Modern CMake

Open source tools to build, test and package software: CMake, CTest, CPack, CDash

Kitware

Bill Hoffman

- CTO and a founder of Kitware Inc
- Originator of CMake build tool
- Barefoot/Sandals Ultra distance runner

Kitware

CMake/CPack/CTest/CDash

Open Source Tools to Build Test and Deploy C++ Software

Bill Hoffman
bill.hoffman@kitware.com

Google Tech Talk 2009

Leadville CO 2018

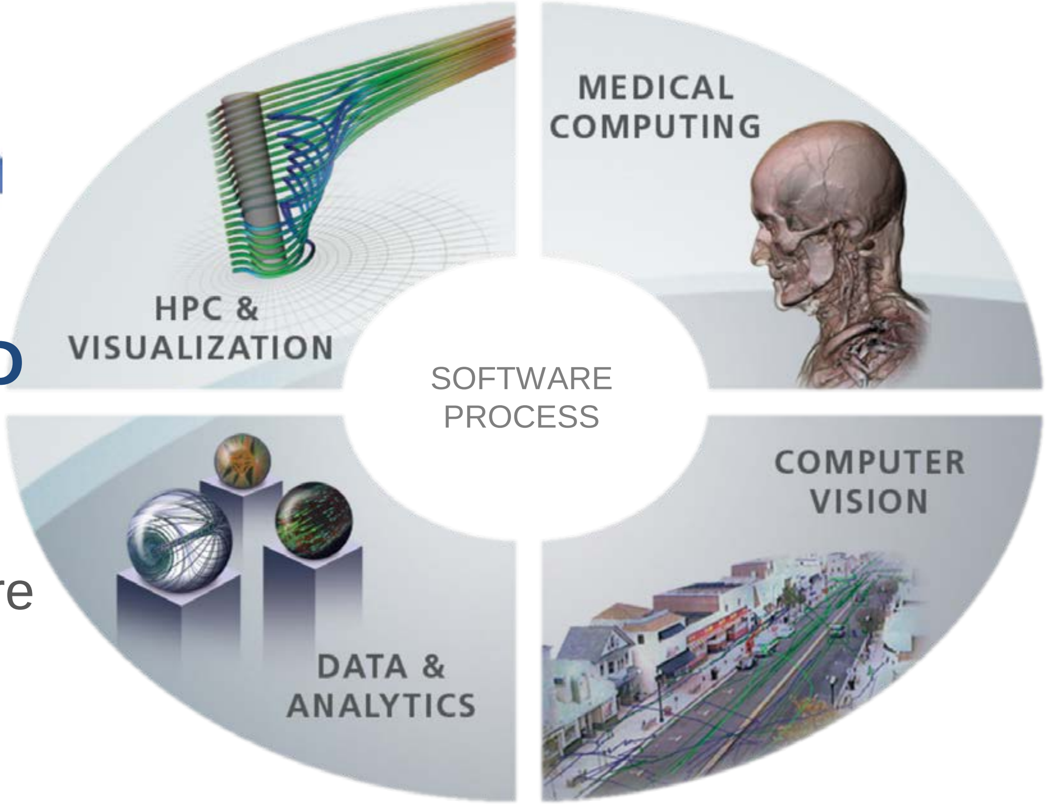
Kitware

Collaborative software R&D

- Technical computing
- Algorithms & applications
- Software process & infrastructure
- Support & training
- Open source leadership

Supporting all sectors

- Industry, government & academia



Kitware

Kitware’s customers & collaborators

Over 75 **academic** institutions…

Harvard
Massachusetts Institute of Technology
University of California, Berkeley
Stanford University
California Institute of Technology
Imperial College London
Johns Hopkins University
Cornell University
Columbia University
Robarts Research Institute
University of Pennsylvania
Rensselaer Polytechnic Institute
University of Utah
University of North Carolina

Over 50 **government** agencies and labs…

National Institutes of Health (NIH)
National Science Foundation (NSF)
National Library of Medicine (NLM)
Department of Defense (DOD)
Department of Energy (DOE)
Defense Advanced Research Projects Agency (DARPA)
Army Research Lab (ARL)
Air Force Research Lab (AFRL)
Sandia (SNL)
Los Alamos National Labs (LANL)
Argonne (ANL)
Oak Ridge (ORNL)
Lawrence Livermore (LLNL)

Over 100 **commercial** companies…

Automotive
Aircraft
Defense
Energy technology
Environmental sciences
Finance
Industrial inspection
Oil & gas
Pharmaceuticals
Publishing
3D Mapping
Medical devices
Security
Simulation

Open source platforms

- **VTK & ParaView** interactive visualization and analysis for scientific data
- **ITK & 3D Slicer** medical image analysis and personalized medicine research
- **CMake** cross-platform build system
  - CDash, CTest, CPack, software process tools
- **Resonant** informatics and infovis
- **KWIVER** computer vision image and video analysis
- Other areas include: Simulation, ultrasound, physiology, information security, materials science, …

The VTK User's Guide
Install, Use and Extend The Visual
The ITK Software Guide
The Insight Segmentation and Reg
The ParaView Guide
A Parallel Visualization Application
Mastering CMake
A Cross-Platform Build System
Luis Ibáñez
William Schroeder

What is CMake?

- CMake is the **cross-platform**, **open-source build system** that lets you use the **native development tools** you love the most.

- It’s a build system **generator**

Ninja

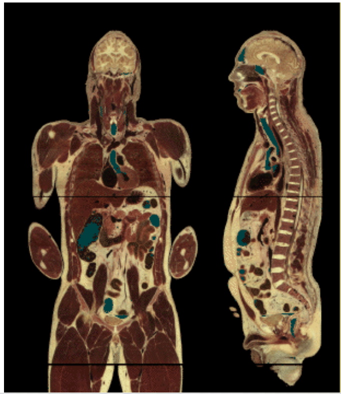
- It takes **plain text files** as input that describe your project and **produces** project files or make files for use with a wide variety of **native development tools.**

- Family of Software Development Tools
  - Build = CMake
  - Test = CTest/CDash
  - Package = CPack

Modern CMake

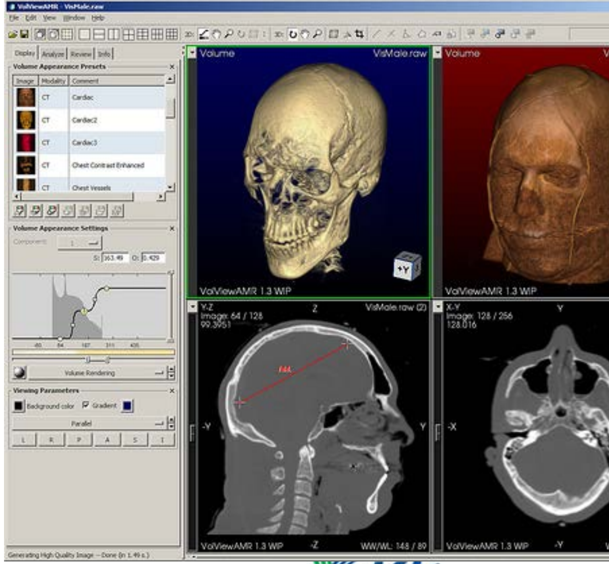
- CMake is code, treat CMakeLists.txt like the rest of the code, comments
- CMake Targets are objects with public and private propeties
- Import third party libraries as imported targets
- Export your libraries so they can be used by other CMake projects

CMake: History



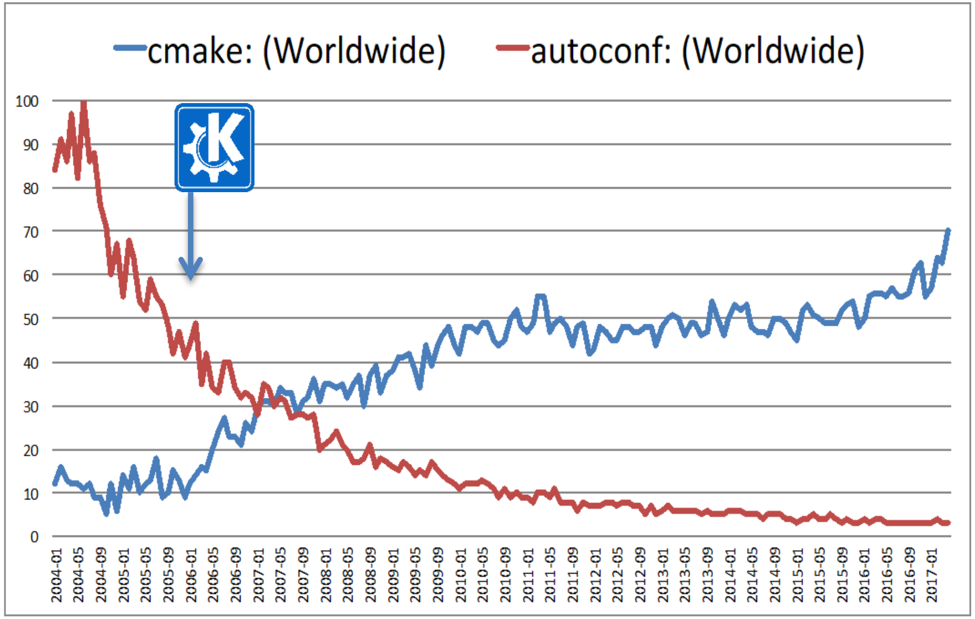
- Built for the Insight Segmentation and Registration Toolkit (ITK) http://www.itk.org

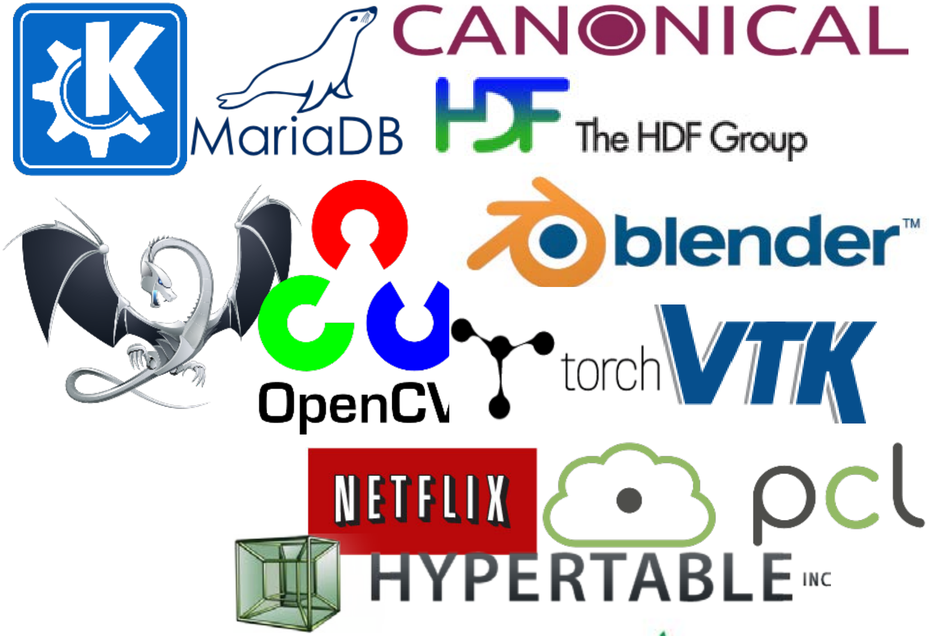
- Funded by National Library of Medicine (NLM): part of the Visible Human Project
  - Data CT/MR/Slice 1994/1995
  - Code (ITK) 1999
    - Cmake Release-1-0 branch created in 2001



CMake has broad usage in the C++ world

KDE 2006 - Tipping Point!





- 7000+ downloads per day from www.cmake.org

Indeed.com CMake jobs Full-time(263)

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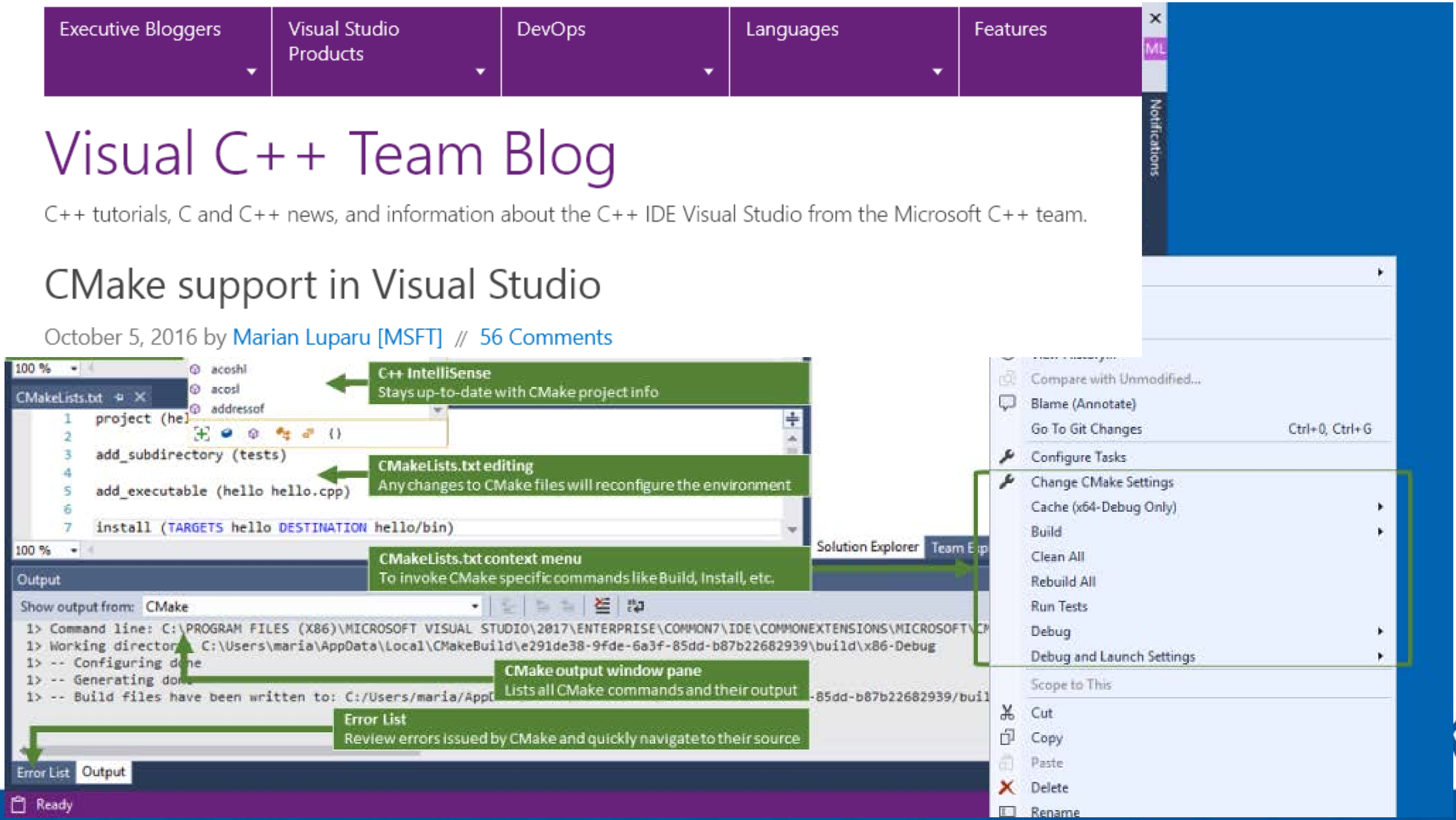
Adopted by Microsoft



Visual C++ Team Blog

C++ tutorials, C and C++ news, and information about the C++ IDE Visual Studio from the Microsoft C++ team.

CMake support in Visual Studio

October 5, 2016 by Marian Luparu [MSFT] // 56 Comments

```
project (hel

add_subdirectory (tests)

add_executable (hello hello.cpp)

install (TARGETS hello DESTINATION hello/bin)
```

```
1> Command line: C:\PROGRAM FILES (X86)\MICROSOFT VISUAL STUDIO\2017\ENTERPRISE\COMMON7\IDE\COMMONEXTENSIONS\MICROSOFT\CM
1> Working director   C:\Users\maria\AppData\Local\CMakeBuild\e291de38-9fde-6a3f-85dd-b87b22682939\build\x86-Debug
1> -- Configuring d ne
1> -- Generating do
1> -- Build files have been written to: C:/Users/maria/AppD                    -85dd-b87b22682939/buil
```

C++ IntelliSense
Stays up-to-date with CMake project info

CMakeLists.txt editing
Any changes to CMake files will reconfigure the environment

CMakeLists.txt context menu
To invoke CMake specific commands like Build, Install, etc.

CMake output window pane
Lists all CMake commands and their output

Error List
Review errors issued by CMake and quickly navigate to their source

Kitware

CMake: Features

- Automatic **dependency** generation (C, C++, CUDA, Fortran)
  - build a target in some directory, and everything this target depends on will be up to date
  - If a header file changes the correct files will be built.

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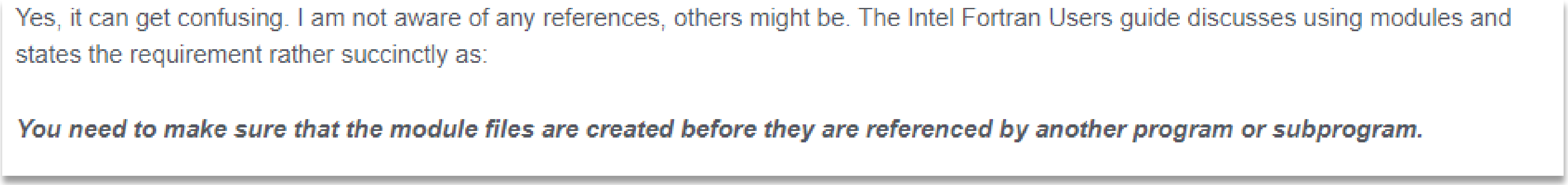
Fortran Module Order



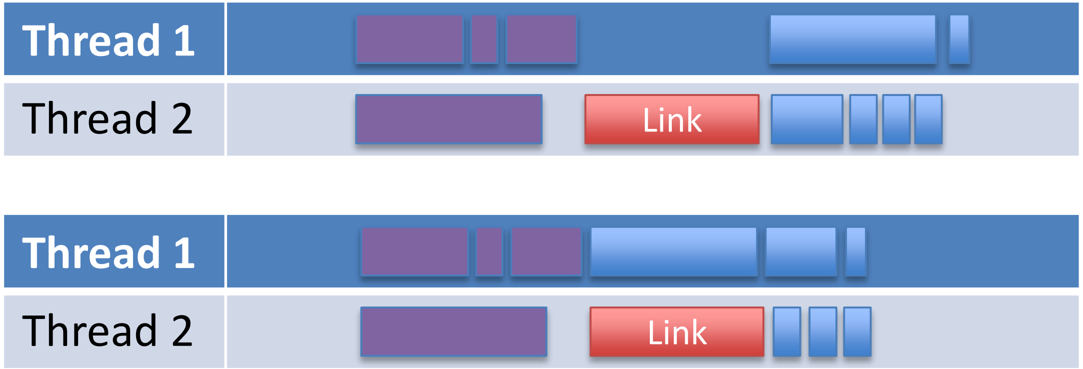
Yes, it can get confusing. I am not aware of any references, others might be. The Intel Fortran Users guide discusses using modules and states the requirement rather succinctly as:

You need to make sure that the module files are created before they are referenced by another program or subprogram.

