `ASSERT_LEVEL_ASSERT` hopefully
 - Beta testing - `ASSERT_LEVEL_ASSERT_OPT`
 - Production - `ASSERT_LEVEL_ASSERT_OPT`
- What we wanted
 - Developement - `ASSERT_LEVEL_ASSERT` or `ASSERT_LEVEL_SAFE`

Choosing Levels in builds

- What we did
 - Developement - `ASSERT_LEVEL_ASSERT`
 - Unit tests - `ASSERT_LEVEL_ASSERT` hopefully
 - Beta testing - `ASSERT_LEVEL_ASSERT_OPT`
 - Production - `ASSERT_LEVEL_ASSERT_OPT`
- What we wanted
 - Developement - `ASSERT_LEVEL_ASSERT` or `ASSERT_LEVEL_SAFE`
 - Unit tests - `ASSERT_LEVEL_ASSERT` or `ASSERT_LEVEL_SAFE`

Choosing Levels in builds

- What we did
 - Developement - `ASSERT_LEVEL_ASSERT`
 - Unit tests - `ASSERT_LEVEL_ASSERT` hopefully
 - Beta testing - `ASSERT_LEVEL_ASSERT_OPT`
 - Production - `ASSERT_LEVEL_ASSERT_OPT`
- What we wanted
 - Developement - `ASSERT_LEVEL_ASSERT` or `ASSERT_LEVEL_SAFE`
 - Unit tests - `ASSERT_LEVEL_ASSERT` or `ASSERT_LEVEL_SAFE`
 - Beta testing - `ASSERT_LEVEL_ASSERT` or `ASSERT_LEVEL_SAFE`

Choosing Levels in builds

- What we did
 - Developement - `ASSERT_LEVEL_ASSERT`
 - Unit tests - `ASSERT_LEVEL_ASSERT` hopefully
 - Beta testing - `ASSERT_LEVEL_ASSERT_OPT`
 - Production - `ASSERT_LEVEL_ASSERT_OPT`
- What we wanted
 - Developement - `ASSERT_LEVEL_ASSERT` or `ASSERT_LEVEL_SAFE`
 - Unit tests - `ASSERT_LEVEL_ASSERT` or `ASSERT_LEVEL_SAFE`
 - Beta testing - `ASSERT_LEVEL_ASSERT` or `ASSERT_LEVEL_SAFE`
 - Production - `ASSERT_LEVEL_ASSERT`

Choosing Levels in builds

- What we did
 - Development - `ASSERT_LEVEL_ASSERT`
 - Unit tests - `ASSERT_LEVEL_ASSERT` hopefully
 - Beta testing - `ASSERT_LEVEL_ASSERT_OPT`
 - Production - `ASSERT_LEVEL_ASSERT_OPT`
- What we wanted
 - Development - `ASSERT_LEVEL_ASSERT` or `ASSERT_LEVEL_SAFE`
 - Unit tests - `ASSERT_LEVEL_ASSERT` or `ASSERT_LEVEL_SAFE`
 - Beta testing - `ASSERT_LEVEL_ASSERT` or `ASSERT_LEVEL_SAFE`
 - Production - `ASSERT_LEVEL_ASSERT`
- ... which is where we are

The Next Step

- Adding more assertions

The Next Step

- Adding more assertions

- `~bsl::string() { ASSERT(m_data[m_size] == 0); }`

The Next Step

- Adding more assertions
 - `~bsl::string() { ASSERT(m_data[m_size] == 0); }`
 - Time ABI change

The Next Step

- Adding more assertions
 - `~bsl::string() { ASSERT(m_data[m_size] == 0); }`
 - Time ABI change
- Changing levels of assertions

The Next Step

- Adding more assertions
 - `~bsl::string() { ASSERT(m_data[m_size] == 0); }`
 - Time ABI change
- Changing levels of assertions
 - SAFE to ASSERT

The Next Step

- Adding more assertions
 - `~bsl::string() { ASSERT(m_data[m_size] == 0); }`
 - Time ABI change
- Changing levels of assertions
 - SAFE to ASSERT
 - ASSERT to OPT

The Next Step

- Adding more assertions
 - `~bsl::string() { ASSERT(m_data[m_size] == 0); }`
 - Time ABI change
- Changing levels of assertions
 - SAFE to ASSERT
 - ASSERT to OPT
- Changing deployed assertion levels

The Next Step

- Adding more assertions
 - `~bsl::string() { ASSERT(m_data[m_size] == 0); }`
 - Time ABI change
- Changing levels of assertions
 - SAFE to ASSERT
 - ASSERT to OPT
- Changing deployed assertion levels
- Everyone will need to do this in 202x!

