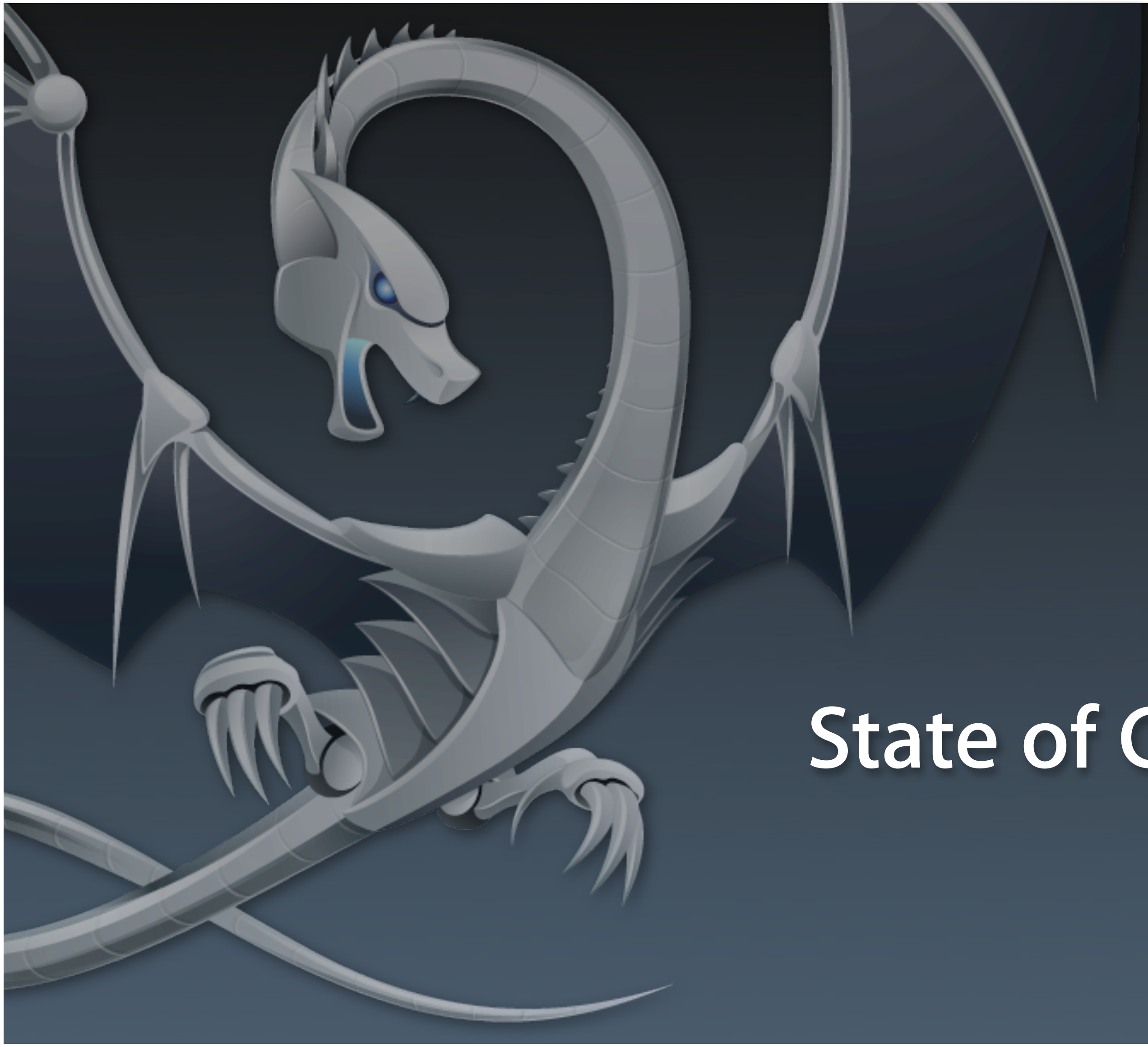


State of Clang

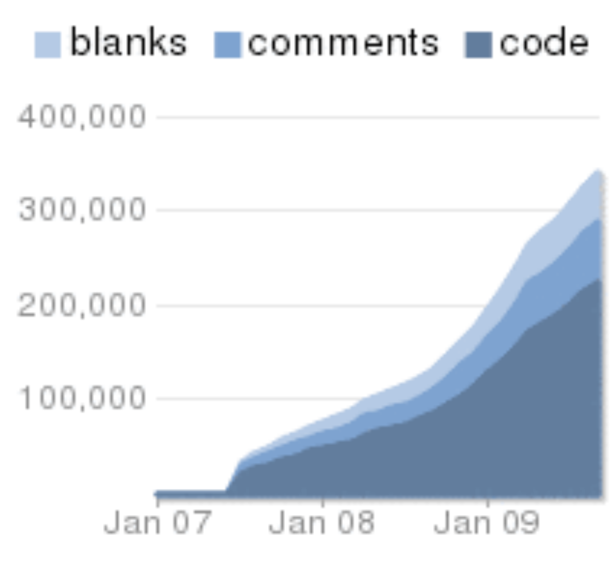
]

This talk in brief

- Clang as a compiler
- Applications of Clang libraries
- Clang C++ and future directions

Clang Goals and Ambitions

- C Language Family (C/C++/ObjC) Front-end Technology
  - Parser + AST Generation Libraries
  - Code generation through LLVM
  - Infrastructure for source level tools
- Tools built from the libraries:
  - GCC compatible compiler
  - Static Analyzer
  - Chris' crazy automatic code review and correction tool?
  - Your feature here :-)