- Old way: make;make;make until it works
- CMake way: cmake; make or cmake; ninja
  - CMake will automatically order Fortran files based on use statements in the code for a library

Ninja

- Improved parallelism for ninja builds in CMake 3.9



Thread 1

Thread 2

Link

Thread 1

Thread 2

Link

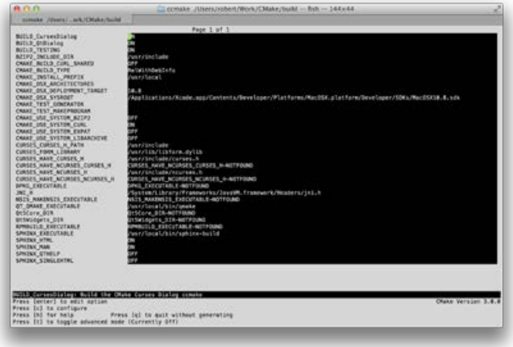
- Can control pools to limit concurrent links

Random list of things CMake does well

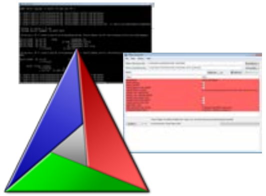
- Excellent install commands
- Excellent packaging tools
- Ability to find/link system libraries
- Handles shared libraries and versioning across platforms (linux, mac, windows)
- Keeps up to date with current and obscure compilers
- Cross platform development support (Linux/Mac/Windows/android/HPC)
- Integration of static/dynamic analysis tools
- Integration of code coverage tools
- Excellent backwards compatibility with itself (policy system)
- Open and dynamic community accepting of changes small and large
- Supports many workflows and IDEs

CMake Workflow

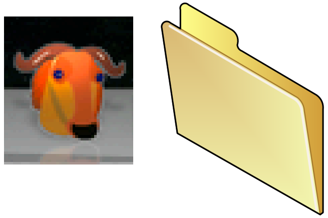
cmake –GNinja



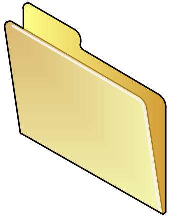
```
ccmake ./Users/robert/Work/CMake/build — fish — 144x44
ccmake /Users/...ork/CMake/build
                                   Page 1 of 1
 BUILD_CursesDialog               ON
 BUILD_QtDialog                   ON
 BUILD_TESTING                    ON
 BZIP2_INCLUDE_DIR                /usr/include
 CMAKE_BUILD_CURL_SHARED          OFF
 CMAKE_BUILD_TYPE                 RelWithDebInfo
 CMAKE_INSTALL_PREFIX             /usr/local
 CMAKE_OSX_ARCHITECTURES
 CMAKE_OSX_DEPLOYMENT_TARGET      10.8
 CMAKE_OSX_SYSROOT                /Applications/Xcode.app/Contents/Developer/Platforms/MacOSX.platform/Developer/SDKs/MacOSX10.8.sdk
 CMAKE_TEST_GENERATOR
 CMAKE_TEST_MAKEPROGRAM
 CMAKE_USE_SYSTEM_BZIP2           OFF
 CMAKE_USE_SYSTEM_CURL            ON
 CMAKE_USE_SYSTEM_EXPAT           OFF
 CMAKE_USE_SYSTEM_LIBARCHIVE      OFF
 CURSES_CURSES_H_PATH             /usr/include
 CURSES_FORM_LIBRARY              /usr/lib/libform.dylib
 CURSES_HAVE_CURSES_H             /usr/include/curses.h
 CURSES_HAVE_NCURSES_CURSES_H     CURSES_HAVE_NCURSES_CURSES_H-NOTFOUND
 CURSES_HAVE_NCURSES_H            /usr/include/ncurses.h
 CURSES_HAVE_NCURSES_NCURSES_H    CURSES_HAVE_NCURSES_NCURSES_H-NOTFOUND
 DPKG_EXECUTABLE                  DPKG_EXECUTABLE-NOTFOUND
 JNI_H                            /System/Library/Frameworks/JavaVM.framework/Headers/jni.h
 NSIS_MAKENSIS_EXECUTABLE         NSIS_MAKENSIS_EXECUTABLE-NOTFOUND
 QT_QMAKE_EXECUTABLE              /usr/local/bin/qmake
 Qt5Core_DIR                      Qt5Core_DIR-NOTFOUND
 Qt5Widgets_DIR                   Qt5Widgets_DIR-NOTFOUND
 RPMBUILD_EXECUTABLE              RPMBUILD_EXECUTABLE-NOTFOUND
 SPHINX_EXECUTABLE                /usr/local/bin/sphinx-build
 SPHINX_HTML                      ON
 SPHINX_MAN                       ON
 SPHINX_QTHELP                    OFF
 SPHINX_SINGLEHTML                OFF

BUILD_CursesDialog: Build the CMake Curses Dialog ccmake
Press [enter] to edit option                                                              CMake Version 3.0.0
Press [c] to configure
Press [h] for help           Press [q] to quit without generating
Press [t] to toggle advanced mode (Currently Off)
```



2. Run cmake-gui (or cmake or ccmake) to configure and generate native build system files

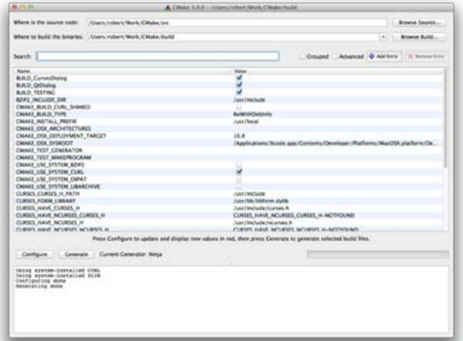


1. Edit files in the source tree



build tree

3. Open project files from the build tree and use the native build tools



CMake 3.0.0 - /Users/robert/Work/CMake/build

Where is the source code: /Users/robert/Work/CMake/src

Where to build the binaries: /Users/robert/Work/CMake/build

Search:

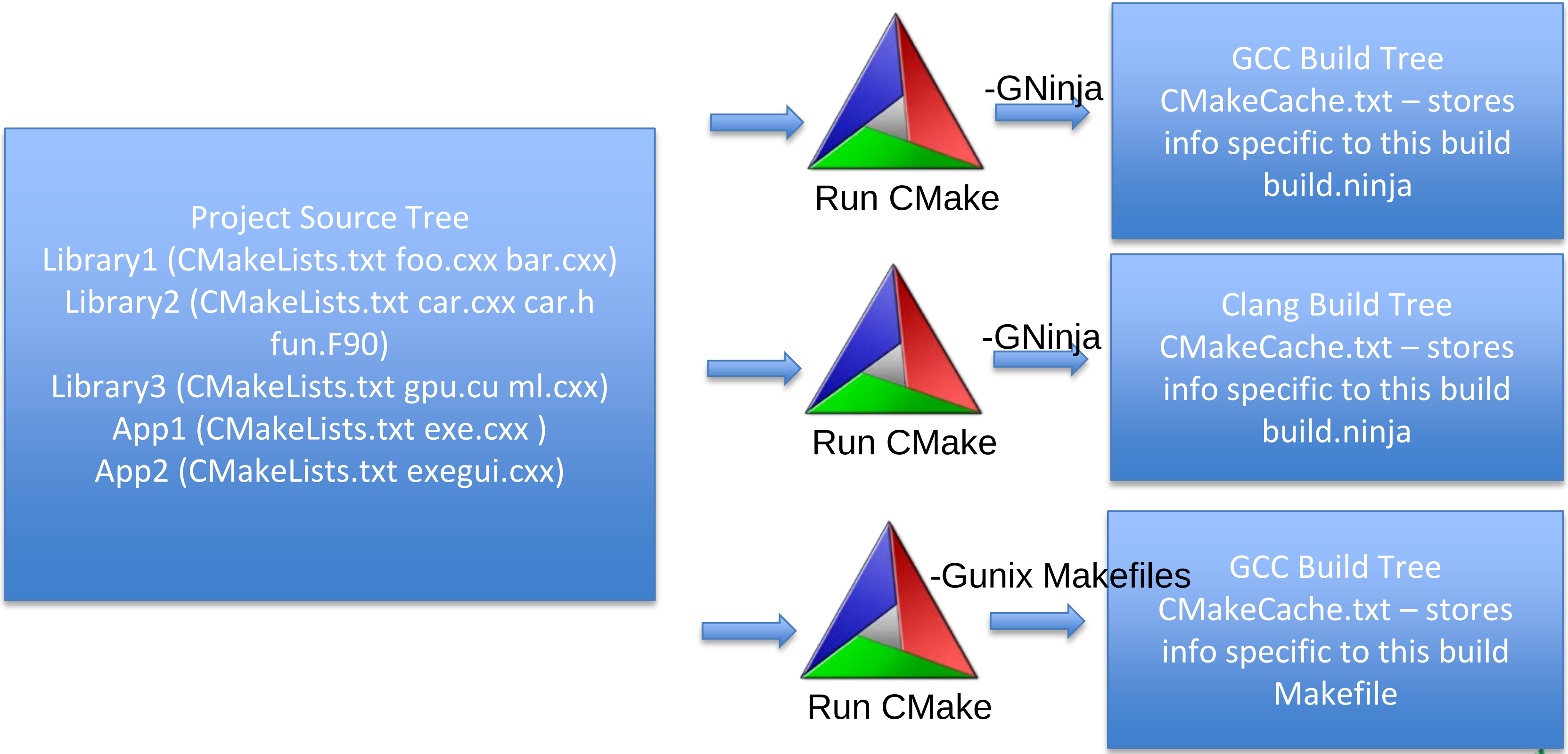
Name	Value
BUILD_CursesDialog	☑
BUILD_QtDialog	☑
BUILD_TESTING	☑
BZIP2_INCLUDE_DIR	/usr/include
CMAKE_BUILD_CURL_SHARED	□
CMAKE_BUILD_TYPE	RelWithDebInfo
CMAKE_INSTALL_PREFIX	/usr/local
CMAKE_OSX_ARCHITECTURES	
CMAKE_OSX_DEPLOYMENT_TARGET	10.8
CMAKE_OSX_SYSROOT	/Applications/Xcode.app/Contents/Developer/Platforms/MacOSX.platform/De...
CMAKE_TEST_GENERATOR	
CMAKE_TEST_MAKEPROGRAM	
CMAKE_USE_SYSTEM_BZIP2	□
CMAKE_USE_SYSTEM_CURL	☑
CMAKE_USE_SYSTEM_EXPAT	□
CMAKE_USE_SYSTEM_LIBARCHIVE	□
CURSES_CURSES_H_PATH	/usr/include
CURSES_FORM_LIBRARY	/usr/lib/libform.dylib
CURSES_HAVE_CURSES_H	/usr/include/curses.h
CURSES_HAVE_NCURSES_CURSES_H	CURSES_HAVE_NCURSES_CURSES_H-NOTFOUND
CURSES_HAVE_NCURSES_H	/usr/include/ncurses.h
CURSES_HAVE_NCURSES_NCURSES_H	CURSES_HAVE_NCURSES_NCURSES_H-NOTFOUND

Press Configure to update and display new values in red, then press Generate to generate selected build files.

Current Generator: Ninja

```
Using system-installed CURL
Using system-installed ZLIB
Configuring done
Generating done
```

Out of source builds



Project Source Tree
Library1 (CMakeLists.txt foo.cxx bar.cxx)
Library2 (CMakeLists.txt car.cxx car.h fun.F90)
Library3 (CMakeLists.txt gpu.cu ml.cxx)
App1 (CMakeLists.txt exe.cxx)
App2 (CMakeLists.txt exegui.cxx)

Run CMake

-GNinja

GCC Build Tree
CMakeCache.txt – stores info specific to this build
build.ninja

Run CMake

-GNinja

Clang Build Tree
CMakeCache.txt – stores info specific to this build
build.ninja

Run CMake

-Gunix Makefiles

GCC Build Tree
CMakeCache.txt – stores info specific to this build
Makefile

Modern CMake

CMake Then and Now

CMake 2001

CMakeLists.txt

```
SUBDIRS = \
Code/Common \

ME = ITK
```

Code/Common/CMakeLists.txt

```
ME = ITKCommon

COMPILE_CLASSES =\
itkDataObject \
itkDirectory

WIN32_CLASSES =\
itkWin32OutputWindow
```

CMake 2008

CMakeLists.txt

```
cmake_minimum_required(VERSION 2.8)
project(ITK)
add_subdirectory(Code/Common)
```

Code/Common/CMakeLists.txt

```
set(ITKCommonSources
itkDataObject.cxx itkDirectory.cxx)
if(WIN32)
  set(ITKCommonSources
${ITKCommonSources}
itkWin32OutputWindow.cxx)
endif()
add_library(ITKCommon
${ITKCommonSources})
```

CMake 2018

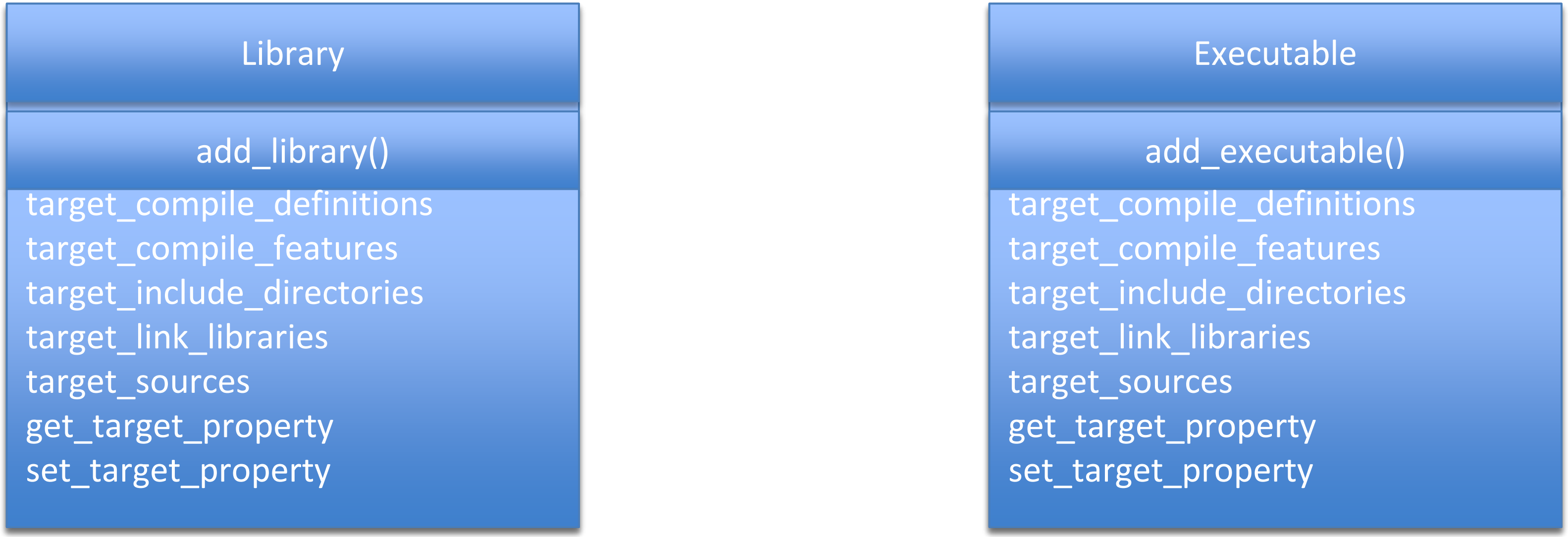
CMakeLists.txt

```
cmake_minimum_required(VERSION 2.8)
project(ITK)
add_subdirectory(Code/Common)
```

Code/Common/CMakeLists.txt

```
add_library(ITKCommon)
target_sources(ITKCommon PRIVATE
itkDataObject.cxx itkDirectory.cxx ...)
if(WIN32)
  target_sources(ITKCommon PRIVATE
itkWin32OutputWindow.cxx)
endif()
```

Targets are Objects



Library

add_library()

target_compile_definitions
target_compile_features
target_include_directories
target_link_libraries
target_sources
get_target_property
set_target_property

Executable

add_executable()

target_compile_definitions
target_compile_features
target_include_directories
target_link_libraries
target_sources
get_target_property
set_target_property

Targets are Objects

- Developer can focus on a single target and not the whole system
  - What include directories will users need?
  - What –D flags will users need?
  - What compile flags will users need?
  - What version of C++ will users need?
  - What flags and options will the users not need?
    - controlled with public and private declarations

“Usage Requirements” aka Modern CMake

Modern style: target-centric

```
target_include_directories(mylib PUBLIC "mydir")
```

mylib and anything that links to gets `-Imydir`

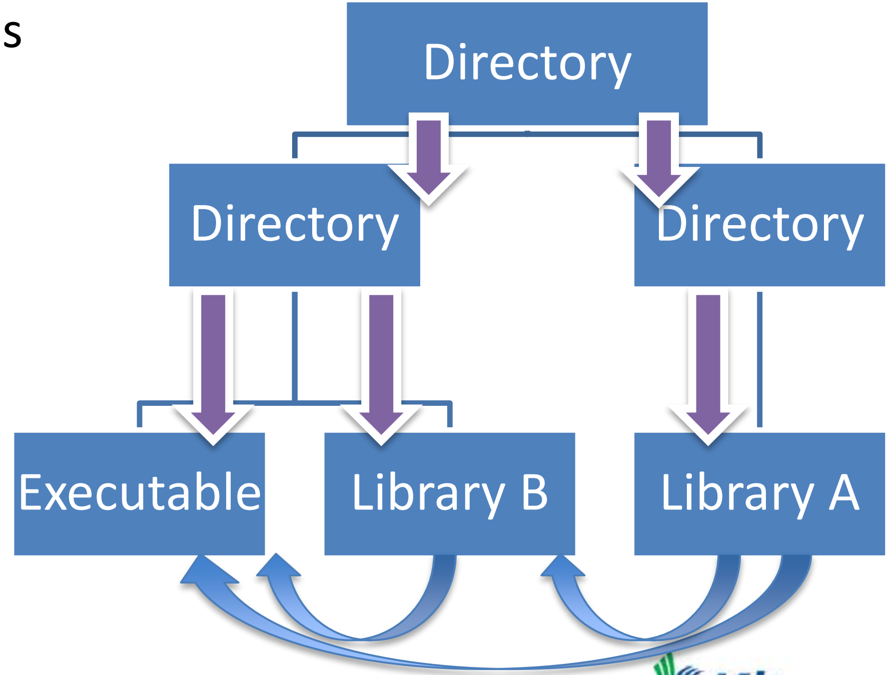
Classic style: directory-centric

```
include_directories("mydir")
```