The Next Step

- Adding more assertions
 - `~bsl::string() { ASSERT(m_data[m_size] == 0); }`
 - Time ABI change
- Changing levels of assertions
 - SAFE to ASSERT
 - ASSERT to OPT
- Changing deployed assertion levels
- Everyone will need to do this in 202x!
 - Using language contracts when they come will be a case of adding new assertions to existing code.

Mis-Step #1

- Continuing violation handler (2008-2015)

Mis-Step #1

- Continuing violation handler (2008-2015)
 - Requires cooperation from main

Mis-Step #1

- Continuing violation handler (2008-2015)
 - Requires cooperation from main
 - Allows new bugs to go through unnoticed

Mis-Step #1

- Continuing violation handler (2008-2015)
 - Requires cooperation from main
 - Allows new bugs to go through unnoticed
 - At least 1 major Bloomberg (WP) bug was because of this

Mis-Step #1

- Continuing violation handler (2008-2015)
 - Requires cooperation from main
 - Allows new bugs to go through unnoticed
 - At least 1 major Bloomberg (WP) bug was because of this
 - Blanket continuation unsafe

Mis-Step #2

- Extra Smart violation handler (2016)

Mis-Step #2

- Extra Smart violation handler (2016)
 - Configuration to allow continuation

Mis-Step #2

- Extra Smart violation handler (2016)
 - Configuration to allow continuation
 - Tracking failure counts

Mis-Step #2

- Extra Smart violation handler (2016)
 - Configuration to allow continuation
 - Tracking failure counts
 - Alternate logging

Mis-Step #2

- Extra Smart violation handler (2016)
 - Configuration to allow continuation
 - Tracking failure counts
 - Alternate logging
- Still unsuccessful

Mis-Step #2

- Extra Smart violation handler (2016)
 - Configuration to allow continuation
 - Tracking failure counts
 - Alternate logging
- Still unsuccessful
 - Requires even more cooperation from main

Mis-Step #2

- Extra Smart violation handler (2016)
 - Configuration to allow continuation
 - Tracking failure counts
 - Alternate logging
- Still unsuccessful
 - Requires even more cooperation from main
 - No way to indicate in code that a check is “new”

Mis-Step #2

- Extra Smart violation handler (2016)
 - Configuration to allow continuation
 - Tracking failure counts
 - Alternate logging
- Still unsuccessful
 - Requires even more cooperation from main
 - No way to indicate in code that a check is “new”
 - Rarely used, minimal progress

Step?

- BSLS_REVIEW (2018)

Step?

- BSLS_REVIEW (2018)
 - No explicit cooperation from main needed

Step?

- BSLs_REVIEW (2018)
 - No explicit cooperation from main needed
 - Contracts can be marked as “new” in code

Step?

- BSLs_REVIEW (2018)
 - No explicit cooperation from main needed
 - Contracts can be marked as “new” in code
 - Build-time controls to mark all assertions at a level as “new”

Step?

- BSLs_REVIEW (2018)
 - No explicit cooperation from main needed
 - Contracts can be marked as “new” in code
 - Build-time controls to mark all assertions at a level as “new”

BSLS_REVIEW overview

- Parallel structure to BSLS_ASSERT

BSLS_REVIEW overview

- Parallel structure to BSLS_ASSERT
- Separate violation handler, defaults to logging

BSLS_REVIEW overview

- Parallel structure to BSLS_ASSERT
- Separate violation handler, defaults to logging
- Lifecycle BSLS_ASSERT_SAFE to BSLS_REVIEW to BSLS_ASSERT

BSLS_REVIEW overview

- Parallel structure to BSLS_ASSERT
- Separate violation handler, defaults to logging
- Lifecycle BSLS_ASSERT_SAFE to BSLS_REVIEW to BSLS_ASSERT
- Alternately, <nothing> to BSLS_REVIEW_? to BSLS_ASSERT_?