Clang Lines of Code

http://ohloh.net/p/clang

Two Clang Releases

- Apple Xcode 3.2: “Apple Clang 1.0”
  - Production quality C and ObjC support for Darwin X86
  - Branched from mainline ~May’09

- LLVM 2.6: “Clang 2.6”
  - New warnings, code generation improvements, many bug fixes
  - The FreeBSD kernel and 99% of user space builds and works with clang!
  - Branched from mainline ~Sep’09

User Visible Features over Mainline GCC

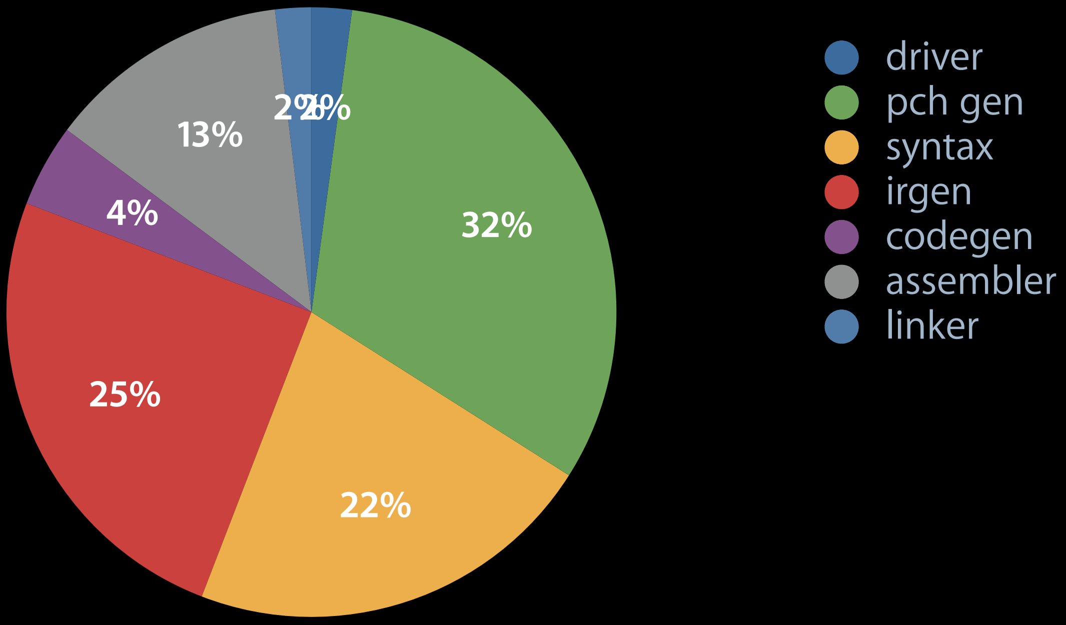
- Language feature support:
  - Full Objective-C 2 and Apple "Blocks" Support
  - Generic vector extensions (from OpenCL)
  - Feature checking macros: #if __has_builtin(__builtin_unreachable)
- Better compile-time performance
- Better diagnostics

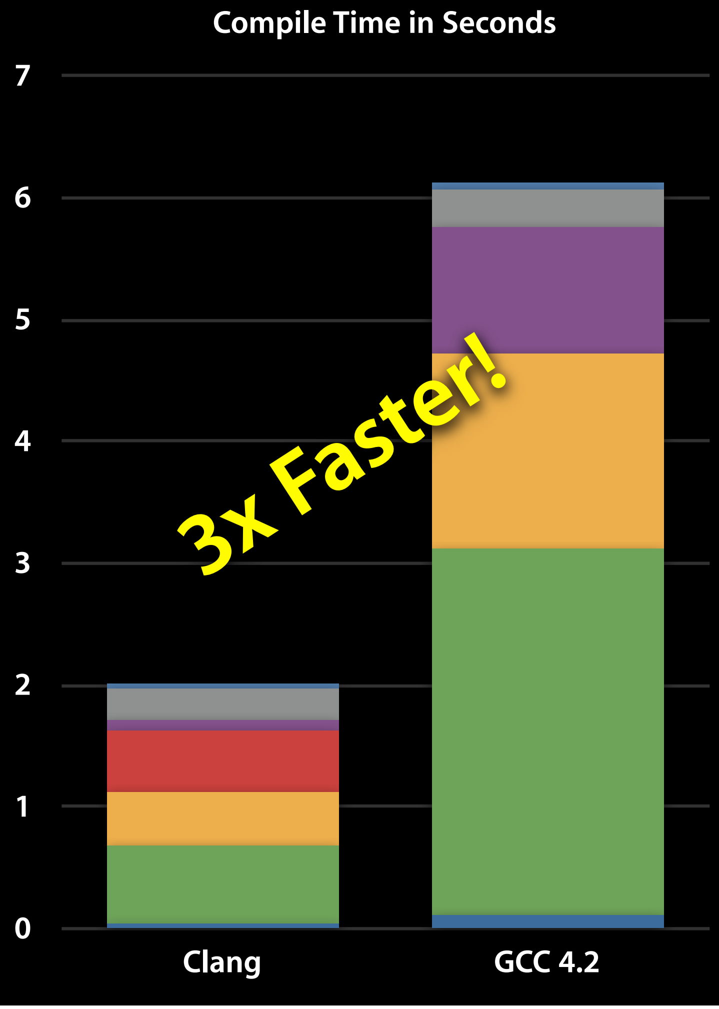
http://clang.llvm.org/docs/LanguageExtensions.html