Targets in this directory and subdirs get `-Imydir`

Before Usage Requirements

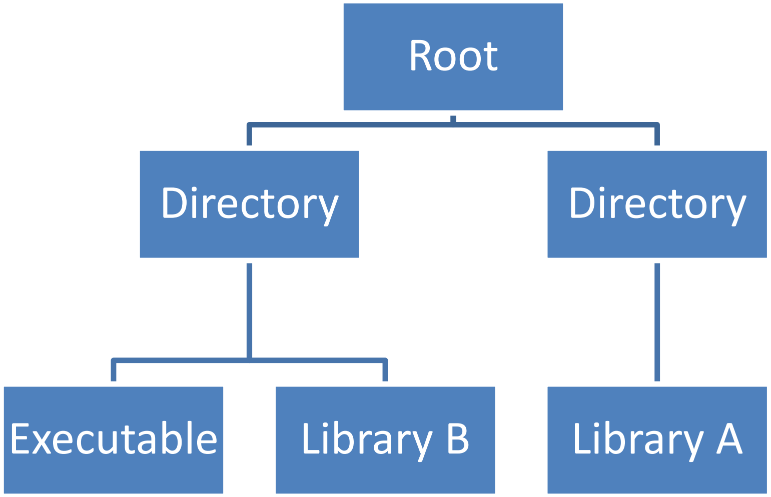
- Before Usage Requirements existed we used directory scoped commands such as:
  - `include_directories`
  - `compile_definitions`
  - `compile_options`
- Consumers have to know:
  - Does the dependency generate build tree files
  - Does the dependency use any new external package

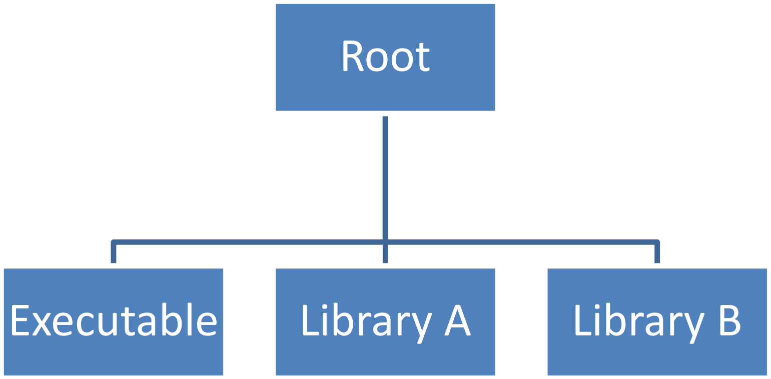


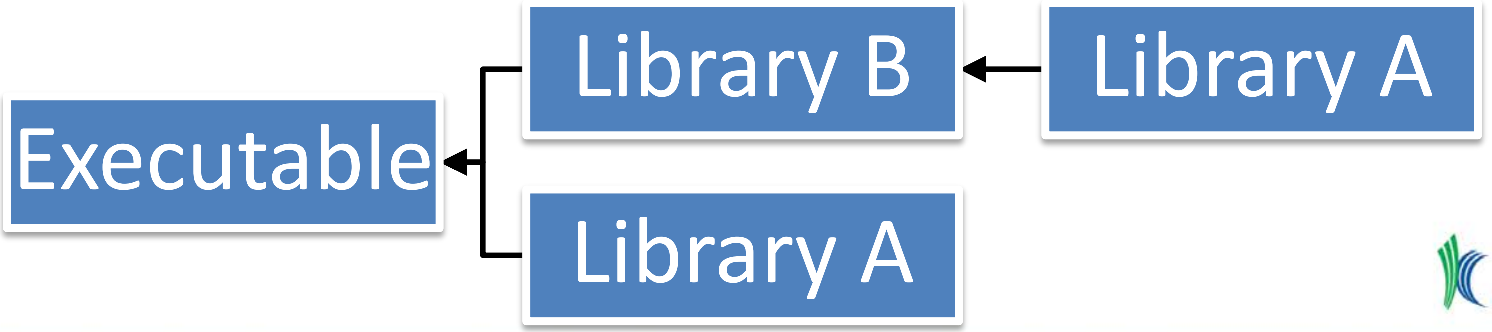
Modern CMake / Usage Requirements

- Modern CMake goal is to have each target fully describe how to properly use it.
- No difference between using internal and external generated targets

Modern CMake layout independent







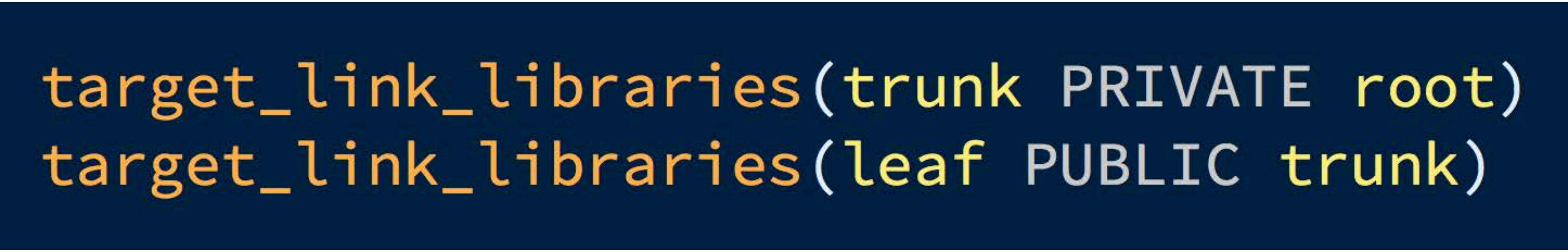
Modern CMake Mostly about not using these commands

- ~~add_compile_options()~~
- ~~add_definitions()~~
- ~~include_directories()~~
- ~~link_directories()~~
- ~~link_libraries()~~

And treating targets like objects

Usage Requirements

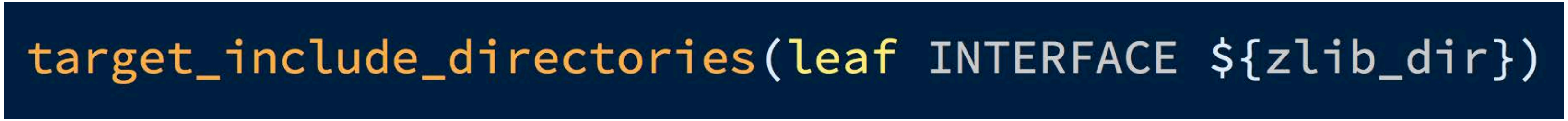
- `target_link_libraries` is the foundation for usage requirements
- This foundation is formed by
  - PUBLIC
  - PRIVATE
  - INTERFACE



```
target_link_libraries(trunk PRIVATE root)
target_link_libraries(leaf PUBLIC trunk)
```

target_include_directories

- Propagates include directories

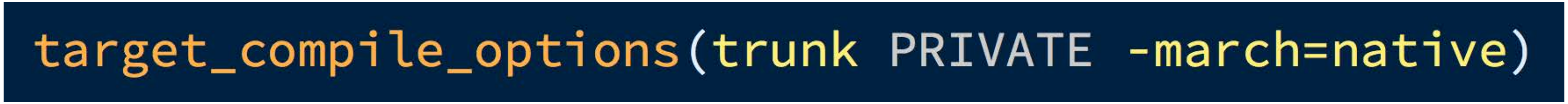


```
target_include_directories(leaf INTERFACE ${zlib_dir})
```

- Anything that links to leaf will automatically have the zlib_dir on the include line

target_compile_options

- Propagates compiler options

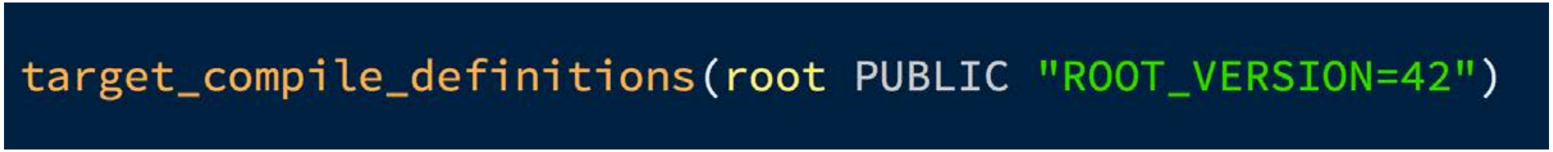


```
target_compile_options(trunk PRIVATE -march=native)
```

- Only trunk will be built optimized for the current hardware. Anything that links to trunk will not get this flag

target_compile_definitions

- Propagates pre-processor definitions

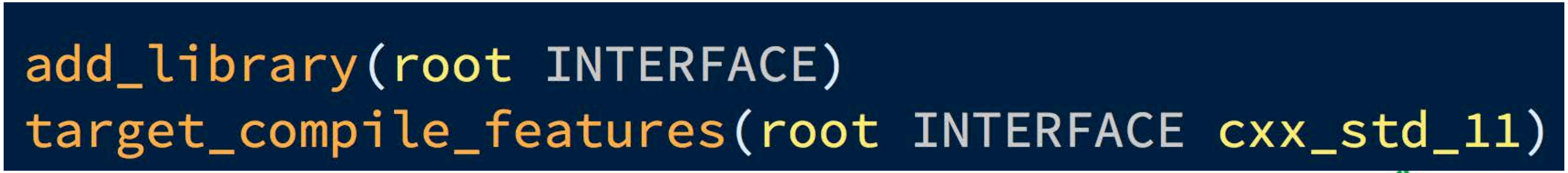


```
target_compile_definitions(root PUBLIC "ROOT_VERSION=42")
```

- Root will have ROOT_VERSION defined and anything that links to it will also

INTERFACE Libraries

- An `INTERFACE` library target does not directly create build output, though it may have properties set on it and it may be installed, exported, and imported.

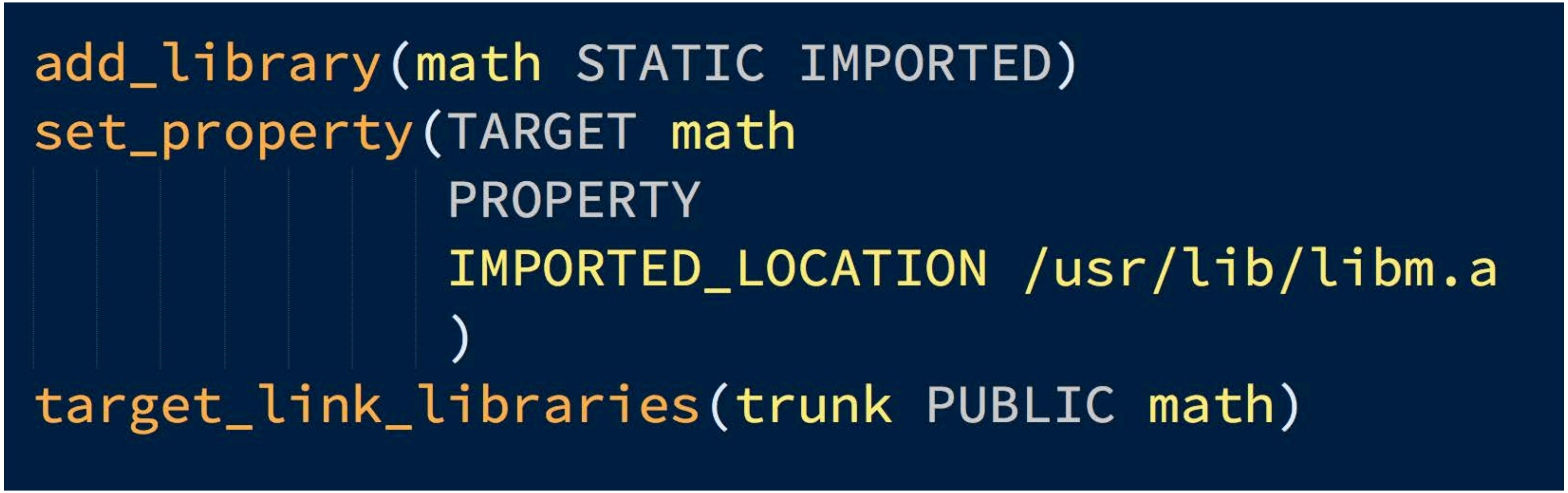


```
add_library(root INTERFACE)
target_compile_features(root INTERFACE cxx_std_11)
```

IMPORTING / EXPORTING

Imported Targets

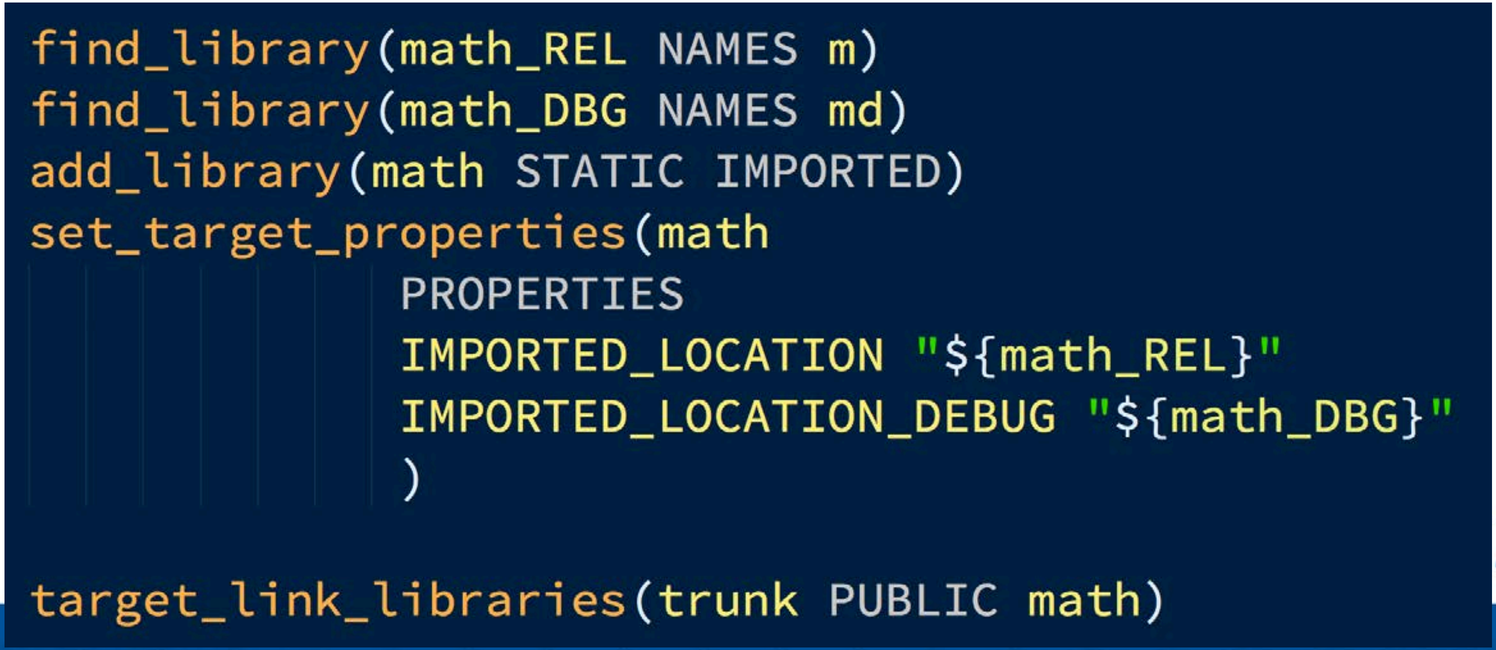
- Logical name for an outside library
- Reference like any other target



```
add_library(math STATIC IMPORTED)
set_property(TARGET math
             PROPERTY
             IMPORTED_LOCATION /usr/lib/libm.a
             )
target_link_libraries(trunk PUBLIC math)
```

Imported Targets

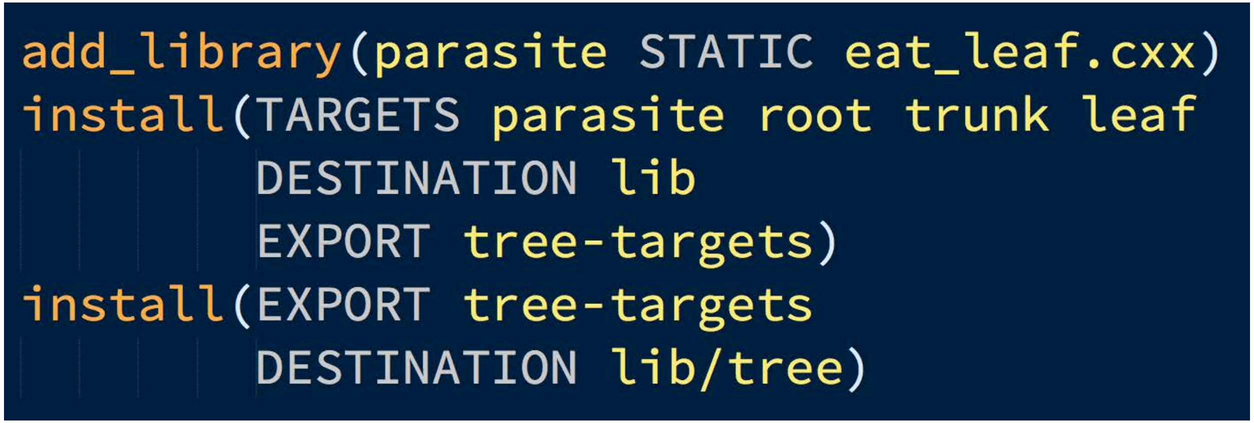
- Per-configuration import rules
- Better than optimized/debug keywords



```cmake
find_library(math_REL NAMES m)
find_library(math_DBG NAMES md)
add_library(math STATIC IMPORTED)
set_target_properties(math
             PROPERTIES
             IMPORTED_LOCATION "${math_REL}"
             IMPORTED_LOCATION_DEBUG "${math_DBG}"
             )

target_link_libraries(trunk PUBLIC math)
```

Exporting Targets

- Install rules can generate imported targets

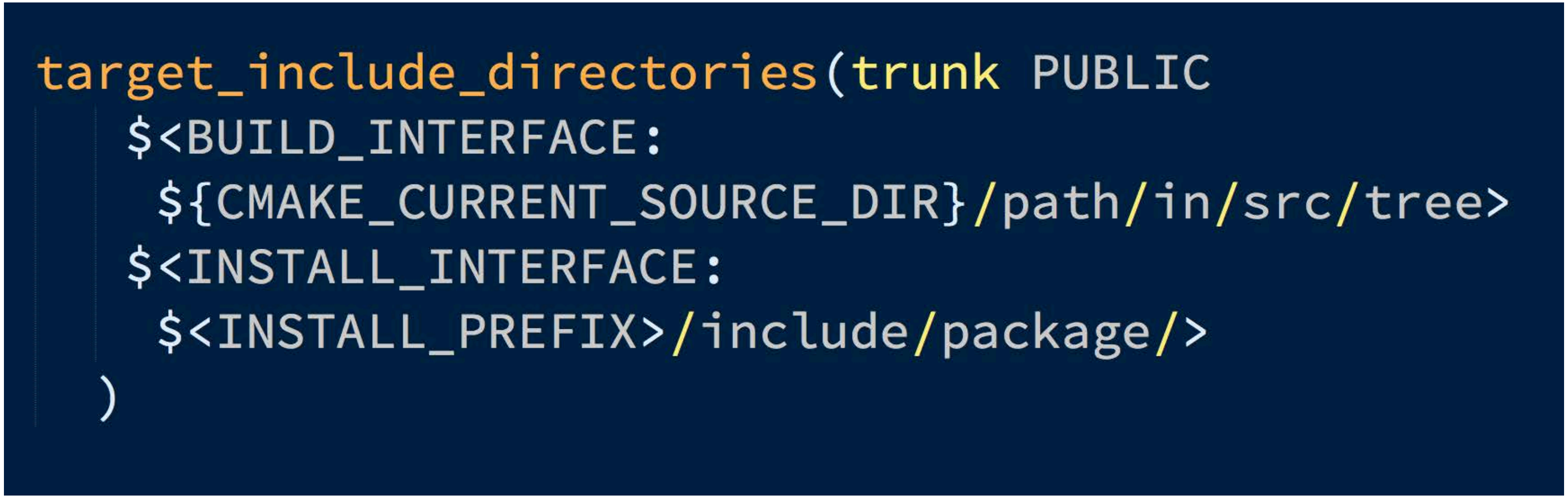


```
add_library(parasite STATIC eat_leaf.cxx)
install(TARGETS parasite root trunk leaf
        DESTINATION lib
        EXPORT tree-targets)
install(EXPORT tree-targets
        DESTINATION lib/tree)
```