BSLS_REVIEW

- Initially a copy of ASSERT

```
#define REVIEW_IMP(X) if (!(X)) { \
    bb::assert_violation violation(__FILE__, __LINE__, #X); \
    bb::Review::invoke_violation_handler(violation); \
}
```

BSLS_REVIEW

- Initially a copy of ASSERT
- Number of failures is important

```
#define REVIEW_IMP(X) if (!(X)) {                                \
    static std::atomic<int> count;                                \
    bb::review_violation violation(__FILE__, __LINE__, ++count, #X);\
    bb::Review::invoke_violation_handler(violation);              \
}
```

BSLS_REVIEW

- Initially a copy of ASSERT
- Number of failures is important
- Default violation handler logs only

```
void Review::default_violation_handler(  
    const bb::review_violation &violation)  
{  
    // Log a message, with contents of violation  
    // Log a stack trace  
    // Return  
}
```

BSLS_REVIEW

- Initially a copy of ASSERT
- Number of failures is important
- Default violation handler logs only
- With exponential backoff

```
void Review::default_violation_handler(  
    const bb::review_violation &violation)  
{  
    int count = violation.count();  
    if (0 == (count & (count-1))) {  
        // Log a message, with contents of violation  
        // Log a stack trace  
    }  
    // Return  
}
```

BSLS_REVIEW Build time control

- Mutually exclusive

```
#if defined(REVIEW_LEVEL_NONE)    ? 1 : 0 \
    + defined(REVIEW_LEVEL_OPT)    ? 1 : 0 \
    + defined(REVIEW_LEVEL_REVIEW) ? 1 : 0 \
    + defined(REVIEW_LEVEL_SAFE)   ? 1 : 0 \
    > 1
#error Multiple REVIEW_LEVEL macros defined
#endif
```


BSLS_REVIEW Build time control

- Mutually exclusive
- Default to assert level

```
#if defined(ASSERT_LEVEL_NONE)
#define REVIEW_LEVEL_NONE
#elif defined(ASSERT_LEVEL_OPT)
#define REVIEW_LEVEL_OPT
#elif defined(ASSERT_LEVEL_ASSERT)
#define REVIEW_LEVEL_REVIEW
#elif defined(ASSERT_LEVEL_SAFE)
#define REVIEW_LEVEL_SAFE
#else
#define REVIEW_LEVEL_REVIEW
#endif
```

BSLS_REVIEW Build time control

- Mutually exclusive
- Default to assert level (In reality copies assert logic)

```
#if defined(ASSERT_LEVEL_NONE)
#define REVIEW_LEVEL_NONE
#elif defined(ASSERT_LEVEL_OPT)
#define REVIEW_LEVEL_OPT
#elif defined(ASSERT_LEVEL_ASSERT)
#define REVIEW_LEVEL_REVIEW
#elif defined(ASSERT_LEVEL_SAFE)
#define REVIEW_LEVEL_SAFE
#else
#define REVIEW_LEVEL_REVIEW
#endif
```

BSLS_REVIEW Build time control

- Mutually exclusive
- Default to assert level
- Controls just like ASSERT

```
#if defined(REVIEW_LEVEL_NONE)  
#define REVIEW_OPT(X) REVIEW_DISABLED_IMP(X)  
#define REVIEW(X) REVIEW_DISABLED_IMP(X)  
#define REVIEW_SAFE(X) REVIEW_DISABLED_IMP(X)  
//..
```

BSLS_REVIEW Build time control

- Mutually exclusive
- Default to assert level
- Controls just like ASSERT

```
//..  
#elif defined(REVIEW_LEVEL_OPT)  
#define REVIEW_OPT(X)    REVIEW_IMP(X)  
#define REVIEW(X)        REVIEW_DISABLED_IMP(X)  
#define REVIEW_SAFE(X)   REVIEW_DISABLED_IMP(X)  
//..
```

BSLS_REVIEW Build time control

- Mutually exclusive
- Default to assert level
- Controls just like ASSERT

```
//..  
#elif defined(REVIEW_LEVEL_REVIEW)  
#define REVIEW_OPT(X)    REVIEW_IMP(X)  
#define REVIEW(X)        REVIEW_IMP(X)  
#define REVIEW_SAFE(X)   REVIEW_DISABLED_IMP(X)  
//..
```

BSLS_REVIEW Build time control

- Mutually exclusive
- Default to assert level
- Controls just like ASSERT

```
//..  
#elif defined(REVIEW_LEVEL_SAFE)  
#define REVIEW_OPT(X)    REVIEW_IMP(X)  
#define REVIEW(X)        REVIEW_IMP(X)  
#define REVIEW_SAFE(X)   REVIEW_IMP(X)  
#endif
```