Frontend Performance

- C and C++ are hostile to fast compile times:
  - Many phases of translation: trigraphs, escaped newlines, macros
  - Textual #include of (large) headers
  - File system abuse searching for header files
- Compiler users and tools both want fast compiles:
  - We compare debug "-O0 -g" compile times vs GCC 4.2

Sketch Compile Time Breakdown



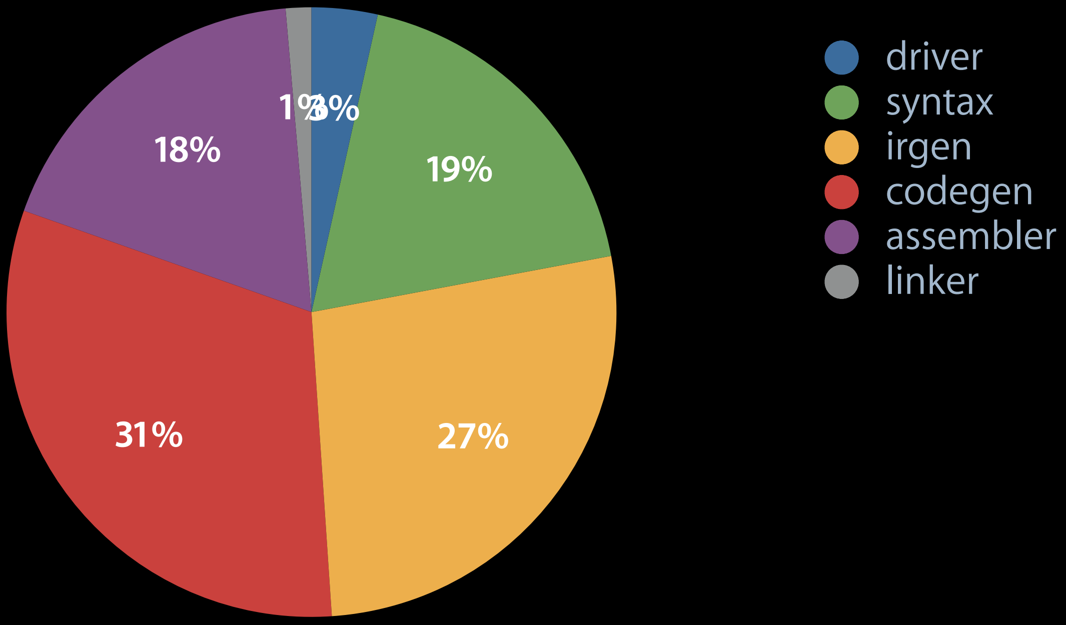


3x Faster!

- Much faster PCH generation and syntax checking!
- Time pretty evenly split between phases

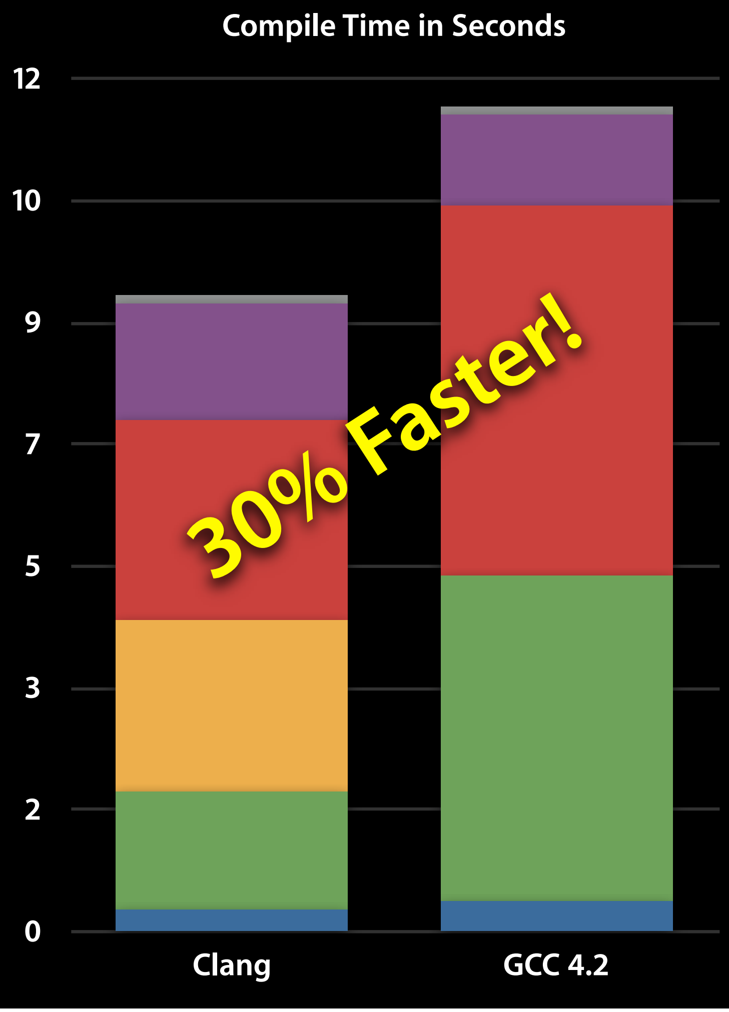
http://clang.llvm.org/performance.html

176.gcc Compile Time Breakdown



- Builtin assembler could be ~18% win!
- Heavily irgen and codegen (llvm) bound
    - Much left to do!

http://clang.llvm.org/performance.html



30% Faster!