- Installs library and target import rules
  - `<prefix>/lib/tree/libparasite.a`
  - `<prefix>/lib/tree/tree-targets.cmake`

Conditional Includes

- Able to specify include directories based on if we are building a library or using the installed version

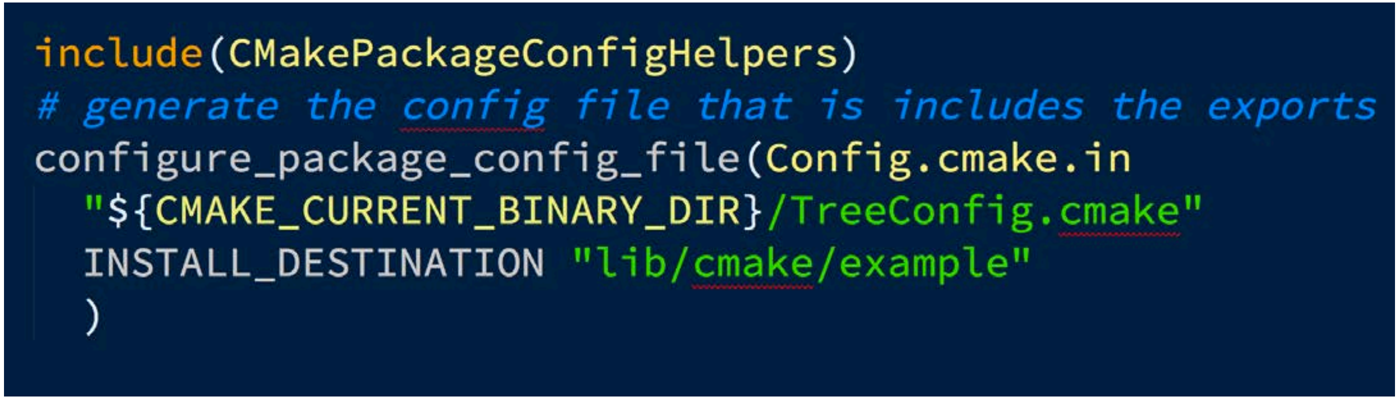


```
target_include_directories(trunk PUBLIC
    $<BUILD_INTERFACE:
     ${CMAKE_CURRENT_SOURCE_DIR}/path/in/src/tree>
    $<INSTALL_INTERFACE:
     $<INSTALL_PREFIX>/include/package/>
  )
```

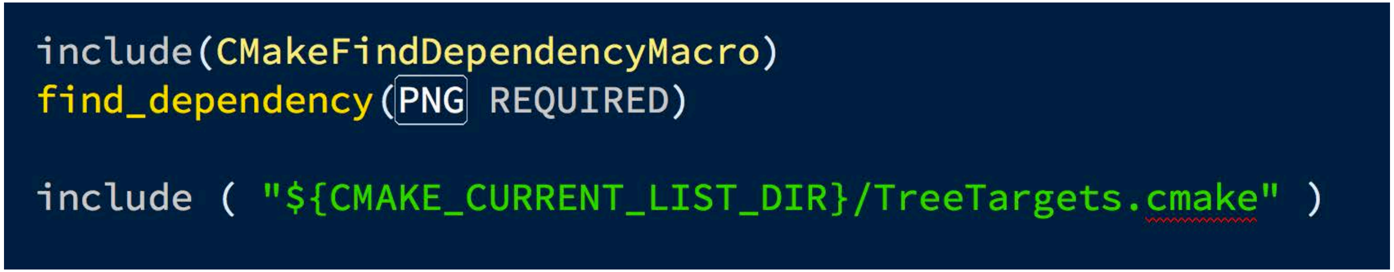
Generating Export Package

- This is constructing components needed for the CMake-aware config package
- CMakePackageConfigHelpers can help with the generation of the <Name>Config.cmake file
- Exporting of find package calls has to replicated inside <Name>Config.cmake, but CMakeFindDependencyMacro helps simplfy this

Generating Export Package

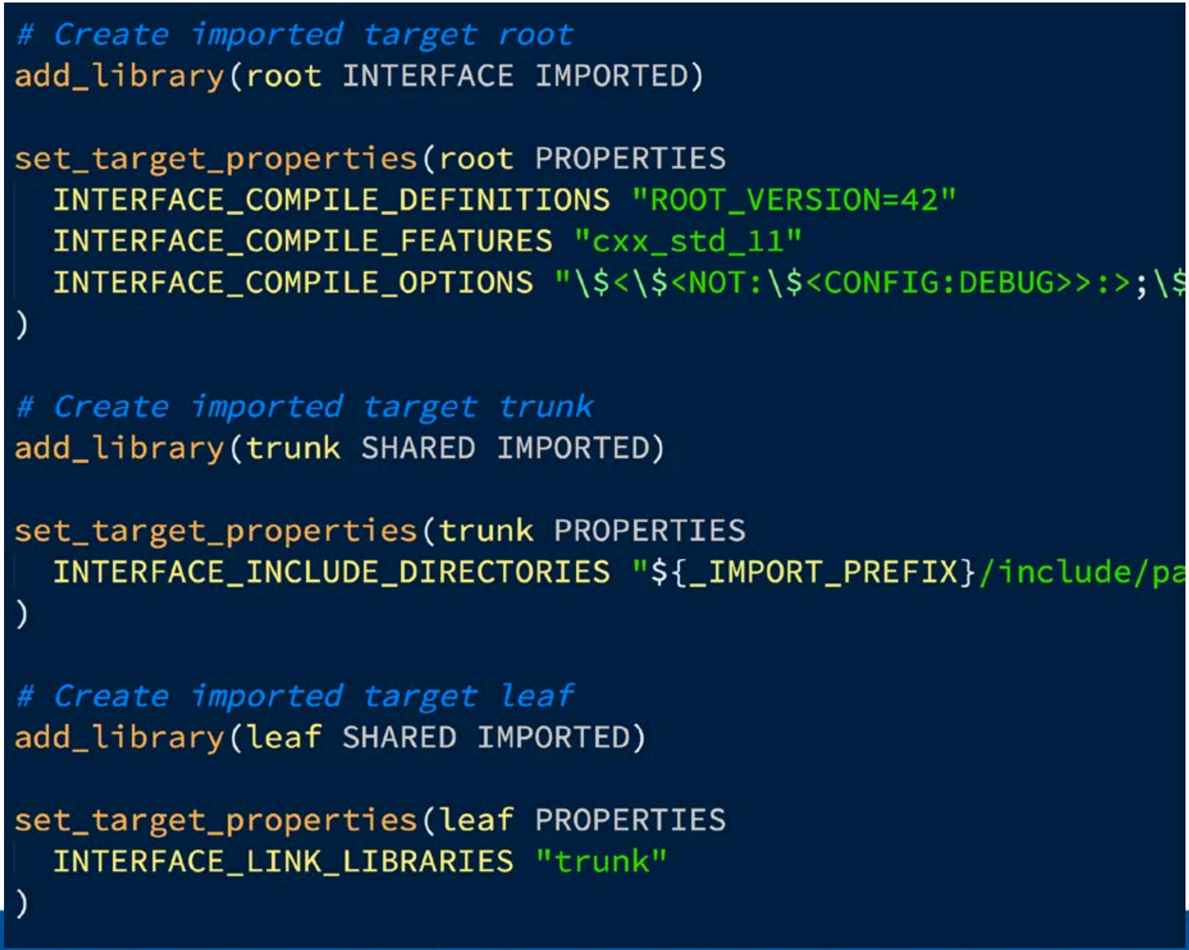


```
include(CMakePackageConfigHelpers)
# generate the config file that is includes the exports
configure_package_config_file(Config.cmake.in
  "${CMAKE_CURRENT_BINARY_DIR}/TreeConfig.cmake"
  INSTALL_DESTINATION "lib/cmake/example"
  )
```



```
include(CMakeFindDependencyMacro)
find_dependency(PNG REQUIRED)

include ( "${CMAKE_CURRENT_LIST_DIR}/TreeTargets.cmake" )
```

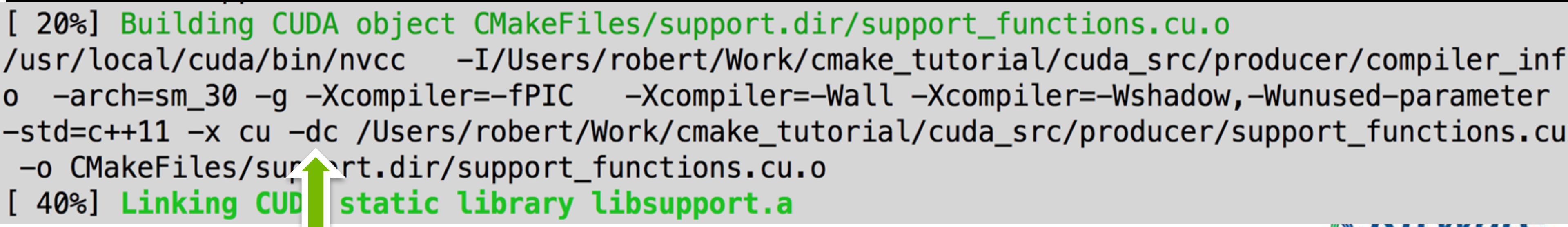
Exporting Targets



```
# Create imported target root
add_library(root INTERFACE IMPORTED)

set_target_properties(root PROPERTIES
  INTERFACE_COMPILE_DEFINITIONS "ROOT_VERSION=42"
  INTERFACE_COMPILE_FEATURES "cxx_std_11"
  INTERFACE_COMPILE_OPTIONS "\$<\$<NOT:\$<CONFIG:DEBUG>>:>;\$
)

# Create imported target trunk
add_library(trunk SHARED IMPORTED)

set_target_properties(trunk PROPERTIES
  INTERFACE_INCLUDE_DIRECTORIES "${_IMPORT_PREFIX}/include/pa
)

# Create imported target leaf
add_library(leaf SHARED IMPORTED)

set_target_properties(leaf PROPERTIES
  INTERFACE_LINK_LIBRARIES "trunk"
)
```

CMake 3.8: CUDA

```
add_library(support STATIC support_functions.cu)
set_target_properties(support PROPERTIES
  CUDA_SEPARABLE_COMPILATION ON
  POSITION_INDEPENDENT_CODE ON)
target_link_libraries(support PRIVATE compiler_info)

add_library(black_scholes
  black_scholes/Serial.cpp
  black_scholes/Parallel.cu
)
target_link_libraries(black_scholes PUBLIC compiler_info support)
```



```
[ 20%] Building CUDA object CMakeFiles/support.dir/support_functions.cu.o
/usr/local/cuda/bin/nvcc   -I/Users/robert/Work/cmake_tutorial/cuda_src/producer/compiler_inf
o  -arch=sm_30 -g -Xcompiler=-fPIC   -Xcompiler=-Wall -Xcompiler=-Wshadow,-Wunused-parameter
-std=c++11 -x cu -dc /Users/robert/Work/cmake_tutorial/cuda_src/producer/support_functions.cu
 -o CMakeFiles/support.dir/support_functions.cu.o
[ 40%] Linking CUDA static library libsupport.a
```

INSTALL RULES

Install Rules

- Specify rules to run at install time
- Can install targets, files, or directories

```
add_library(leaf SHARED leaf.cxx)
install(TARGETS root trunk leaf parasite
  RUNTIME DESTINATION bin
  LIBRARY DESTINATION lib
  ARCHIVE DESTINATION lib
)
```

Install Rules

- To install files:

```cmake
install(FILES
  trunk.h
  leaf.h
  DESTINATION include
)
```

Using Config Modules

- `find_package` also supports config modules
- Config modules are generated by CMake export command
- Automatically generate import targets with all information, removing the need for consuming projects to write a find module

CMake Scripts

- cmake –E command
  - Cross platform command line utility for:
  - Copy file, Remove file, Compare and conditionally copy, time, others

- cmake –P script.cmake
  - Cross platform scripting utility
  - Does not generate CMakeCache.txt
  - Ignores commands specific to generating build environment

OBJECT Libraries

```
add_library(root  OBJECT root.cxx)
add_library(trunk OBJECT trunk.cxx)
add_library(leaf  SHARED leaf.cxx)
target_link_libraries(leaf root trunk)
```

```
[100%] Linking CXX shared library libleaf.so
/usr/bin/c++ -fPIC   -shared -Wl,-soname,libleaf.so
             -o libleaf.so leaf.cxx.o root.cxx.o trunk.cxx.o
```

CTEST

Automatic Testing Benefits

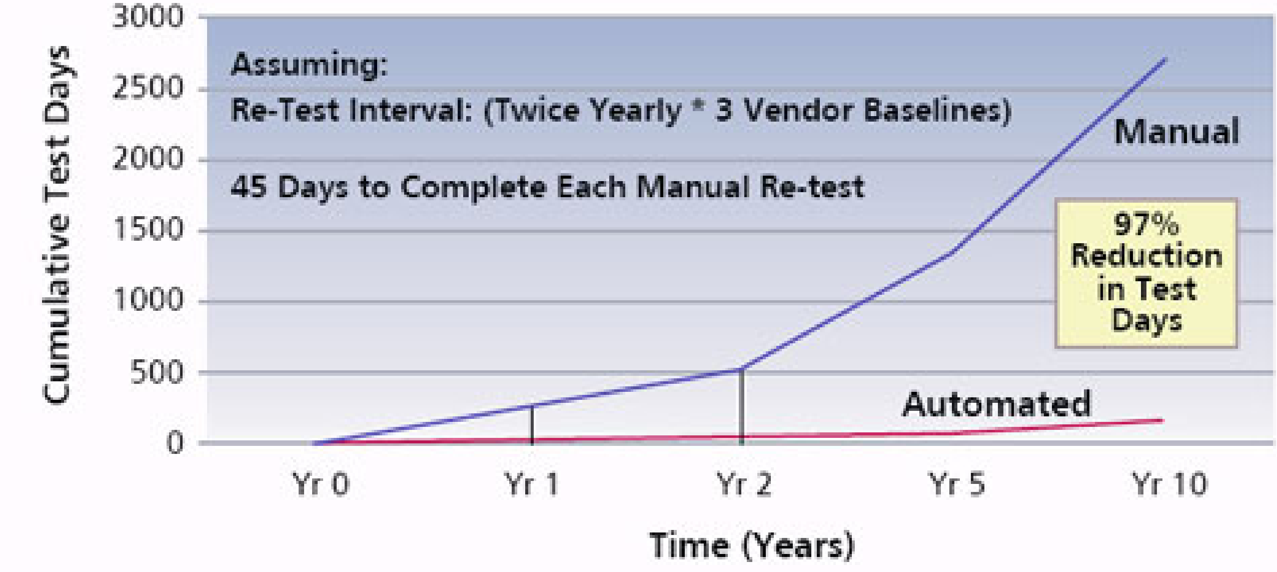
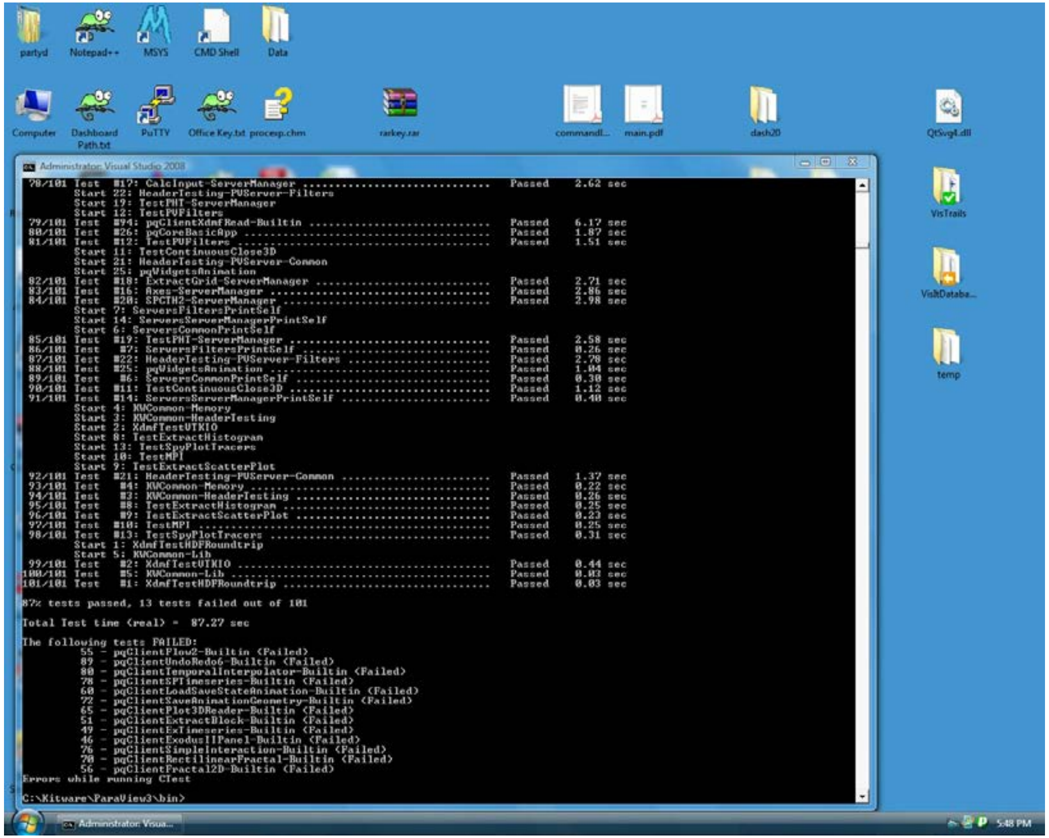


Figure 2. "Example Automated Software Testing Savings over Time"