BSLS_REVIEW Build time control

- Mutually exclusive
- Default to assert level
- Controls just like ASSERT

```
#if defined(REVIEW_LEVEL_OPT) \
    defined(REVIEW_LEVEL_REVIEW) \
    defined(REVIEW_LEVEL_SAFE)
#define REVIEW_OPT(X) REVIEW_IMP(X)
#else
    // defined(REVIEW_LEVEL_NONE)
#define REVIEW_OPT(X) REVIEW_DISABLED_IMP(X)
#endif
```

BSLS_REVIEW Build time control

- Mutually exclusive
- Default to assert level
- Controls just like ASSERT

```
#if defined(REVIEW_LEVEL_REVIEW) \
    defined(REVIEW_LEVEL_SAFE)
#define REVIEW(X) REVIEW_IMP(X)
#else
    // defined(REVIEW_LEVEL_OPT)
    // defined(REVIEW_LEVEL_NONE)
#define REVIEW(X) REVIEW_DISABLED_IMP(X)
#endif
```


BSLS_REVIEW Build time control

- Mutually exclusive
- Default to assert level
- Controls just like ASSERT

```
#if defined(REVIEW_LEVEL_SAFE)
#define REVIEW_SAFE(X) REVIEW_IMP(X)
#else
    // defined(REVIEW_LEVEL_OPT)
    // defined(REVIEW_LEVEL_REVIEW)
    // defined(REVIEW_LEVEL_NONE)
#define REVIEW_SAFE(X) REVIEW_DISABLED_IMP(X)
#endif
```

ASSERT and REVIEW interaction

- Changing build levels requires reviewing all asserts at the target level

ASSERT and REVIEW interaction

- Changing build levels requires reviewing all asserts at the target level
- BSLS_ASSERT again

```
#if defined(BSLS_ASSERT_LEVEL_ASSERT) \  
    defined(BSLS_ASSERT_LEVEL_SAFE)  
#define BSLS_ASSERT(X) ASSERT_IMP(X)  
#else  
#define BSLS_ASSERT(X)  
#endif
```

ASSERT and REVIEW interaction

- Changing build levels requires reviewing all asserts at the target level
- BSLS_ASSERT again

```
#if defined(BSLS_ASSERT_LEVEL_ASSERT) \
    defined(BSLS_ASSERT_LEVEL_SAFE)
#define BSLS_ASSERT(X) ASSERT_IMP(X)
#elif defined(BSLS_REVIEW_LEVEL_REVIEW) \
    defined(BSLS_REVIEW_LEVEL_SAFE)
#define BSLS_ASSERT(X) REVIEW_IMP(X)
#else
#define BSLS_ASSERT(X) ASSERT_DISABLED_IMP(X)
#endif
```

ASSERT and REVIEW interaction

- Changing build levels requires reviewing all asserts at the target level
- BSLS_ASSERT again
- Same for BSLS_ASSERT_OPT and BSLS_ASSERT_SAFE

```
#if defined(BSLS_ASSERT_LEVEL_OPT) \
    defined(BSLS_ASSERT_LEVEL_ASSERT) \
    defined(BSLS_ASSERT_LEVEL_SAFE)
#define BSLS_ASSERT_OPT(X) ASSERT_IMP(X)
#elif defined(BSLS_REVIEW_LEVEL_OPT) \
    defined(BSLS_REVIEW_LEVEL_REVIEW) \
    defined(BSLS_REVIEW_LEVEL_SAFE)
#define BSLS_ASSERT_OPT(X) REVIEW_IMP(X)
#else
#define BSLS_ASSERT_OPT(X) ASSERT_DISABLED_IMP(X)
#endif
```

ASSERT and REVIEW interaction

- Changing build levels requires reviewing all asserts at the target level
- BSLS_ASSERT again
- Same for BSLS_ASSERT_OPT and BSLS_ASSERT_SAFE

```
#if defined(BSLS_ASSERT_LEVEL_SAFE)
#define BSLS_ASSERT_SAFE(X) ASSERT_IMP(X)
#elif defined(BSLS_REVIEW_LEVEL_SAFE)
#define BSLS_ASSERT_SAFE(X) REVIEW_IMP(X)
#else
#define BSLS_ASSERT_SAFE(X) ASSERT_DISABLED_IMP(X)
#endif
```

BSLS_REVIEW Takeaways

- So far a success

BSLS_REVIEW Takeaways

- So far a success
 - Thousands of BSLS_ASSERT_SAFE instances have become BSLS_REVIEW

BSLS_REVIEW Takeaways

- So far a success
 - Thousands of BSLS_ASSERT_SAFE instances have become BSLS_REVIEW
 - More than 90% are now BSLS_ASSERT