Error and Warning Improvements

- "Diagnostics" are error and warning reports
  - Compiler detects something is wrong
  - Tries to guess why and explain it

- GCC diagnostics are often not helpful
  - Confusing, poorly worded, not precise

http://clang.llvm.org/diagnostics.html

Range and Location Information

GCC 4.2

```
$ gcc t.c
t.c: In function ‘foo’:
t.c:8: error: invalid operands to binary + (have ‘int’ and ‘struct A’)
```

Clang

```
$ clang t.c
t.c:8:36: error: invalid operands to binary expression ('int' and 'struct A')
  X = X + func(X ? ((SomeA.F + 40) + SomeA) / 42 + SomeA.F : Ptr->F);
                    ~~~~~~~~~~~~~~ ^ ~~~~~
```

http://clang.llvm.org/diagnostics.html

Better Diagnosis of the Problem

GCC 4.2

```
$ gcc t.c
t.c:2: error: expected ‘=’, ‘,’, ‘;’, ‘asm’ or ‘__attribute__’ before ‘P’
```

Clang

```
$ clang t.c
t.c:2:1: error: unknown type name 'foo_t'
foo_t P = 42;
^
```

http://clang.llvm.org/diagnostics.html

Macro Expansion Information

GCC 4.2

```
$ gcc t.c
t.c: In function ‘foo’:
t.c:9: error: invalid operands to binary > (have ‘int’ and ‘struct A’)
```

Clang

```
$ clang t.c
t.c:9:7: error: invalid operands to binary expression ('int' and 'struct A')
  X = MAX(X, *Ptr);
      ^~~~~~~~~~~
t.c:2:24: note: instantiated from:
#define MAX(A, B) ((A) > (B) ? (A) : (B))
                   ~~~ ^ ~~~
```

http://clang.llvm.org/diagnostics.html

Other Great Refinements

```
$ clang t.c
t.c:9:8: warning: extra tokens at end of #endif directive [-Wextra-tokens]
#endif foo
       ^
       //

$ clang t.c
t.c:18:10: error: expected ';' after expression
  test1()
         ^
         ;
```

- Diagnostics tell you which -W flag controls them
- Fixit hints for obvious fixes (and -fixit mode that applies them)
- Diagnostics really are color coded on the command line

http://clang.llvm.org/diagnostics.html

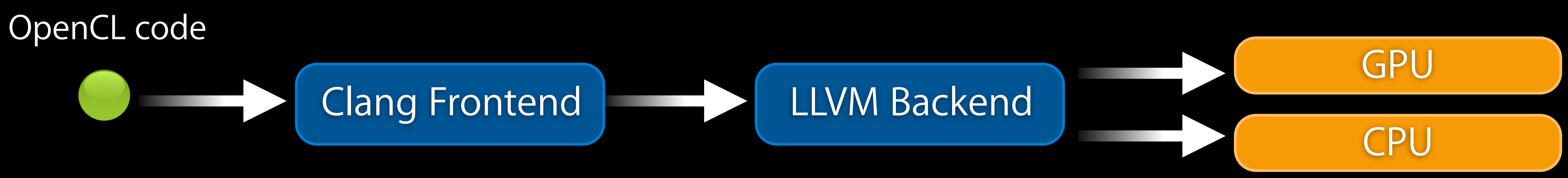
Summary: Clang as a Compiler

- Clang is a great compiler to use:
  - Ridiculously fast
  - Great “user interface”
  - Useful language extensions
- Not quite done yet:
  - Missing warnings: e.g. 64-bit portability warnings
  - Support for every crazy target triple
  - Fully featured cross compiler support
  - C++!
- Clang is a super hackable compiler front-end, come help!

Clang Applications

OpenCL

- Language and framework for general purpose use of GPUs and CPUs
- Use Clang and LLVM to JIT compile "C" code