"Automated Software Testing,"
1999, Dustin, et al, Addison Wesley

Kitware

Video of ParaView Nightly Testing



```
 78/101 Test  #17: CalcInput-ServerManager ......................................   Passed    2.62 sec
        Start 22: HeaderTesting-PVServer-Filters
        Start 19: TestPHT-ServerManager
        Start 12: TestPVFilters
 79/101 Test  #94: pqClientXdmfRead-Builtin .....................................   Passed    6.17 sec
 80/101 Test  #26: pqCoreBasicApp ...............................................   Passed    1.87 sec
 81/101 Test  #12: TestPVFilters ................................................   Passed    1.51 sec
        Start 11: TestContinuousClose3D
        Start 21: HeaderTesting-PVServer-Common
        Start 25: pqWidgetsAnimation
 82/101 Test  #18: ExtractGrid-ServerManager ....................................   Passed    2.71 sec
 83/101 Test  #16: Axes-ServerManager ...........................................   Passed    2.86 sec
 84/101 Test  #20: SPCTH2-ServerManager .........................................   Passed    2.98 sec
        Start 7: ServersFiltersPrintSelf
        Start 14: ServersServerManagerPrintSelf
        Start 6: ServersCommonPrintSelf
 85/101 Test  #19: TestPHT-ServerManager ........................................   Passed    2.58 sec
 86/101 Test   #7: ServersFiltersPrintSelf ......................................   Passed    0.26 sec
 87/101 Test  #22: HeaderTesting-PVServer-Filters ...............................   Passed    2.70 sec
 88/101 Test  #25: pqWidgetsAnimation ...........................................   Passed    1.04 sec
 89/101 Test   #6: ServersCommonPrintSelf .......................................   Passed    0.30 sec
 90/101 Test  #11: TestContinuousClose3D ........................................   Passed    1.12 sec
 91/101 Test  #14: ServersServerManagerPrintSelf ................................   Passed    0.40 sec
        Start 4: KWCommon-Memory
        Start 3: KWCommon-HeaderTesting
        Start 2: XdmfTestVTKIO
        Start 8: TestExtractHistogram
        Start 13: TestSpyPlotTracers
        Start 10: TestMPI
        Start 9: TestExtractScatterPlot
 92/101 Test  #21: HeaderTesting-PVServer-Common ................................   Passed    1.37 sec
 93/101 Test   #4: KWCommon-Memory ..............................................   Passed    0.22 sec
 94/101 Test   #3: KWCommon-HeaderTesting .......................................   Passed    0.26 sec
 95/101 Test   #8: TestExtractHistogram .........................................   Passed    0.25 sec
 96/101 Test   #9: TestExtractScatterPlot .......................................   Passed    0.23 sec
 97/101 Test  #10: TestMPI ......................................................   Passed    0.25 sec
 98/101 Test  #13: TestSpyPlotTracers ...........................................   Passed    0.31 sec
        Start 1: XdmfTestHDFRoundtrip
        Start 5: KWCommon-Lib
 99/101 Test   #2: XdmfTestVTKIO ................................................   Passed    0.44 sec
100/101 Test   #5: KWCommon-Lib .................................................   Passed    0.03 sec
101/101 Test   #1: XdmfTestHDFRoundtrip .........................................   Passed    0.03 sec

87% tests passed, 13 tests failed out of 101

Total Test time (real) =  87.27 sec

The following tests FAILED:
         55 - pqClientFlow2-Builtin (Failed)
         89 - pqClientUndoRedo6-Builtin (Failed)
         80 - pqClientTemporalInterpolator-Builtin (Failed)
         78 - pqClientSPTimeseries-Builtin (Failed)
         60 - pqClientLoadSaveStateAnimation-Builtin (Failed)
         72 - pqClientSaveAnimationGeometry-Builtin (Failed)
         65 - pqClientPlot3DReader-Builtin (Failed)
         51 - pqClientExtractBlock-Builtin (Failed)
         49 - pqClientExTimeseries-Builtin (Failed)
         46 - pqClientExodusIIPanel-Builtin (Failed)
         76 - pqClientSimpleInteraction-Builtin (Failed)
         70 - pqClientRectilinearFractal-Builtin (Failed)
         56 - pqClientFractal2D-Builtin (Failed)
Errors while running CTest

C:\Kitware\ParaView3\bin>
```

Testing with CMake

- Testing needs to be enabled by calling `include(CTest)` or `enable_testing()`

```
add_test(NAME testname
         COMMAND exename arg1 arg2 ...)
```

  - Executable should return 0 for a test that passes
- ctest – an executable that is distributed with cmake that can run tests in a project.
- CDash – Web based dashboard to show testing results.

CTest

- Run ctest at the top of a binary directory to run all tests

```
$ ctest
Test project /tmp/example/bin
    Start 1: case1
1/1 Test #1: case1 .............................   Passed    0.00 sec
    Start 2: case2
2/2 Test #2: case2 .............................   Passed    0.00 sec

100% tests passed, 0 tests failed out of 2

Total Test time (real) =   0.01 sec
```

CTest

- -j option allows you to run tests in parallel
- -R option allows you to choose a test
- Running tests from Makefiles or projects
  - make test
  - Build RUN_TESTS project
- ctest --help for more information

GoogleTest integration

```
include(GoogleTest)
add_executable(tests tests.cpp)
target_link_libraries(tests GTest::GTest)
```

- gtest_discover_tests: new in CMake 3.10.
  - CMake asks the test executable to list its tests. Finds new tests without rerunning CMake.

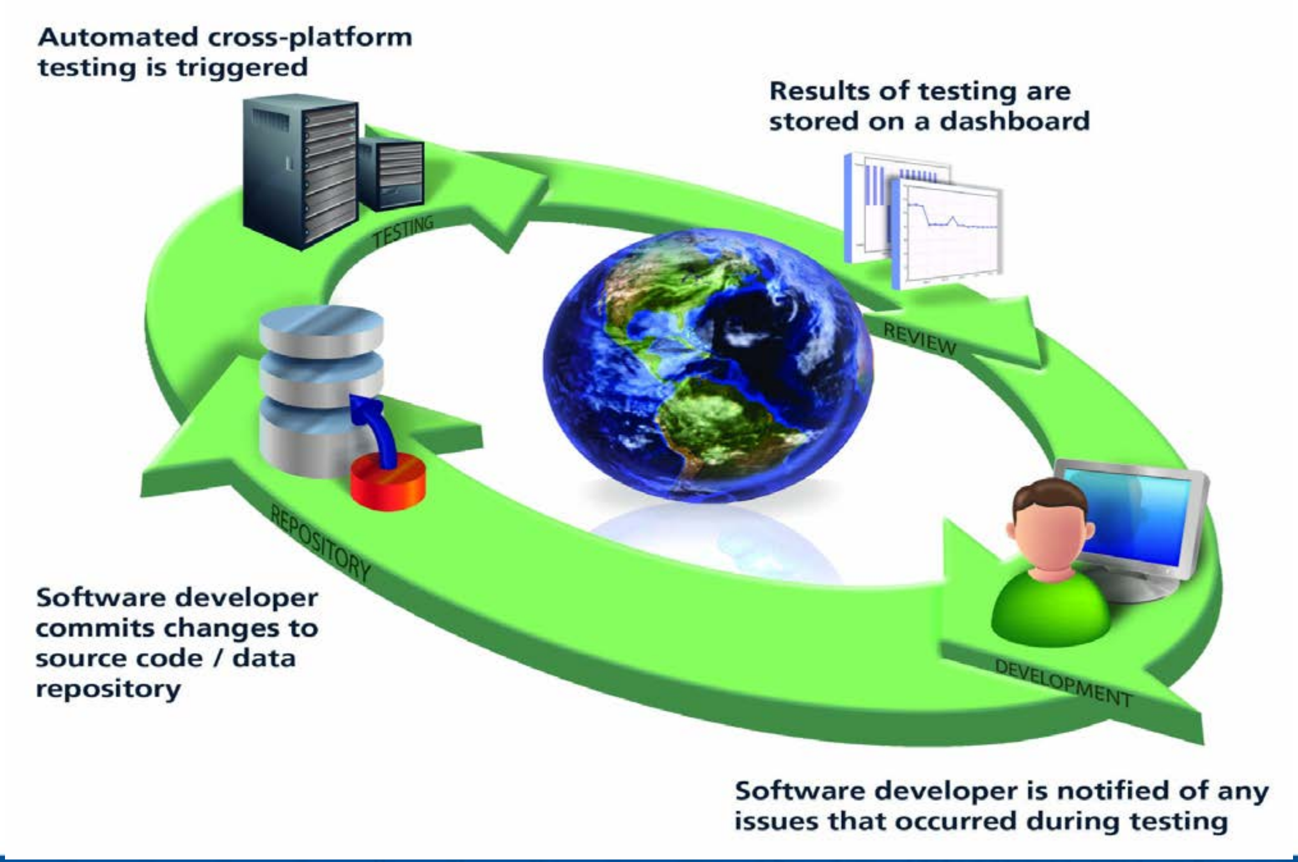
```
gtest_discover_tests(tests TEST_PREFIX new:)
```

Static Analysis

- Supported tools include:
  - include-what-you-use
  - link-what-you-use
  - clang-tidy
  - cpplint
  - cppcheck
- Setup instructions available here:
  - https://blog.kitware.com/static-checks-with-cmake-cdash-iwyu-clang-tidy-lwyu-cpplint-and-cppcheck/

CDash

Software Process Dashboards



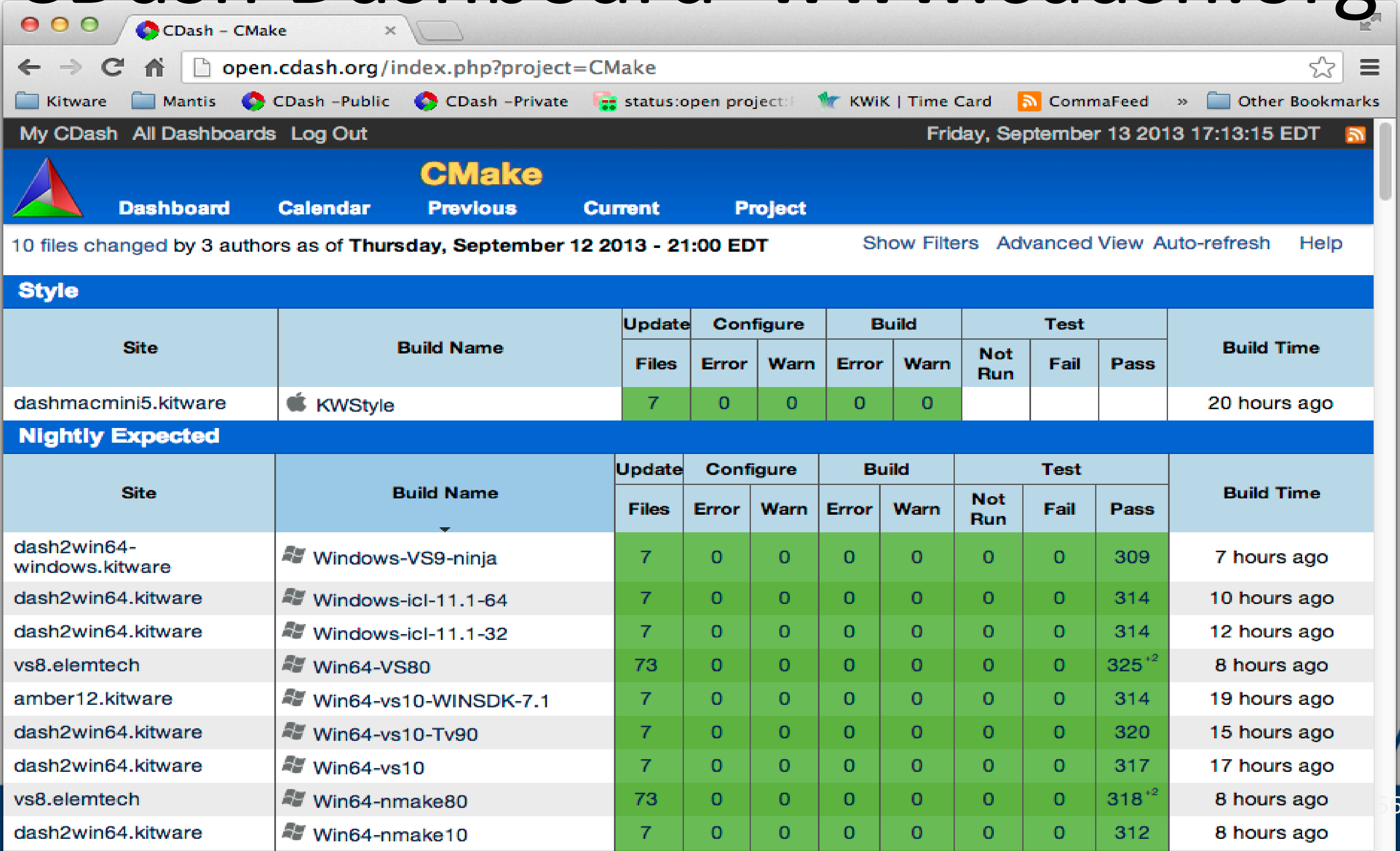
Automated cross-platform testing is triggered

Results of testing are stored on a dashboard

Software developer commits changes to source code / data repository

Software developer is notified of any issues that occurred during testing

CDash Dashboard www.cdash.org



Friday, September 13 2013 17:13:15 EDT

10 files changed by 3 authors as of **Thursday, September 12 2013 - 21:00 EDT**

Style

Site	Build Name	Update	Configure		Build		Test			Build Time
		Files	Error	Warn	Error	Warn	Not Run	Fail	Pass	
dashmacmini5.kitware	KWStyle	7	0	0	0	0				20 hours ago

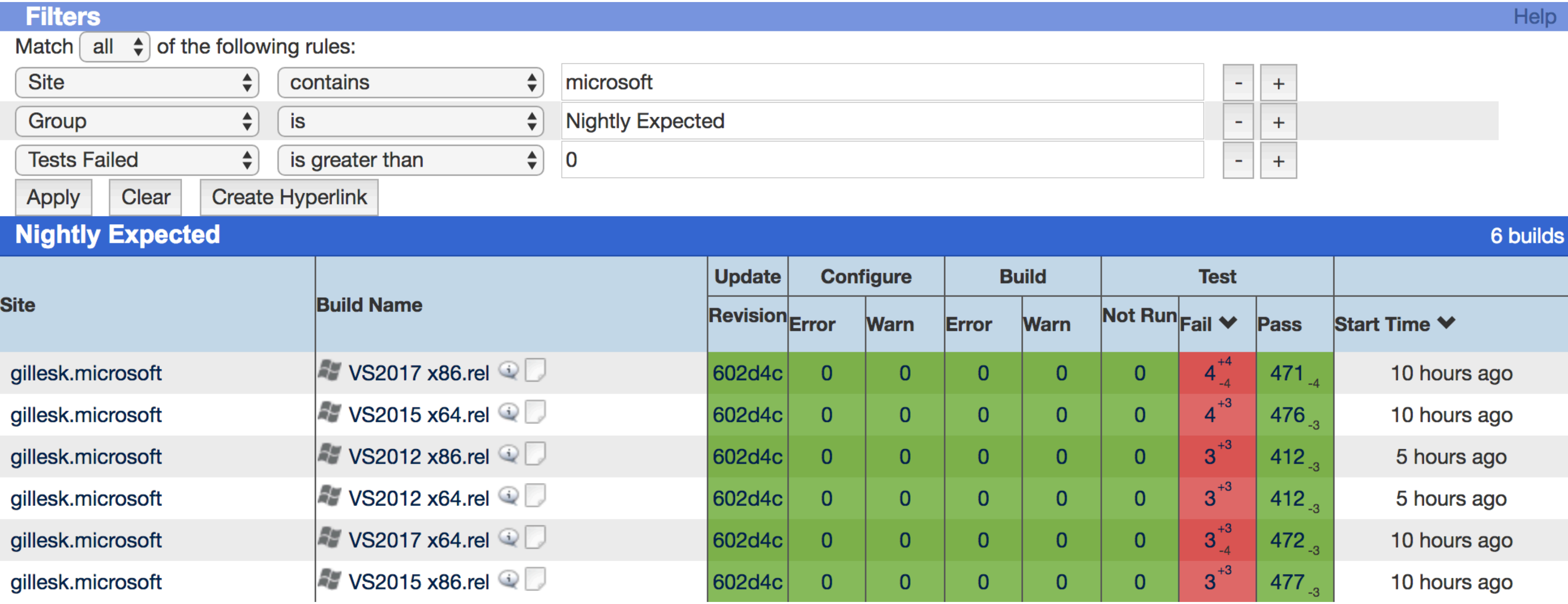
Nightly Expected

Site	Build Name	Update	Configure		Build		Test			Build Time
		Files	Error	Warn	Error	Warn	Not Run	Fail	Pass	
dash2win64-windows.kitware	Windows-VS9-ninja	7	0	0	0	0	0	0	309	7 hours ago
dash2win64.kitware	Windows-icl-11.1-64	7	0	0	0	0	0	0	314	10 hours ago
dash2win64.kitware	Windows-icl-11.1-32	7	0	0	0	0	0	0	314	12 hours ago
vs8.elemtech	Win64-VS80	73	0	0	0	0	0	0	325^{+2}	8 hours ago
amber12.kitware	Win64-vs10-WINSDK-7.1	7	0	0	0	0	0	0	314	19 hours ago
dash2win64.kitware	Win64-vs10-Tv90	7	0	0	0	0	0	0	320	15 hours ago
dash2win64.kitware	Win64-vs10	7	0	0	0	0	0	0	317	17 hours ago
vs8.elemtech	Win64-nmake80	73	0	0	0	0	0	0	318^{+2}	8 hours ago
dash2win64.kitware	Win64-nmake10	7	0	0	0	0	0	0	312	8 hours ago

CDash works with other CI tools

- Jenkins
- Buildbot
- Gitlab/CI
- ctest scripts and cronjobs
- CircleCI
- Travis

Search for relevant results



Filters Help

Match all of the following rules:

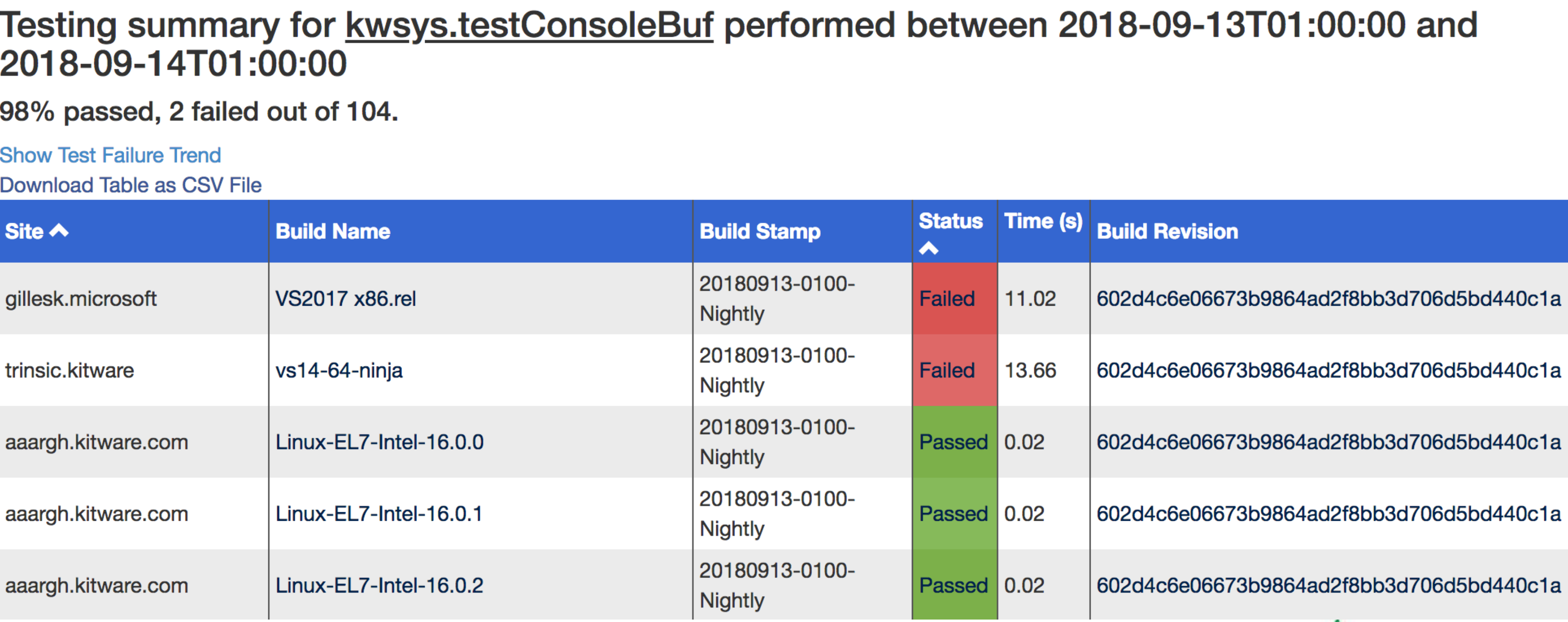
Site	contains	microsoft
Group	is	Nightly Expected
Tests Failed	is greater than	0

Nightly Expected 6 builds

Site	Build Name	Update	Configure		Build		Test			
		Revision	Error	Warn	Error	Warn	Not Run	Fail ⌄	Pass	Start Time ⌄
gillesk.microsoft	VS2017 x86.rel	602d4c	0	0	0	0	0	4^{+4}_{-4}	471_{-4}	10 hours ago
gillesk.microsoft	VS2015 x64.rel	602d4c	0	0	0	0	0	4^{+3}	476_{-3}	10 hours ago
gillesk.microsoft	VS2012 x86.rel	602d4c	0	0	0	0	0	3^{+3}	412_{-3}	5 hours ago
gillesk.microsoft	VS2012 x64.rel	602d4c	0	0	0	0	0	3^{+3}	412_{-3}	5 hours ago
gillesk.microsoft	VS2017 x64.rel	602d4c	0	0	0	0	0	3^{+3}_{-4}	472_{-3}	10 hours ago
gillesk.microsoft	VS2015 x86.rel	602d4c	0	0	0	0	0	3^{+3}	477_{-3}	10 hours ago

Kitware

Compare results across systems



Testing summary for kwsys.testConsoleBuf performed between 2018-09-13T01:00:00 and 2018-09-14T01:00:00

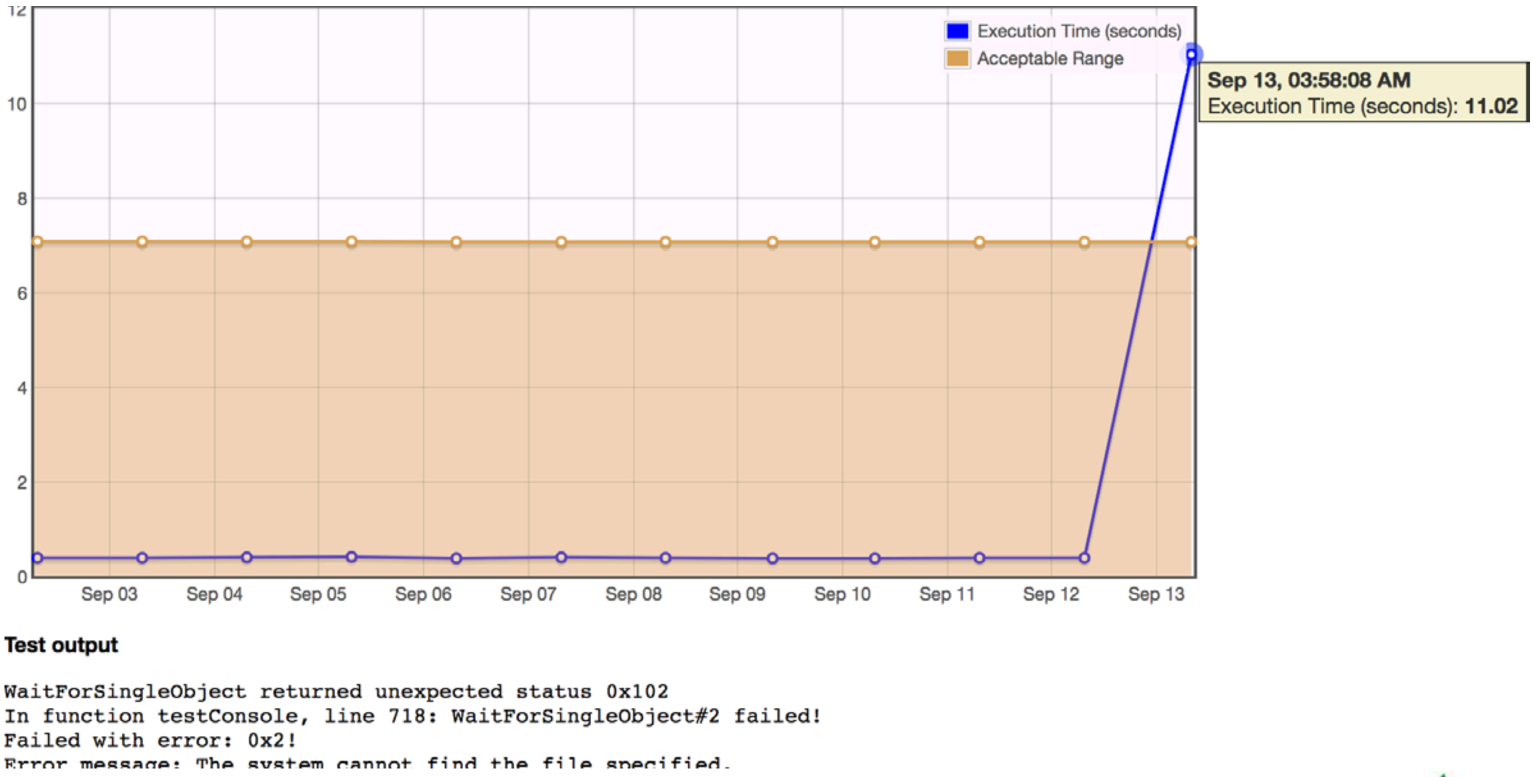
98% passed, 2 failed out of 104.

Show Test Failure Trend

Download Table as CSV File

Site	Build Name	Build Stamp	Status	Time (s)	Build Revision
gillesk.microsoft	VS2017 x86.rel	20180913-0100-Nightly	Failed	11.02	602d4c6e06673b9864ad2f8bb3d706d5bd440c1a
trinsic.kitware	vs14-64-ninja	20180913-0100-Nightly	Failed	13.66	602d4c6e06673b9864ad2f8bb3d706d5bd440c1a
aaargh.kitware.com	Linux-EL7-Intel-16.0.0	20180913-0100-Nightly	Passed	0.02	602d4c6e06673b9864ad2f8bb3d706d5bd440c1a
aaargh.kitware.com	Linux-EL7-Intel-16.0.1	20180913-0100-Nightly	Passed	0.02	602d4c6e06673b9864ad2f8bb3d706d5bd440c1a
aaargh.kitware.com	Linux-EL7-Intel-16.0.2	20180913-0100-Nightly	Passed	0.02	602d4c6e06673b9864ad2f8bb3d706d5bd440c1a

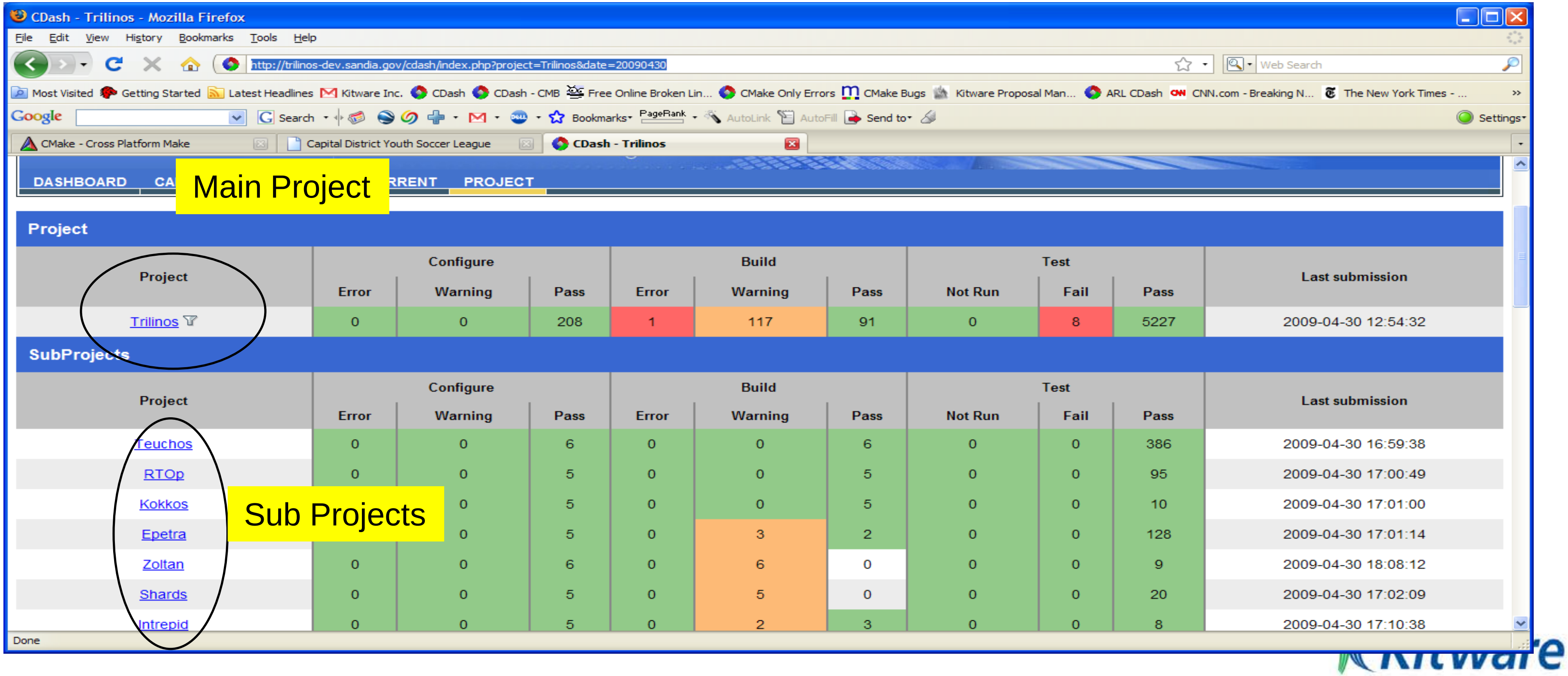
Track test timing



Test output

```
WaitForSingleObject returned unexpected status 0x102
In function testConsole, line 718: WaitForSingleObject#2 failed!
Failed with error: 0x2!
Error message: The system cannot find the file specified.
```

CDash Subproject Support


CDash - Trilinos - Mozilla Firefox
File Edit View History Bookmarks Tools Help
http://trilinos-dev.sandia.gov/cdash/index.php?project=Trilinos&date=20090430
Most Visited Getting Started Latest Headlines Kitware Inc. CDash CDash - CMB Free Online Broken Lin... CMake Only Errors CMake Bugs Kitware Proposal Man... ARL CDash CNN.com - Breaking N... The New York Times - ...
Google Search Bookmarks PageRank AutoLink AutoFill Send to Settings
CMake - Cross Platform Make
Capital District Youth Soccer League
CDash - Trilinos
DASHBOARD
CA
RRENT
PROJECT
Done

Main Project

Project

Project	Configure			Build			Test			Last submission
	Error	Warning	Pass	Error	Warning	Pass	Not Run	Fail	Pass	
Trilinos	0	0	208	1	117	91	0	8	5227	2009-04-30 12:54:32

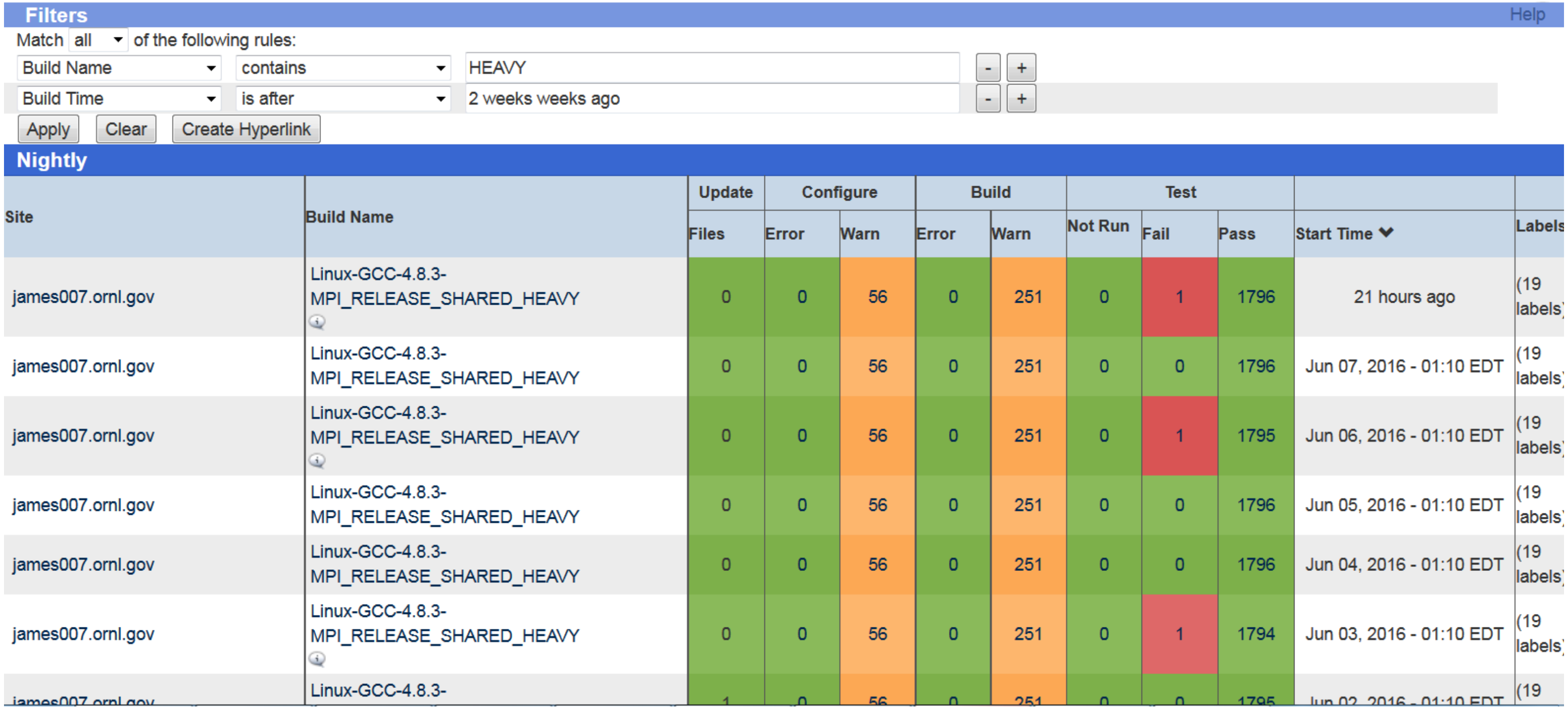
SubProjects

Project	Configure			Build			Test			Last submission
	Error	Warning	Pass	Error	Warning	Pass	Not Run	Fail	Pass	
Teuchos	0	0	6	0	0	6	0	0	386	2009-04-30 16:59:38
RTOp	0	0	5	0	0	5	0	0	95	2009-04-30 17:00:49
Kokkos		0	5	0	0	5	0	0	10	2009-04-30 17:01:00
Epetra		0	5	0	3	2	0	0	128	2009-04-30 17:01:14
Zoltan	0	0	6	0	6	0	0	0	9	2009-04-30 18:08:12
Shards	0	0	5	0	5	0	0	0	20	2009-04-30 17:02:09
Intrepid	0	0	5	0	2	3	0	0	8	2009-04-30 17:10:38

Sub Projects

CDash Queries

Show the HEAVY builds for the last two weeks:



Match all of the following rules:

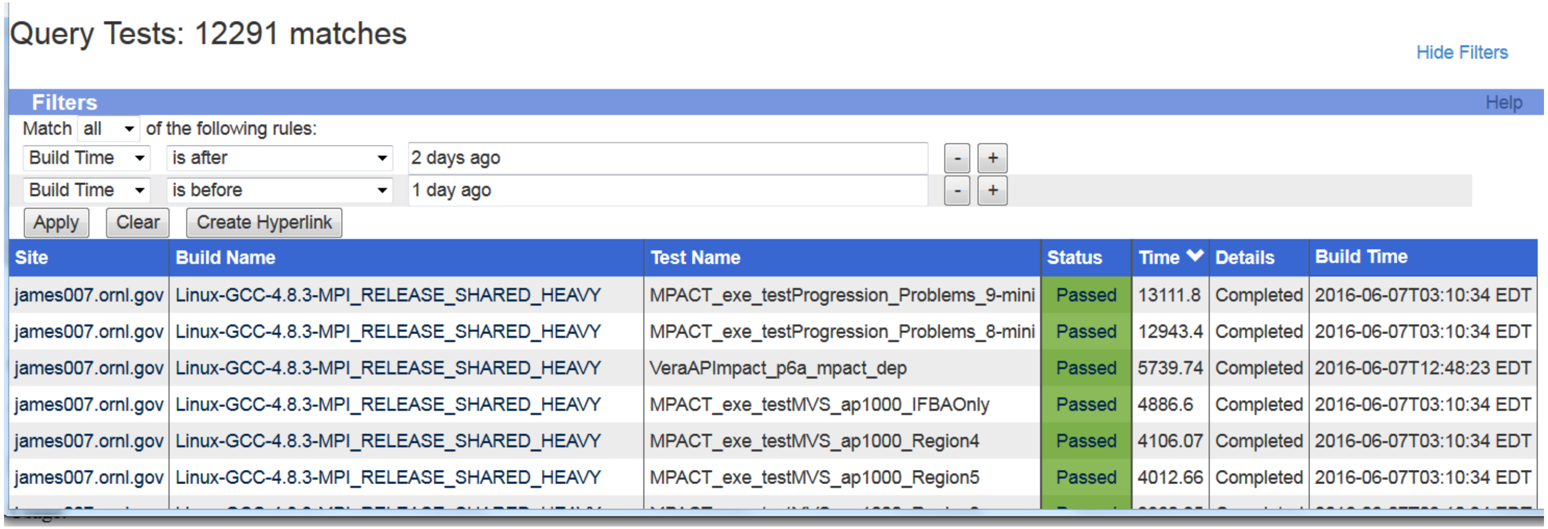
Build Name contains HEAVY

Build Time is after 2 weeks weeks ago

Site	Build Name	Update	Configure		Build		Test				Labels
		Files	Error	Warn	Error	Warn	Not Run	Fail	Pass	Start Time	
james007.ornl.gov	Linux-GCC-4.8.3-MPI_RELEASE_SHARED_HEAVY	0	0	56	0	251	0	1	1796	21 hours ago	(19 labels)
james007.ornl.gov	Linux-GCC-4.8.3-MPI_RELEASE_SHARED_HEAVY	0	0	56	0	251	0	0	1796	Jun 07, 2016 - 01:10 EDT	(19 labels)
james007.ornl.gov	Linux-GCC-4.8.3-MPI_RELEASE_SHARED_HEAVY	0	0	56	0	251	0	1	1795	Jun 06, 2016 - 01:10 EDT	(19 labels)
james007.ornl.gov	Linux-GCC-4.8.3-MPI_RELEASE_SHARED_HEAVY	0	0	56	0	251	0	0	1796	Jun 05, 2016 - 01:10 EDT	(19 labels)
james007.ornl.gov	Linux-GCC-4.8.3-MPI_RELEASE_SHARED_HEAVY	0	0	56	0	251	0	0	1796	Jun 04, 2016 - 01:10 EDT	(19 labels)
james007.ornl.gov	Linux-GCC-4.8.3-MPI_RELEASE_SHARED_HEAVY	0	0	56	0	251	0	1	1794	Jun 03, 2016 - 01:10 EDT	(19 labels)
james007.ornl.gov	Linux-GCC-4.8.3-	1	0	56	0	251	0	0	1795	Jun 02, 2016 - 01:10 EDT	(19

CDash Queries

Show most expensive tests yesterday:



Query Tests: 12291 matches

Filters

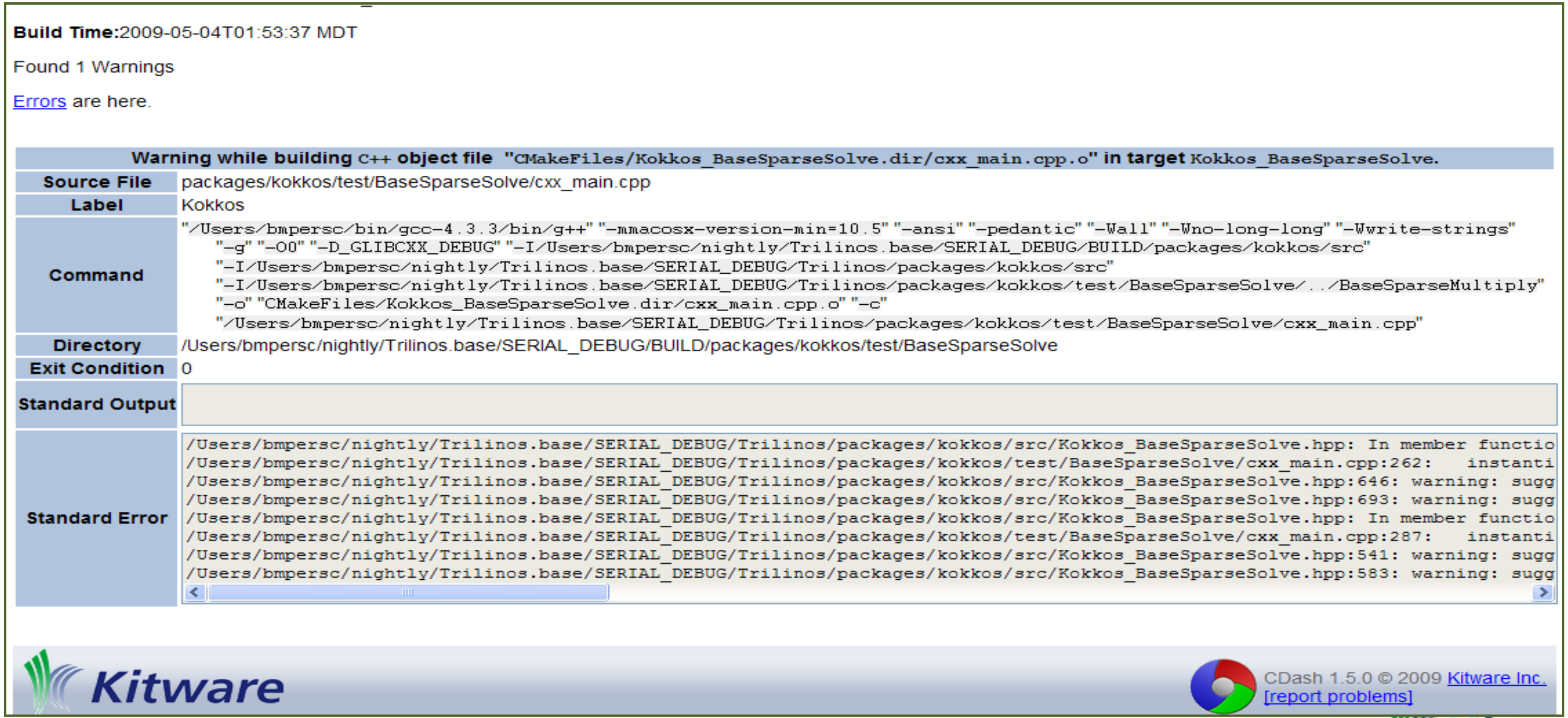
Match all of the following rules:

Build Time is after 2 days ago

Build Time is before 1 day ago

Site	Build Name	Test Name	Status	Time	Details	Build Time
james007.ornl.gov	Linux-GCC-4.8.3-MPI_RELEASE_SHARED_HEAVY	MPACT_exe_testProgression_Problems_9-mini	Passed	13111.8	Completed	2016-06-07T03:10:34 EDT
james007.ornl.gov	Linux-GCC-4.8.3-MPI_RELEASE_SHARED_HEAVY	MPACT_exe_testProgression_Problems_8-mini	Passed	12943.4	Completed	2016-06-07T03:10:34 EDT
james007.ornl.gov	Linux-GCC-4.8.3-MPI_RELEASE_SHARED_HEAVY	VeraAPImpact_p6a_mpact_dep	Passed	5739.74	Completed	2016-06-07T12:48:23 EDT
james007.ornl.gov	Linux-GCC-4.8.3-MPI_RELEASE_SHARED_HEAVY	MPACT_exe_testMVS_ap1000_IFBAOnly	Passed	4886.6	Completed	2016-06-07T03:10:34 EDT
james007.ornl.gov	Linux-GCC-4.8.3-MPI_RELEASE_SHARED_HEAVY	MPACT_exe_testMVS_ap1000_Region4	Passed	4106.07	Completed	2016-06-07T03:10:34 EDT
james007.ornl.gov	Linux-GCC-4.8.3-MPI_RELEASE_SHARED_HEAVY	MPACT_exe_testMVS_ap1000_Region5	Passed	4012.66	Completed	2016-06-07T03:10:34 EDT

CTest Command Wrappers Output



Build Time:2009-05-04T01:53:37 MDT

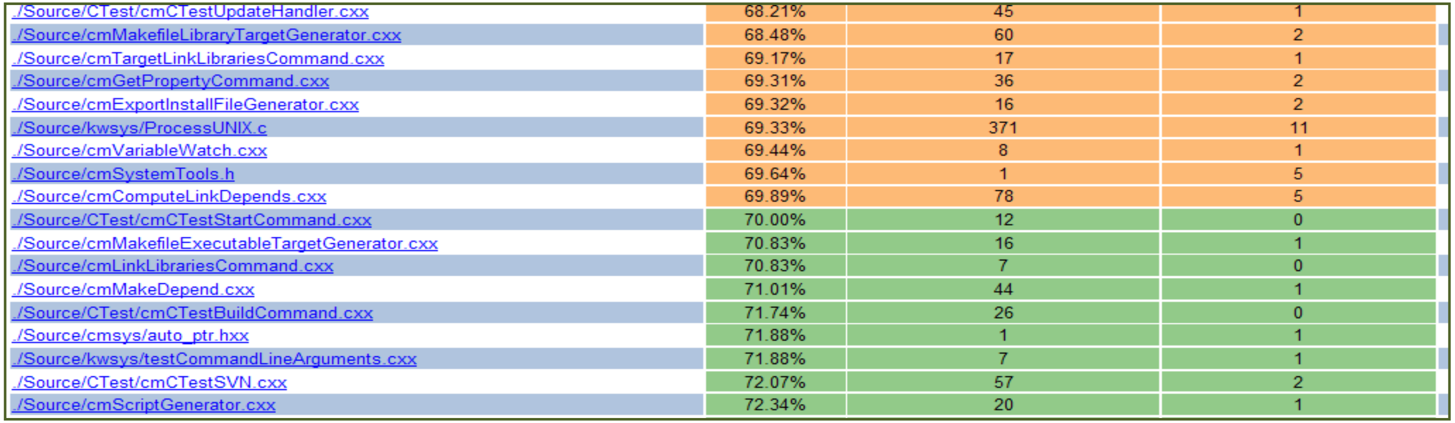
Found 1 Warnings

Errors are here.

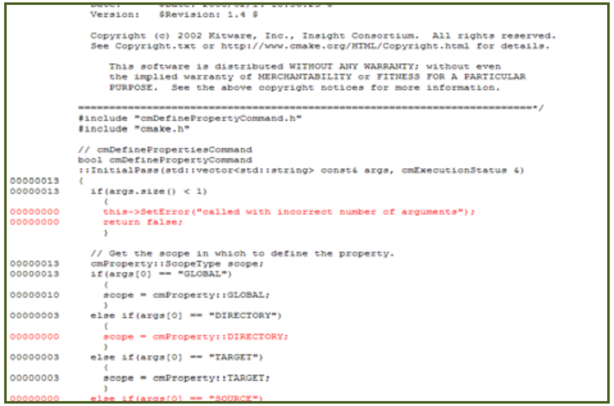
Warning while building C++ **object file** "CMakeFiles/Kokkos_BaseSparseSolve.dir/cxx_main.cpp.o" **in target** Kokkos_BaseSparseSolve.	
Source File	packages/kokkos/test/BaseSparseSolve/cxx_main.cpp
Label	Kokkos
Command	"/Users/bmpersc/bin/gcc-4.3.3/bin/g++" "-mmacosx-version-min=10.5" "-ansi" "-pedantic" "-Wall" "-Wno-long-long" "-Wwrite-strings" "-g" "-O0" "-D_GLIBCXX_DEBUG" "-I/Users/bmpersc/nightly/Trilinos.base/SERIAL_DEBUG/BUILD/packages/kokkos/src" "-I/Users/bmpersc/nightly/Trilinos.base/SERIAL_DEBUG/Trilinos/packages/kokkos/src" "-I/Users/bmpersc/nightly/Trilinos.base/SERIAL_DEBUG/Trilinos/packages/kokkos/test/BaseSparseSolve/../BaseSparseMultiply" "-o" "CMakeFiles/Kokkos_BaseSparseSolve.dir/cxx_main.cpp.o" "-c" "/Users/bmpersc/nightly/Trilinos.base/SERIAL_DEBUG/Trilinos/packages/kokkos/test/BaseSparseSolve/cxx_main.cpp"
Directory	/Users/bmpersc/nightly/Trilinos.base/SERIAL_DEBUG/BUILD/packages/kokkos/test/BaseSparseSolve
Exit Condition	0
Standard Output	
Standard Error	/Users/bmpersc/nightly/Trilinos.base/SERIAL_DEBUG/Trilinos/packages/kokkos/src/Kokkos_BaseSparseSolve.hpp: In member functio /Users/bmpersc/nightly/Trilinos.base/SERIAL_DEBUG/Trilinos/packages/kokkos/test/BaseSparseSolve/cxx_main.cpp:262: instanti /Users/bmpersc/nightly/Trilinos.base/SERIAL_DEBUG/Trilinos/packages/kokkos/src/Kokkos_BaseSparseSolve.hpp:646: warning: sugg /Users/bmpersc/nightly/Trilinos.base/SERIAL_DEBUG/Trilinos/packages/kokkos/src/Kokkos_BaseSparseSolve.hpp:693: warning: sugg /Users/bmpersc/nightly/Trilinos.base/SERIAL_DEBUG/Trilinos/packages/kokkos/src/Kokkos_BaseSparseSolve.hpp: In member functio /Users/bmpersc/nightly/Trilinos.base/SERIAL_DEBUG/Trilinos/packages/kokkos/test/BaseSparseSolve/cxx_main.cpp:287: instanti /Users/bmpersc/nightly/Trilinos.base/SERIAL_DEBUG/Trilinos/packages/kokkos/src/Kokkos_BaseSparseSolve.hpp:541: warning: sugg /Users/bmpersc/nightly/Trilinos.base/SERIAL_DEBUG/Trilinos/packages/kokkos/src/Kokkos_BaseSparseSolve.hpp:583: warning: sugg

CDash 1.5.0 © 2009 Kitware Inc.
[report problems]

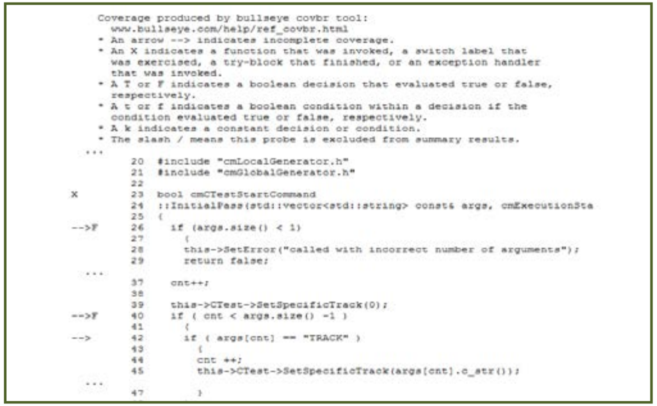
Coverage Display GCov/Bullseye



./Source/CTest/cmCTestUpdateHandler.cxx	68.21%	45	1
./Source/cmMakefileLibraryTargetGenerator.cxx	68.48%	60	2
./Source/cmTargetLinkLibrariesCommand.cxx	69.17%	17	1
./Source/cmGetPropertyCommand.cxx	69.31%	36	2
./Source/cmExportInstallFileGenerator.cxx	69.32%	16	2
./Source/kwsys/ProcessUNIX.c	69.33%	371	11
./Source/cmVariableWatch.cxx	69.44%	8	1
./Source/cmSystemTools.h	69.64%	1	5
./Source/cmComputeLinkDepends.cxx	69.89%	78	5
./Source/CTest/cmCTestStartCommand.cxx	70.00%	12	0
./Source/cmMakefileExecutableTargetGenerator.cxx	70.83%	16	1
./Source/cmLinkLibrariesCommand.cxx	70.83%	7	0
./Source/cmMakeDepend.cxx	71.01%	44	1
./Source/CTest/cmCTestBuildCommand.cxx	71.74%	26	0
./Source/cmsys/auto_ptr.hxx	71.88%	1	1
./Source/kwsys/testCommandLineArguments.cxx	71.88%	7	1
./Source/CTest/cmCTestSVN.cxx	72.07%	57	2
./Source/cmScriptGenerator.cxx	72.34%	20	1

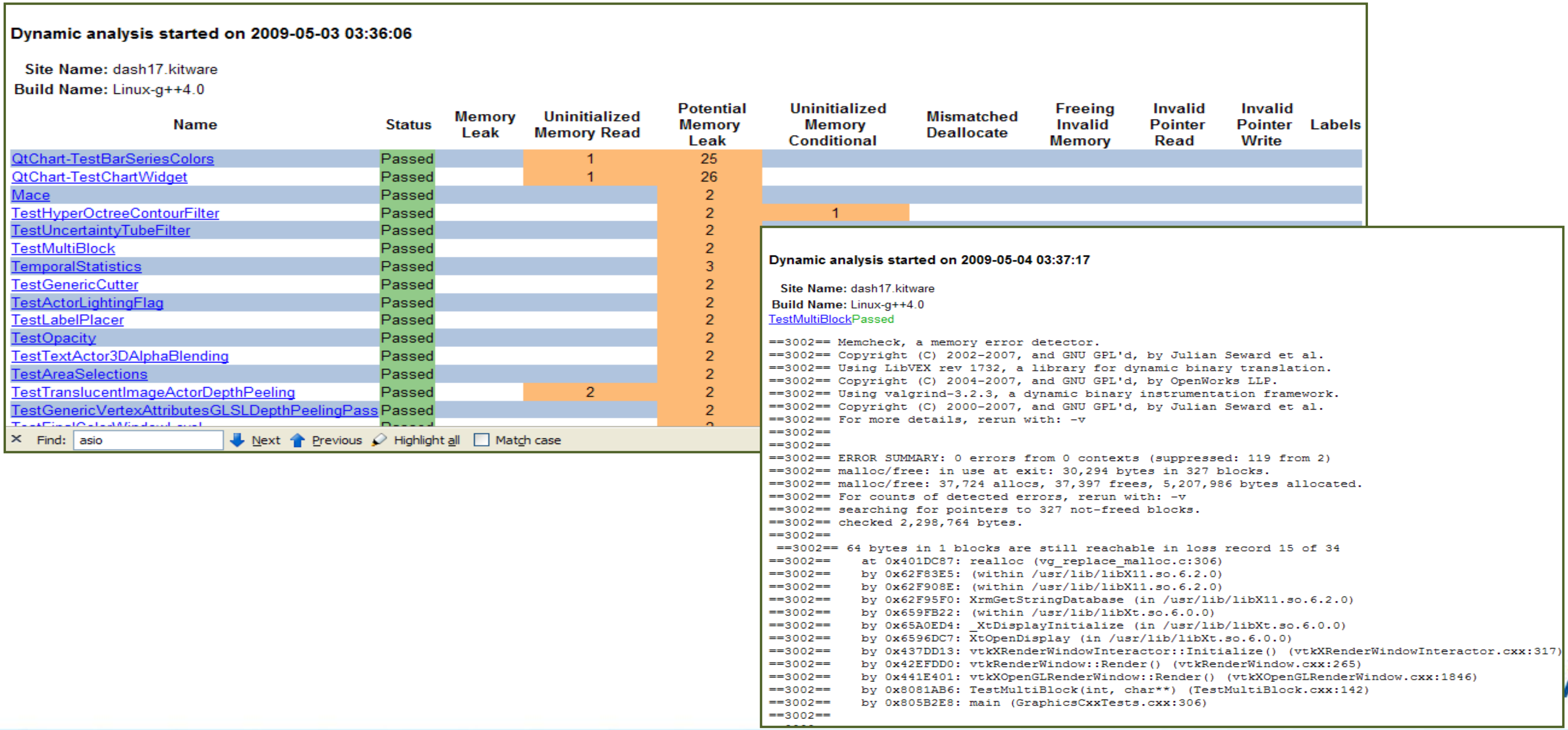


```
               Version:    $Revision: 1.4 $

               Copyright (c) 2002 Kitware, Inc., Insight Consortium.  All rights reserved.
               See Copyright.txt or http://www.cmake.org/HTML/Copyright.html for details.

                  This software is distributed WITHOUT ANY WARRANTY; without even
                  the implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR
                  PURPOSE.  See the above copyright notices for more information.

             =========================================================================*/
             #include "cmDefinePropertyCommand.h"
             #include "cmake.h"

             // cmDefinePropertiesCommand
             bool cmDefinePropertyCommand
             ::InitialPass(std::vector<std::string> const& args, cmExecutionStatus &)
00000013     {
00000013       if(args.size() < 1)
                 {
00000000         this->SetError("called with incorrect number of arguments");
00000000         return false;
                 }

               // Get the scope in which to define the property.
00000013       cmProperty::ScopeType scope;
00000013       if(args[0] == "GLOBAL")
                 {
00000010         scope = cmProperty::GLOBAL;
                 }
00000003       else if(args[0] == "DIRECTORY")
                 {
00000000         scope = cmProperty::DIRECTORY;
                 }
00000003       else if(args[0] == "TARGET")
                 {
00000003         scope = cmProperty::TARGET;
                 }
00000000       else if(args[0] == "SOURCE")
```



```
           Coverage produced by bullseye covbr tool:
             www.bullseye.com/help/ref_covbr.html
           * An arrow --> indicates incomplete coverage.
           * An X indicates a function that was invoked, a switch label that
             was exercised, a try-block that finished, or an exception handler
             that was invoked.
           * A T or F indicates a boolean decision that evaluated true or false,
             respectively.
           * A t or f indicates a boolean condition within a decision if the
             condition evaluated true or false, respectively.
           * A k indicates a constant decision or condition.
           * The slash / means this probe is excluded from summary results.
     ...
                20  #include "cmLocalGenerator.h"
                21  #include "cmGlobalGenerator.h"
                22
     X          23  bool cmCTestStartCommand
                24  ::InitialPass(std::vector<std::string> const& args, cmExecutionSta
                25  {
     -->F       26    if (args.size() < 1)
                27      {
                28      this->SetError("called with incorrect number of arguments");
                29      return false;
     ...
                37    cnt++;
                38
                39    this->CTest->SetSpecificTrack(0);
     -->F       40    if ( cnt < args.size() -1 )
                41      {
     -->        42      if ( args[cnt] == "TRACK" )
                43        {
                44        cnt ++;
                45        this->CTest->SetSpecificTrack(args[cnt].c_str());
     ...
                47        }
```