BSLS_REVIEW Takeaways

- So far a success
 - Thousands of BSLS_ASSERT_SAFE instances have become BSLS_REVIEW
 - More than 90% are now BSLS_ASSERT
 - Dozens of reported bugs have been fixed/are being fixed

BSLS_REVIEW Takeaways

- So far a success
 - Thousands of BSLS_ASSERT_SAFE instances have become BSLS_REVIEW
 - More than 90% are now BSLS_ASSERT
 - Dozens of reported bugs have been fixed/are being fixed
 - No crashes have been introduced by these changes

BSLS_REVIEW Takeaways

- So far a success
 - Thousands of BSLS_ASSERT_SAFE instances have become BSLS_REVIEW
 - More than 90% are now BSLS_ASSERT
 - Dozens of reported bugs have been fixed/are being fixed
 - No crashes have been introduced by these changes
- Why?

BSLS_REVIEW Takeaways

- So far a success
 - Thousands of BSLS_ASSERT_SAFE instances have become BSLS_REVIEW
 - More than 90% are now BSLS_ASSERT
 - Dozens of reported bugs have been fixed/are being fixed
 - No crashes have been introduced by these changes
- Why?
 - Ability to make a check a review alongside existing asserts.

BSLS_REVIEW Takeaways

- So far a success
 - Thousands of BSLS_ASSERT_SAFE instances have become BSLS_REVIEW
 - More than 90% are now BSLS_ASSERT
 - Dozens of reported bugs have been fixed/are being fixed
 - No crashes have been introduced by these changes
- Why?
 - Ability to make a check a review alongside existing asserts.
 - Can control from code

BSLS_REVIEW Takeaways

- So far a success
 - Thousands of BSLS_ASSERT_SAFE instances have become BSLS_REVIEW
 - More than 90% are now BSLS_ASSERT
 - Dozens of reported bugs have been fixed/are being fixed
 - No crashes have been introduced by these changes
- Why?
 - Ability to make a check a review alongside existing asserts.
 - Can control from code
 - Can control at build time

What do you do if you can't prove a contract is being followed?

What do you do if you can't prove a contract is being followed?

Believe

- 1 Introduction
- 2 Basic Contracts
- 3 Doing Stuff With Contracts
 - A Dream
 - Less Bugs
 - Deploying it
 - **Faster Code**
- 4 SG21
- 5 Conclusion

We were promised performance

- Performance improvements come from the compiler *knowing* something will be true

We were promised performance

- Performance improvements come from the compiler *knowing* something will be true
- `[[noreturn]]` on `invoke_violation_handler` lets you safely trade the cost of checking for the benefit of assumption

We were promised performance

- Performance improvements come from the compiler *knowing* something will be true
- `[[noreturn]]` on `invoke_violation_handler` lets you safely trade the cost of checking for the benefit of assumption
- If you believe the contract is being followed, `__builtin_assume` can give you the benefit without the cost

We were promised performance

- Performance improvements come from the compiler *knowing* something will be true
- `[[noreturn]]` on `invoke_violation_handler` lets you safely trade the cost of checking for the benefit of assumption
- If you believe the contract is being followed, `__builtin_assume` can give you the benefit without the cost
- The risk is the strength of your belief

BSLS_ASSERT_LEVEL_ASSUME

- Let's add another choice for mapping the BSLS_ASSERT macros

```
#define BSLS_ASSERT_ASSUME(X) if (!(X)) { std::unreachable(); }
```

BSLS_ASSERT_LEVEL_ASSUME

- Let's add another choice for mapping the BSLS_ASSERT macros
- Lots of ways to implement, different tradeoffs and portability

```
#define BSLS_ASSERT_ASSUME(X) if (!(X)) { std::unreachable(); }  
#define BSLS_ASSERT_ASSUME(X) __builtin_assume(X)  
#define BSLS_ASSERT_ASSUME(X) if (!(X)) { int *p = nullptr; *p = 17; }
```


BSLS_ASSERT_LEVEL_ASSUME

- Let's add another choice for mapping the BSLS_ASSERT macros
- Lots of ways to implement, different tradeoffs and portability
- This almost made it to the standard

```
#define BSLS_ASSERT_ASSUME(X) [[ assert assume : X ]]
```