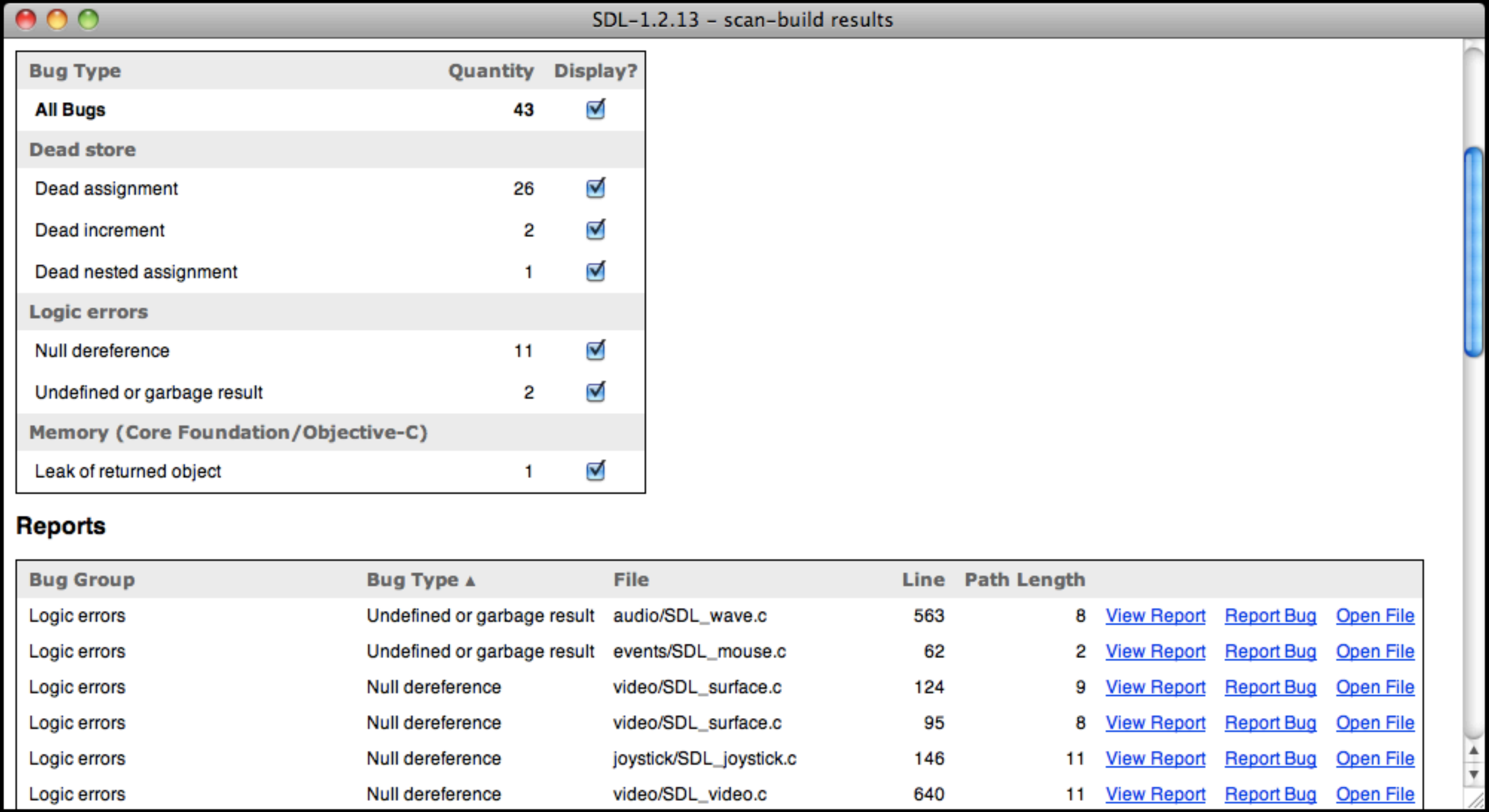
Clang Static Analyzer

- Standalone tool for finding bugs by analyzing source code
- Find deeper bugs than compiler warnings
- Memory leaks, logic errors, API violations, many others