Valgrind / Purify



Dynamic analysis started on 2009-05-03 03:36:06

Site Name: dash17.kitware
Build Name: Linux-g++4.0

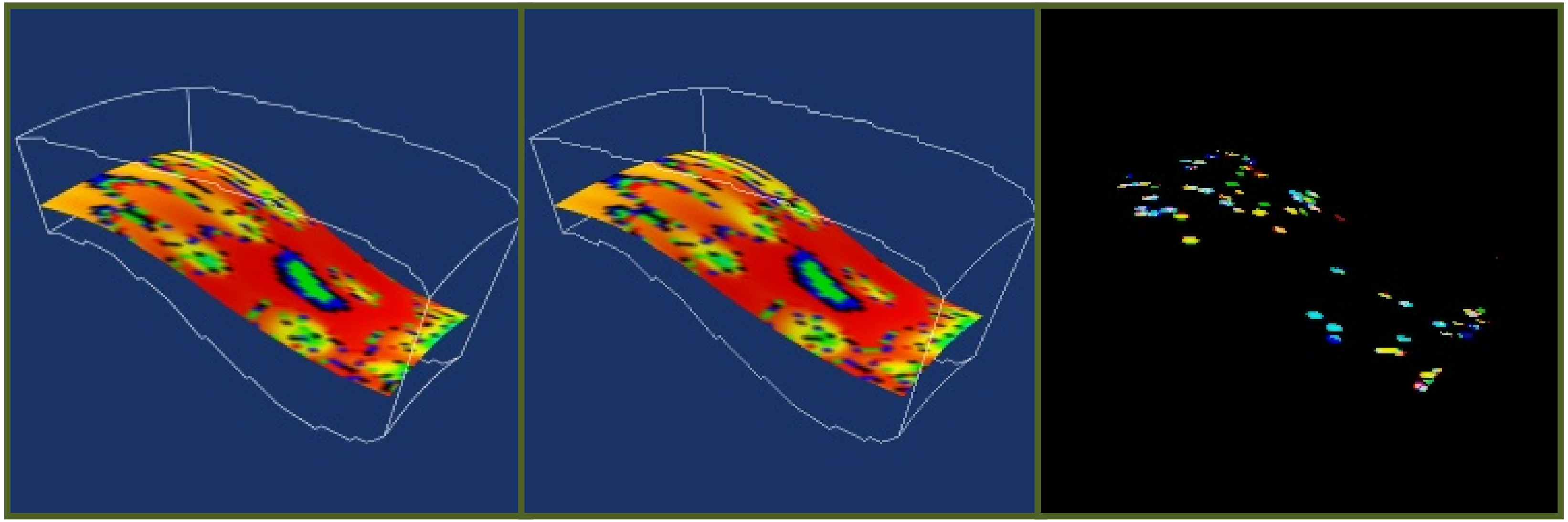
Name	Status	Memory Leak	Uninitialized Memory Read	Potential Memory Leak	Uninitialized Memory Conditional	Mismatched Deallocate	Freeing Invalid Memory	Invalid Pointer Read	Invalid Pointer Write	Labels
QtChart-TestBarSeriesColors	Passed		1	25						
QtChart-TestChartWidget	Passed		1	26						
Mace	Passed			2						
TestHyperOctreeContourFilter	Passed			2	1					
TestUncertaintyTubeFilter	Passed			2						
TestMultiBlock	Passed			2						
TemporalStatistics	Passed			3						
TestGenericCutter	Passed			2						
TestActorLightingFlag	Passed			2						
TestLabelPlacer	Passed			2						
TestOpacity	Passed			2						
TestTextActor3DAlphaBlending	Passed			2						
TestAreaSelections	Passed			2						
TestTranslucentImageActorDepthPeeling	Passed		2	2						
TestGenericVertexAttributesGLSLDepthPeelingPass	Passed			2						

Dynamic analysis started on 2009-05-04 03:37:17

Site Name: dash17.kitware
Build Name: Linux-g++4.0
TestMultiBlockPassed

```
==3002== Memcheck, a memory error detector.
==3002== Copyright (C) 2002-2007, and GNU GPL'd, by Julian Seward et al.
==3002== Using LibVEX rev 1732, a library for dynamic binary translation.
==3002== Copyright (C) 2004-2007, and GNU GPL'd, by OpenWorks LLP.
==3002== Using valgrind-3.2.3, a dynamic binary instrumentation framework.
==3002== Copyright (C) 2000-2007, and GNU GPL'd, by Julian Seward et al.
==3002== For more details, rerun with: -v
==3002==
==3002==
==3002== ERROR SUMMARY: 0 errors from 0 contexts (suppressed: 119 from 2)
==3002== malloc/free: in use at exit: 30,294 bytes in 327 blocks.
==3002== malloc/free: 37,724 allocs, 37,397 frees, 5,207,986 bytes allocated.
==3002== For counts of detected errors, rerun with: -v
==3002== searching for pointers to 327 not-freed blocks.
==3002== checked 2,298,764 bytes.
==3002==
 ==3002== 64 bytes in 1 blocks are still reachable in loss record 15 of 34
==3002==    at 0x401DC87: realloc (vg_replace_malloc.c:306)
==3002==    by 0x62F83E5: (within /usr/lib/libX11.so.6.2.0)
==3002==    by 0x62F908E: (within /usr/lib/libX11.so.6.2.0)
==3002==    by 0x62F95F0: XrmGetStringDatabase (in /usr/lib/libX11.so.6.2.0)
==3002==    by 0x659FB22: (within /usr/lib/libXt.so.6.0.0)
==3002==    by 0x65A0ED4: _XtDisplayInitialize (in /usr/lib/libXt.so.6.0.0)
==3002==    by 0x6596DC7: XtOpenDisplay (in /usr/lib/libXt.so.6.0.0)
==3002==    by 0x437DD13: vtkXRenderWindowInteractor::Initialize() (vtkXRenderWindowInteractor.cxx:317)
==3002==    by 0x42EFDD0: vtkRenderWindow::Render() (vtkRenderWindow.cxx:265)
==3002==    by 0x441E401: vtkXOpenGLRenderWindow::Render() (vtkXOpenGLRenderWindow.cxx:1846)
==3002==    by 0x8081AB6: TestMultiBlock(int, char**) (TestMultiBlock.cxx:142)
==3002==    by 0x805B2E8: main (GraphicsCxxTests.cxx:306)
==3002==
```

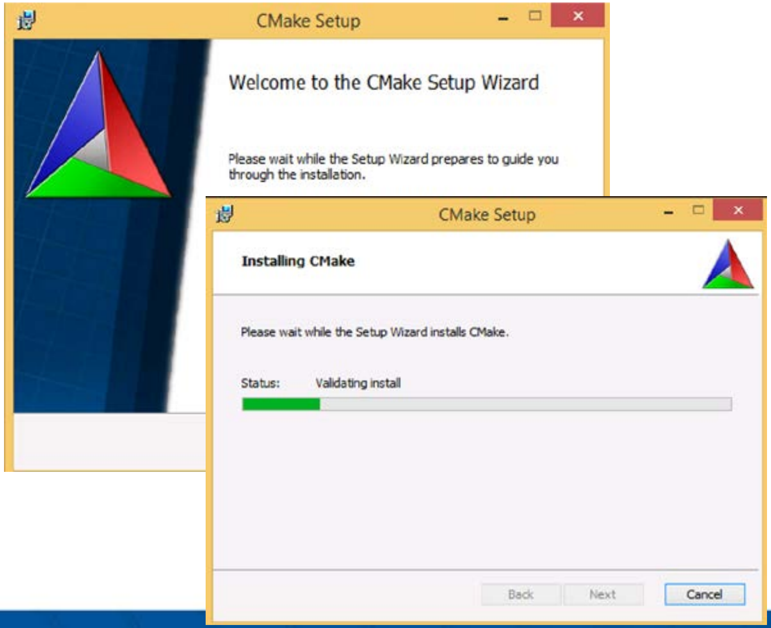
CDash Image Difference



CPack

What is CPack

- CPack is bundled with CMake
- Creates professional platform specific installers



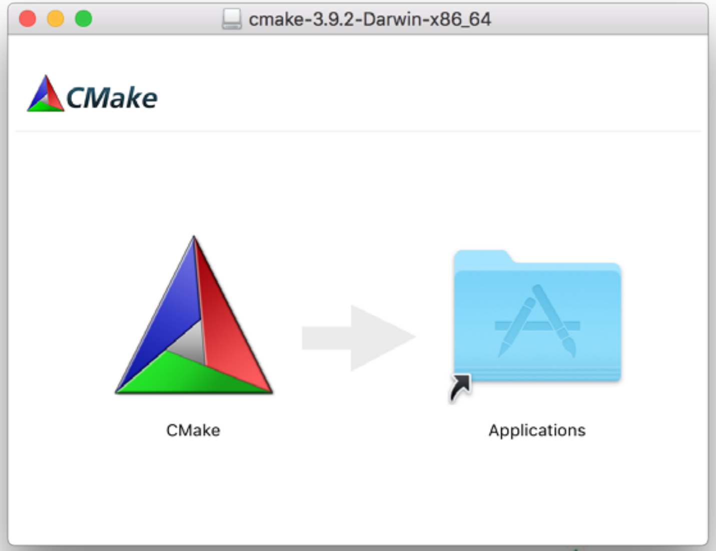
Welcome to the CMake Setup Wizard

Please wait while the Setup Wizard prepares to guide you through the installation.

Installing CMake

Please wait while the Setup Wizard installs CMake.

Status: Validating install



CPack Features

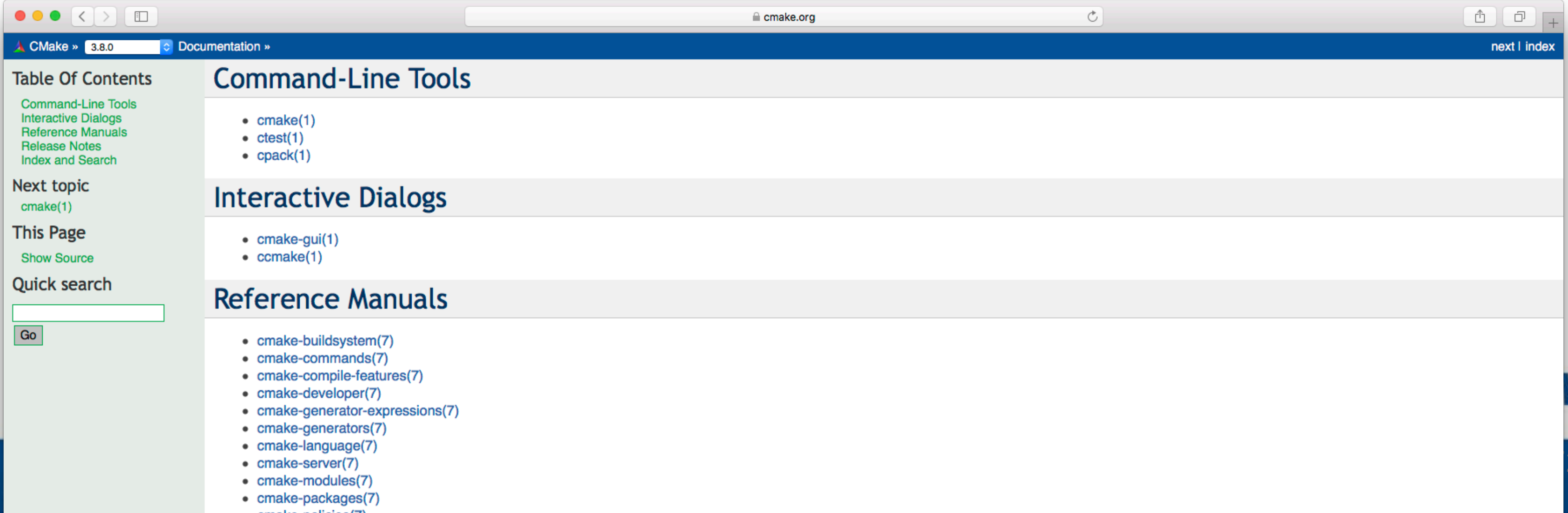
- Supports CMake-based and non-CMake-based projects
- Unix
  - TGZ and self-extracting TGZ (STGZ)
- Windows
  - WiX – MSI installers
  - NullSoft Scriptable Install System (NSIS / NSIS64)
- Mac OSX
  - DragNDrop
  - PackageMaker
- Deb
  - Debian packages
- RPM
  - RPM package manager

Using CPack

- On Windows install command line ZIP program, NSIS and WiX
- Setup your project to work with cpack
  - Get make install to work
    - install(…)
    - make sure your executables work with relative paths and can work from any directory
  - Set cpack option variables if needed
  - include(CPack)

Now that you are inspired

- Read “how to write a CMake buildsystem”
  - https://cmake.org/cmake/help/v3.8/manual/cmake-buildsystem.7.htmlExplore the CMake documentation
- Explore the CMake documentation
  - https://www.cmake.org/cmake/help/v3.8/



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- cmake-compile-features(7)
- cmake-developer(7)
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- cmake-server(7)
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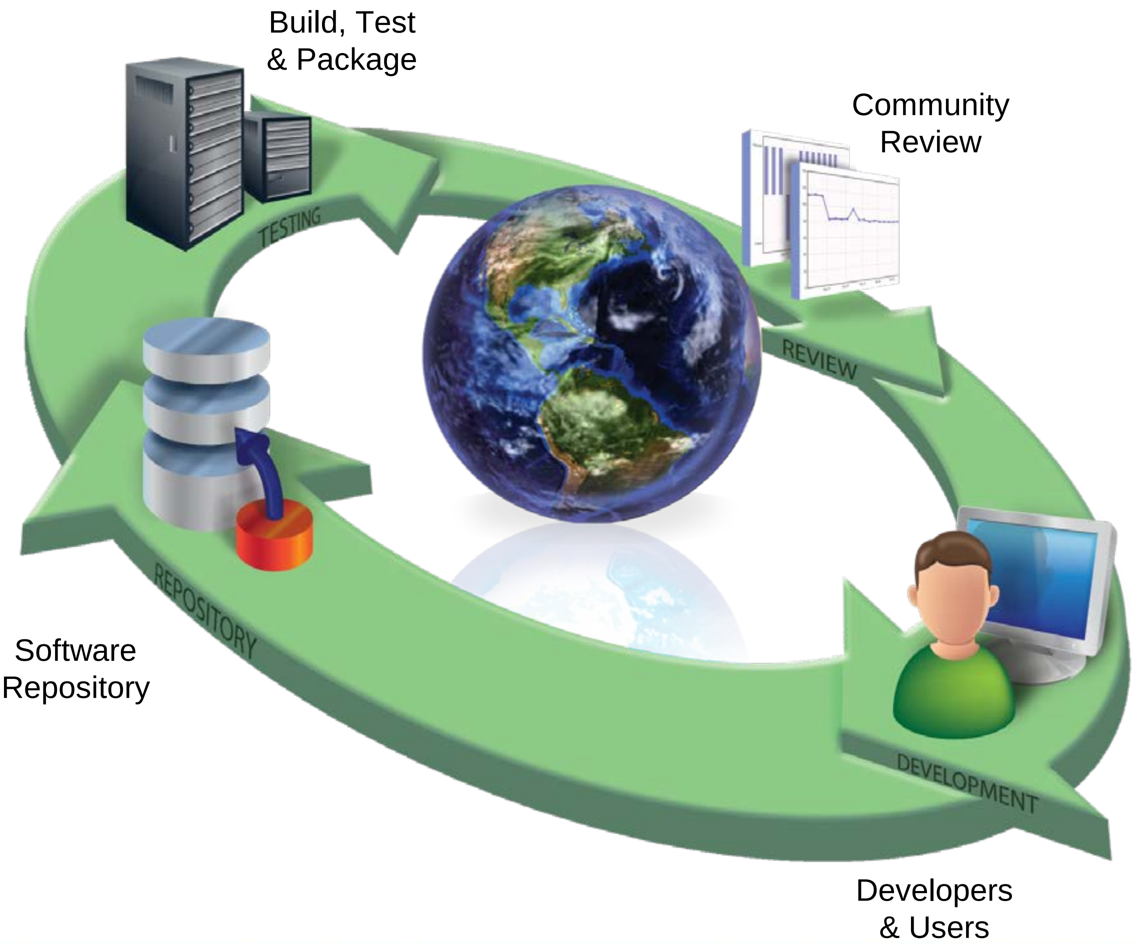
Thanks



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Software
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