BSLS_ASSERT_LEVEL_ASSUME

- Let's add another choice for mapping the BSLS_ASSERT macros
- Lots of ways to implement, different tradeoffs and portability
- This almost made it to the standard
- Coming to BDE with an extended BSLS_ASSERT_LEVEL scale

```
//..  
#elif defined(ASSERT_LEVEL_ASSUME_OPT)  
#define ASSERT_OPT(X)  ASSERT_ASSUME(X)  
#define ASSERT(X)      ASSERT_DISABLED_IMP(X)  
#define ASSERT_SAFE(X) ASSERT_DISABLED_IMP(X)  
//..
```

BSLS_ASSERT_LEVEL_ASSUME

- Let's add another choice for mapping the BSLS_ASSERT macros
- Lots of ways to implement, different tradeoffs and portability
- This almost made it to the standard
- Coming to BDE with an extended BSLS_ASSERT_LEVEL scale

```
//..  
#elif defined(ASSERT_LEVEL_ASSUME_OPT)  
#define ASSERT_OPT(X)  ASSERT_ASSUME(X)  
#define ASSERT(X)      ASSERT_ASSUME(X)  
#define ASSERT_SAFE(X) ASSERT_DISABLED_IMP(X)  
//..
```

BSLS_ASSERT_LEVEL_ASSUME

- Let's add another choice for mapping the BSLS_ASSERT macros
- Lots of ways to implement, different tradeoffs and portability
- This almost made it to the standard
- Coming to BDE with an extended BSLS_ASSERT_LEVEL scale

```
//..  
#elif defined(ASSERT_LEVEL_ASSUME_OPT)  
#define ASSERT_OPT(X)  ASSERT_ASSUME(X)  
#define ASSERT(X)      ASSERT_ASSUME(X)  
#define ASSERT_SAFE(X) ASSERT_ASSUME(X)  
//..
```

- 1 Introduction
- 2 Basic Contracts
- 3 Doing Stuff With Contracts
- 4 SG21**
- 5 Conclusion

What happened?

- Coming into Kona, contracts (in N4800) had a number of issues

What happened?

- Coming into Kona, contracts (in N4800) had a number of issues
 - Continuation was a global flag, and its very existence was contentious

What happened?

- Coming into Kona, contracts (in N4800) had a number of issues
 - Continuation was a global flag, and its very existence was contentious
 - Assumption of any unchecked contracts

What happened?

- Coming into Kona, contracts (in N4800) had a number of issues
 - Continuation was a global flag, and its very existence was contentious
 - Assumption of any unchecked contracts
 - Axiom was isomorphic to `__builtin_assume`

What happened?

- Coming into Kona, contracts (in N4800) had a number of issues
 - Continuation was a global flag, and its very existence was contentious
 - Assumption of any unchecked contracts
 - Axiom was isomorphic to `__builtin_assume`
 - `default/audit/axiom` were both too simplistic and too complicated for many

What happened?

- Coming into Kona, contracts (in N4800) had a number of issues
 - Continuation was a global flag, and its very existence was contentious
 - Assumption of any unchecked contracts
 - Axiom was isomorphic to `__builtin_assume`
 - `default/audit/axiom` were both too simplistic and too complicated for many
 - Numerous edge case decisions had been made without publicizing clearly their reasoning

What happened?

- Numerous papers in Kona and Cologne attempted to fix these problems

What happened?

- Numerous papers in Kona and Cologne attempted to fix these problems
- On Monday, July 15th in Cologne a number of options were presented to EWG

What happened?

- Numerous papers in Kona and Cologne attempted to fix these problems
- On Monday, July 15th in Cologne a number of options were presented to EWG
 - P1711, by Bjarne Stroustrup, proposed some small fixes

What happened?

- Numerous papers in Kona and Cologne attempted to fix these problems
- On Monday, July 15th in Cologne a number of options were presented to EWG
 - P1711, by Bjarne Stroustrup, proposed some small fixes
 - P1429, revised after Kona, proposed adding literal semantics

What happened?

- Numerous papers in Kona and Cologne attempted to fix these problems
- On Monday, July 15th in Cologne a number of options were presented to EWG
 - P1711, by Bjarne Stroustrup, proposed some small fixes
 - P1429, revised after Kona, proposed adding literal semantics
 - P1607 proposed two options - remove all but a nicer c assert, or remove all but add in literal semantics

What happened?

- Numerous papers in Kona and Cologne attempted to fix these problems
- On Monday, July 15th in Cologne a number of options were presented to EWG
 - P1711, by Bjarne Stroustrup, proposed some small fixes
 - P1429, revised after Kona, proposed adding literal semantics
 - P1607 proposed two options - remove all but a nicer c assert, or remove all but add in literal semantics
- P1607's two options were the only consensus reached that day by EWG

What happened?