http://clang-analyzer.llvm.org

What we showed you last year ....

```
$ scan-build <build command>
```

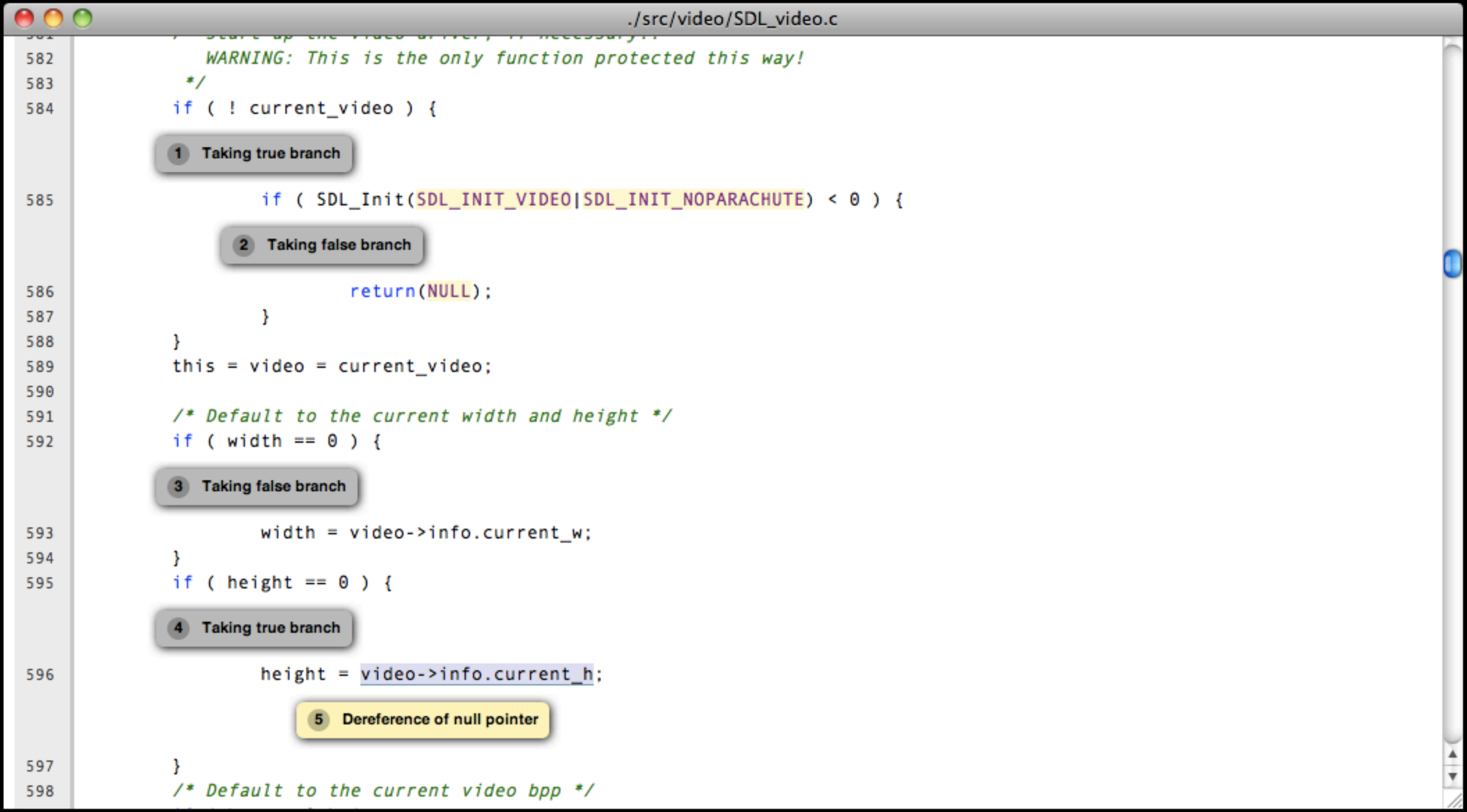


SDL-1.2.13 – scan-build results

Bug Type	Quantity	Display?
All Bugs	**43**	☑
Dead store		
Dead assignment	26	☑
Dead increment	2	☑
Dead nested assignment	1	☑
Logic errors		
Null dereference	11	☑
Undefined or garbage result	2	☑
Memory (Core Foundation/Objective-C)		
Leak of returned object	1	☑

Reports

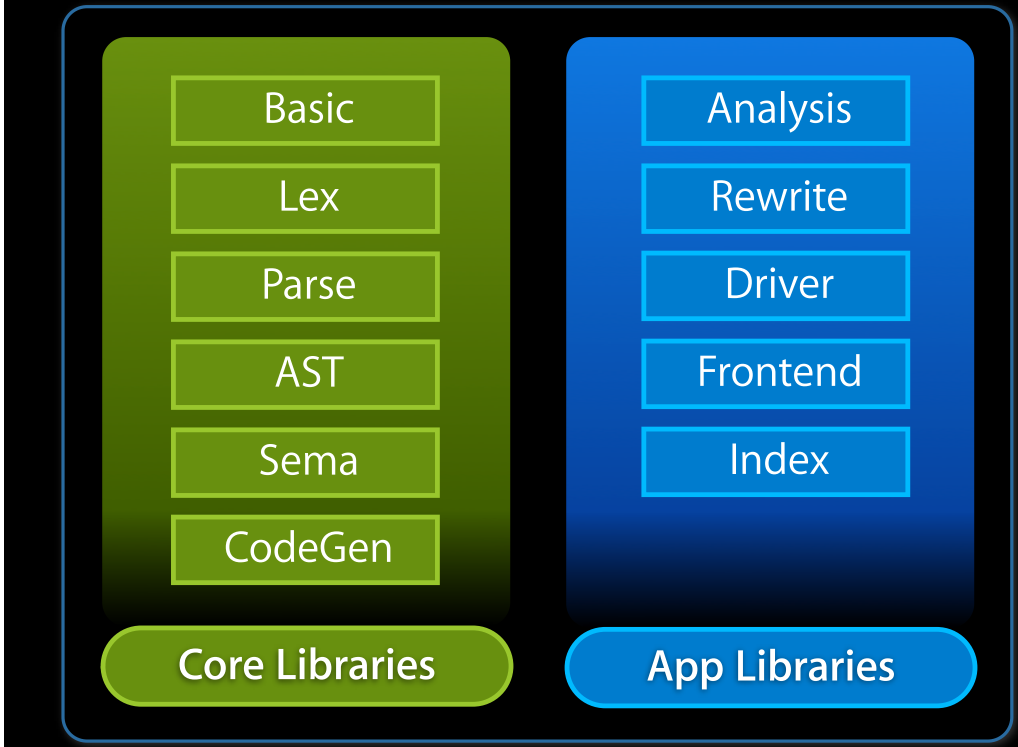
Bug Group	Bug Type ▲	File	Line	Path Length			
Logic errors	Undefined or garbage result	audio/SDL_wave.c	563	8	View Report	Report Bug	Open File
Logic errors	Undefined or garbage result	events/SDL_mouse.c	62	2	View Report	Report Bug	Open File
Logic errors	Null dereference	video/SDL_surface.c	124	9	View Report	Report Bug	Open File
Logic errors	Null dereference	video/SDL_surface.c	95	8	View Report	Report Bug	Open File
Logic errors	Null dereference	joystick/SDL_joystick.c	146	11	View Report	Report Bug	Open File
Logic errors	Null dereference	video/SDL_video.c	640	11	View Report	Report Bug	Open File



./src/video/SDL_video.c

```
         /* Start up the video driver, if necessary..
           WARNING: This is the only function protected this way!
         */
        if ( ! current_video ) {

             1  Taking true branch

                if ( SDL_Init(SDL_INIT_VIDEO|SDL_INIT_NOPARACHUTE) < 0 ) {

                    2  Taking false branch

                        return(NULL);
                }
        }
        this = video = current_video;

        /* Default to the current width and height */
        if ( width == 0 ) {

             3  Taking false branch

                width = video->info.current_w;
        }
        if ( height == 0 ) {

             4  Taking true branch

                height = video->info.current_h;

                           5  Dereference of null pointer

        }
        /* Default to the current video bpp */
```

Building Blocks for Source-level Technologies



- **libAnalysis** (Static analyzer)
  - Control-flow graphs
  - Path-sensitive analysis engine
  - Now used for some Clang warnings
- **libRewrite** (Syntactic code editing)
  - Used by Fixit-hints
- **libDriver & libFrontend**
- **libIndex**
  - Uses serialized ASTs
  - Cross translation unit symbol resolution