- On Wednesday, July 17th in Cologne P1823 was proposed and accepted by a massive margin

What happened?

- On Wednesday, July 17th in Cologne P1823 was proposed and accepted by a massive margin
- On Saturday, July 20th, P1823 was ratified and SG21 was announced to pursue contracts again

What's the plan?

- SG21 is getting off the ground:

What's the plan?

- SG21 is getting off the ground:
 - Very active reflector

What's the plan?

- SG21 is getting off the ground:
 - Very active reflector
 - One telecon so far

What's the plan?

- SG21 is getting off the ground:
 - Very active reflector
 - One telecon so far
 - First official meeting will be in Belfast

What's the plan?

- SG21 is getting off the ground:
 - Very active reflector
 - One telecon so far
 - First official meeting will be in Belfast
- Rough sketch of plan:

What's the plan?

- SG21 is getting off the ground:
 - Very active reflector
 - One telecon so far
 - First official meeting will be in Belfast
- Rough sketch of plan:
 - Gather use cases publicly

What's the plan?

- SG21 is getting off the ground:
 - Very active reflector
 - One telecon so far
 - First official meeting will be in Belfast
- Rough sketch of plan:
 - Gather use cases publicly (Done!)

What's the plan?

- SG21 is getting off the ground:
 - Very active reflector
 - One telecon so far
 - First official meeting will be in Belfast
- Rough sketch of plan:
 - Gather use cases publicly (Done!)
 - Poll on prioritization of use cases

What's the plan?

- SG21 is getting off the ground:
 - Very active reflector
 - One telecon so far
 - First official meeting will be in Belfast
- Rough sketch of plan:
 - Gather use cases publicly (Done!)
 - Poll on prioritization of use cases (In progress!)

What's the plan?

- SG21 is getting off the ground:
 - Very active reflector
 - One telecon so far
 - First official meeting will be in Belfast
- Rough sketch of plan:
 - Gather use cases publicly (Done!)
 - Poll on prioritization of use cases (In progress!)
 - Gather proposed solutions (Future)

What's the plan?

- SG21 is getting off the ground:
 - Very active reflector
 - One telecon so far
 - First official meeting will be in Belfast
- Rough sketch of plan:
 - Gather use cases publicly (Done!)
 - Poll on prioritization of use cases (In progress!)
 - Gather proposed solutions (Future)
 - Refinements on P1607, N4830

What's the plan?

- SG21 is getting off the ground:
 - Very active reflector
 - One telecon so far
 - First official meeting will be in Belfast
- Rough sketch of plan:
 - Gather use cases publicly (Done!)
 - Poll on prioritization of use cases (In progress!)
 - Gather proposed solutions (Future)
 - Refinements on P1607, N4830
 - Changes in syntax? Scope? Behaviors?

What's the plan?

- SG21 is getting off the ground:
 - Very active reflector
 - One telecon so far
 - First official meeting will be in Belfast
- Rough sketch of plan:
 - Gather use cases publicly (Done!)
 - Poll on prioritization of use cases (In progress!)
 - Gather proposed solutions (Future)
 - Refinements on P1607, N4830
 - Changes in syntax? Scope? Behaviors?
 - Review and vote on solutions based on satisfying use cases
 - Hopefully no more “union of minimal solutions”

What's the plan?

- SG21 is getting off the ground:
 - Very active reflector
 - One telecon so far
 - First official meeting will be in Belfast
- Rough sketch of plan:
 - Gather use cases publicly (Done!)
 - Poll on prioritization of use cases (In progress!)
 - Gather proposed solutions (Future)
 - Refinements on P1607, N4830
 - Changes in syntax? Scope? Behaviors?
 - Review and vote on solutions based on satisfying use cases
 - Hopefully no more “union of minimal solutions”
 - Hopefully no more “I don't need this so it can't happen”

What's the plan?

- SG21 is getting off the ground:
 - Very active reflector
 - One telecon so far
 - First official meeting will be in Belfast
- Rough sketch of plan:
 - Gather use cases publicly (Done!)
 - Poll on prioritization of use cases (In progress!)
 - Gather proposed solutions (Future)
 - Refinements on P1607, N4830
 - Changes in syntax? Scope? Behaviors?
 - Review and vote on solutions based on satisfying use cases
 - Hopefully no more “union of minimal solutions”
 - Hopefully no more “I don't need this so it can't happen”
- Land revised contracts in standard

What's the plan?

- SG21 is getting off the ground:
 - Very active reflector
 - One telecon so far
 - First official meeting will be in Belfast
- Rough sketch of plan:
 - Gather use cases publicly (Done!)
 - Poll on prioritization of use cases (In progress!)
 - Gather proposed solutions (Future)
 - Refinements on P1607, N4830
 - Changes in syntax? Scope? Behaviors?
 - Review and vote on solutions based on satisfying use cases
 - Hopefully no more “union of minimal solutions”
 - Hopefully no more “I don't need this so it can't happen”
- Land revised contracts in standard (WG21 SG21 2021!)

Use Cases

- Use cases were gathered from all SG21 participants and edited for clarity

Use Cases

- Use cases were gathered from all SG21 participants and edited for clarity
- All of the form “As an X in order to Y I need to Z”.

Use Cases

- Use cases were gathered from all SG21 participants and edited for clarity
- All of the form “As an X in order to Y I need to Z”.
- This hopefully be the first wg21 paper published “by” SG21.

Use Cases

- Use cases were gathered from all SG21 participants and edited for clarity
- All of the form “As an X in order to Y I need to Z”.
- This hopefully be the first wg21 paper published “by” SG21.
- 29 different classes of users with 196 different use cases

Use Cases

- Use cases were gathered from all SG21 participants and edited for clarity
- All of the form “As an X in order to Y I need to Z”.
- This hopefully be the first wg21 paper published “by” SG21.
- 29 different classes of users with 196 different use cases
- Use cases range from very general to very specific:

Use Cases

- Use cases were gathered from all SG21 participants and edited for clarity
- All of the form “As an X in order to Y I need to Z”.
- This hopefully be the first wg21 paper published “by” SG21.
- 29 different classes of users with 196 different use cases
- Use cases range from very general to very specific:
 - As a Developer, in order to Have readable annotations, I want to Have annotations with a succinct and elegant syntax

Use Cases

- Use cases were gathered from all SG21 participants and edited for clarity
- All of the form “As an X in order to Y I need to Z”.
- This hopefully be the first wg21 paper published “by” SG21.
- 29 different classes of users with 196 different use cases
- Use cases range from very general to very specific:
 - As a Developer, in order to Have readable annotations, I want to Have annotations with a succinct and elegant syntax
 - As a C++ API Developer, in order to Maintain a class hierarchy, I want to Ensure overriding methods have same or wider preconditions

Use Cases

- Use cases were gathered from all SG21 participants and edited for clarity
- All of the form “As an X in order to Y I need to Z”.
- This hopefully be the first wg21 paper published “by” SG21.
- 29 different classes of users with 196 different use cases
- Use cases range from very general to very specific:
 - As a Developer, in order to Have readable annotations, I want to Have annotations with a succinct and elegant syntax
 - As a C++ API Developer, in order to Maintain a class hierarchy, I want to Ensure overriding methods have same or wider preconditions
- Some require vastly more than was possible before:

Use Cases

- Use cases were gathered from all SG21 participants and edited for clarity
- All of the form “As an X in order to Y I need to Z”.
- This hopefully be the first wg21 paper published “by” SG21.
- 29 different classes of users with 196 different use cases
- Use cases range from very general to very specific:
 - As a Developer, in order to Have readable annotations, I want to Have annotations with a succinct and elegant syntax
 - As a C++ API Developer, in order to Maintain a class hierarchy, I want to Ensure overriding methods have same or wider preconditions
- Some require vastly more than was possible before:
 - As a C++ API Developer In Order to Enforce contracts in async code I want to Express contracts on callbacks such as `std::function`, function pointers, or references to functions, lambdas, or function objects

Prioritization

- SG21 members have been asked to rate each use case on behalf of whatever users they feel they best represent:
 - Not important
 - Nice to have
 - Must have

Prioritization

- SG21 members have been asked to rate each use case on behalf of whatever users they feel they best represent:
 - Not important
 - Nice to have
 - Must have
- Expect these results to be ready to analyze and discuss by Belfast.

- 1 Introduction
- 2 Basic Contracts
- 3 Doing Stuff With Contracts
- 4 SG21
- 5 Conclusion**

Conclusion

- Bloomberg's `BSLS_ASSERT` and `BSLS_REVIEW` provide a rich set of contract enforcement utility. Grab the open source BDE to play with it today
- The needs of that facility will hopefully be met by language level contracts in the future, SG21 is working hard to see that happen