Other Potential Applications

- **Refactoring**
  - Many pieces in place
  - libRewrite (code rewriting)
  - libIndex (cross-translation unit symbol resolution)
- **Documentation generation**
- **Advanced code search**
  - Within a codebase
  - Multiple codebases
    - Across an organization
    - Sourceforge.net
- **Advanced revision browsing**
  - Examine semantic changes
  - What is the impact of this change?
- **Language bindings (Scripting)**
- **Incremental Parsing**
- **Intelligent Code Formatting**
- **C++ Interpreter**
- **Many others!**

Going Forward: Clang C++

C++ Is a Large, Complex Language

- Classes
  - Derived classes
  - Multiple, virtual inheritance
  - Constructors, destructors
  - Virtual functions
  - Friends
- Namespaces
  - Argument-Dependent Lookup
  - Using directives
  - Using declarations
- Overload resolution
  - Operator overloading
  - User-defined conversions
- Templates
  - Class & function templates
  - Partial specialization
  - Template instantiation
  - Member templates
  - Template argument deduction/ SFINAE

http://clang.llvm.org/cxx_status.html

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Already implemented!

http://clang.llvm.org/cxx_status.html

Clang C++ Parsing: In the Real World

- Clang can parse real C++ code:
  - C++ Standard Library headers (GNU libstdc++ 4.2)
  - XNU Kernel
  - 105/140 QtCore headers
  - Various LLVM headers
- LLVM IR generation is starting to crawl:

```
#include <string>
#include “llvm/Support/raw_ostream.h”
int main() {
  std::string Hello = "Hello";
  llvm::outs() << (Hello + ", " + "World!") << ‘\n’;
}
```

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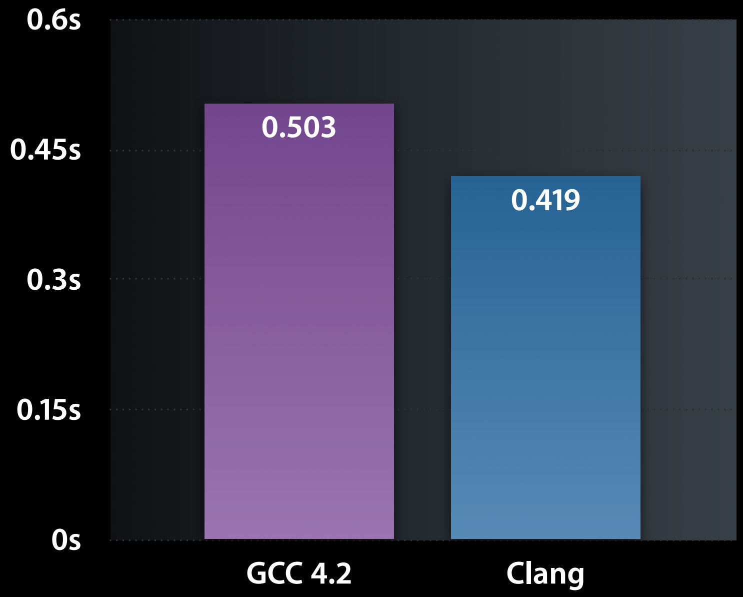
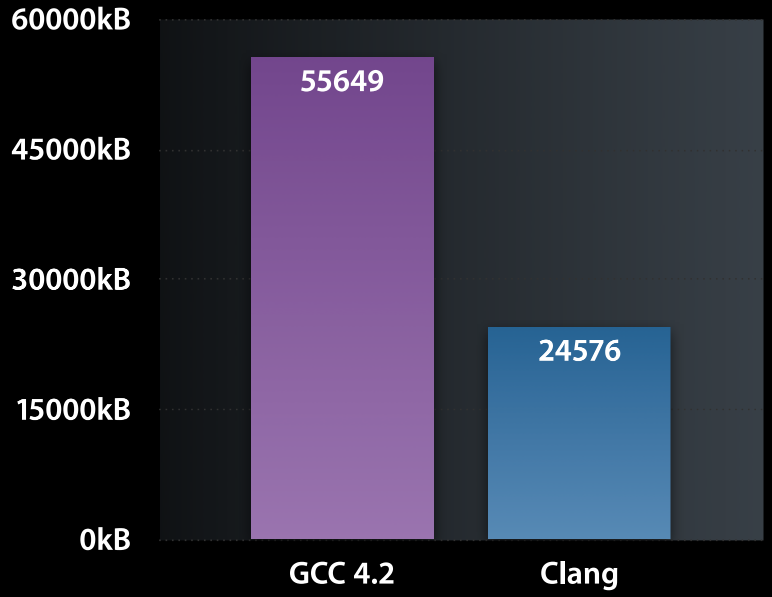
}
```

Performance: Parsing libstdc++ Headers

Parsing Time (64-bit)



Memory Consumed (64-bit)



Better Diagnostics Now: Ambiguities

- GCC 4.2:

```
virtual-ambig.cpp:9: error: invalid covariant return type for ‘virtual TeachingAssistant*
TeachingAssistant::Clone() const’
virtual-ambig.cpp:3: error:   overriding ‘virtual Person* Person::Clone() const’
```

- Clang:

```
virtual-ambig.cpp:9:30: error: return type of virtual function 'Clone' is not
      covariant with the return type of the function it overrides (ambiguous
      conversion from derived class 'class TeachingAssistant' to base class
      'class Person':
    class TeachingAssistant -> class Teacher -> class Person
    class TeachingAssistant -> class Student -> class Person)
  virtual TeachingAssistant *Clone() const;
                             ^

virtual-ambig.cpp:3:19: note: overridden virtual function is here
  virtual Person *Clone() const;
                  ^
```

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                             ^

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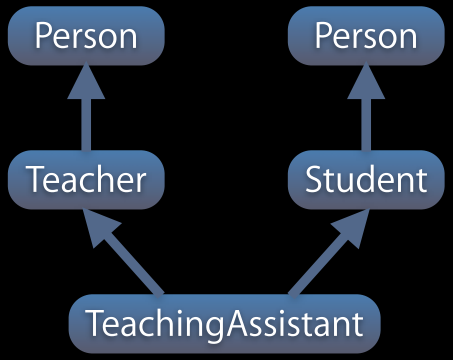

Better Diagnostics Now: Overloading

```
string s = getData();
std::ofstream(“file.txt”) << s << std::endl;
```

- GCC 4.2:

```
os.cpp:8: error: no match for ‘operator<<’ in
‘std::basic_ofstream<char, std::char_traits<char> >(((const char*)"file.txt"),
std::operator|(_S_out, _S_trunc)) << s’
/usr/include/c++/4.2.1/ostream:112: note: candidates are: std::basic_ostream<_CharT,
_Traits>& std::basic_ostream<_CharT, _Traits>::operator<<(std::basic_ostream<_CharT,
_Traits>& (*)(std::basic_ostream<_CharT, _Traits>&)) [with _CharT = char, _Traits =
std::char_traits<char>]
/usr/include/c++/4.2.1/ostream:121: note:                 std::basic_ostream<_CharT,
_Traits>& std::basic_ostream<_CharT, _Traits>::operator<<(std::basic_ios<_CharT,
_Traits>& (*)(std::basic_ios<_CharT, _Traits>&)) [with _CharT = char, _Traits =
std::char_traits<char>]
/usr/include/c++/4.2.1/bits/basic_string.h:2410: note:
std::basic_ostream<_CharT, _Traits>& std::operator<<(std::basic_ostream<_CharT,
_Traits>&, const std::basic_string<_CharT, _Traits, _Alloc>&) [with _CharT = char,
_Traits = std::char_traits<char>, _Alloc = std::allocator<char>]
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```

Better Diagnostics Now: Overloading

- Clang:

```
os.cpp:8:15: error: invalid operands to binary expression ('std::ofstream' (aka 'class
std::basic_ofstream<char, struct std::char_traits<char> >') and 'string' (aka 'class
std::basic_string<char, struct std::char_traits<char>, class std::allocator<char> >'))
  std::ofstream("file.txt") << s << std::endl;
  ~~~~~~~~~~~~~~~~~~~~~~~~~ ^  ~
In file included from os.cpp:1:
In file included from /usr/include/c++/4.2.1/string:53:
/usr/include/c++/4.2.1/bits/basic_string.h:2408:5: note: candidate function template
specialization [with _CharT = char, _Traits = struct std::char_traits<char>, _Alloc =
class std::allocator<char>]
  operator<<(basic_ostream<_CharT, _Traits>& __os,
  ^
/usr/include/c++/4.2.1/ostream:112:35: note: candidate function

      operator<<(__ostream_type& (*__pf)(__ostream_type&))

      ^

/usr/include/c++/4.2.1/ostream:121:31: note: candidate function
      operator<<(__ios_type& (*__pf)(__ios_type&))
      ^
```

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Better Diagnostics Later: Overloading

```
os.cpp:8:15: error: invalid operands to binary << (have ‘std::ofstream’ (aka
`std::basic_ofstream<char>’) and ‘std::string’ (aka `std::basic_string<char>’))
  std::ofstream("file.txt") << s << std::endl;
  ~~~~~~~~~~~~~~~~~~~~~~~~~ ^  ~

/usr/include/c++/4.2.1/bits/basic_string.h:2410: note: cannot initialize a non-const
reference with a temporary of type `std::ofstream’ (aka `basic_ofstream<char>’)

      operator<<(basic_ostream<_CharT, _Traits>& __os,
                                                 ^

/usr/include/c++/4.2.1/ostream:112:35: note: cannot initialize parameter with lvalue of
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                                   ^

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```
os.cpp:8:15: error: invalid operands to binary << (have ‘std::ofstream’ (aka
`std::basic_ofstream<char>’) and ‘std::string’ (aka `std::basic_string<char>’))
  std::ofstream("file.txt") << s << std::endl;
  ~~~~~~~~~~~~~~~~~~~~~~~~~ ^  ~

/usr/include/c++/4.2.1/bits/basic_string.h:2410: note: cannot initialize a non-const
reference with a temporary of type `std::ofstream’ (aka `basic_ofstream<char>’)

      operator<<(basic_ostream<_CharT, _Traits>& __os,
                                                 ^
```

`clang -fshow-minimal-overload-candidates`

(the default)

C++ Future

- We don’t know when C++ will be done, but we’re moving ***fast***.
- C++ Standard Library:
    - GNU libstdc++ support is critical
    - Apache, Dinkumware, STLport should work
- C++’0x support:
    - Clang C++ is designed with C++’0x in mind
    - C++’98 support comes first
- C++ Static Analysis:
    - Existing analyses should work on C++ code
    - Extend for C++ idioms and abstractions (RAII, iterators)

the end.

• Clang web page:	http://clang.llvm.org
• Clang C++ status page:	http://clang.llvm.org/cxx_status.html
• Clang Static Analyzer page:	http://clang-analyzer.llvm.org
• Clang developer mailing list:	cfe-dev@cs.uiuc.edu