Embracing Modern CMake

How to recognize and use modern CMake interfaces

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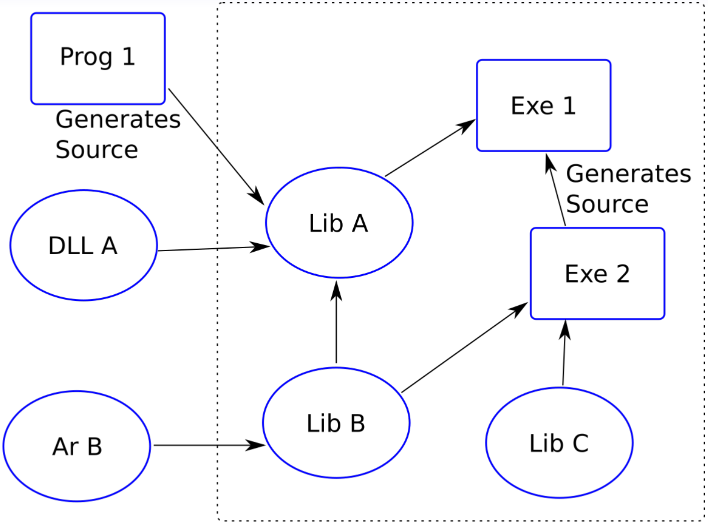
Background

CMake - What, Why, Who

- Buildsystem Generator
- 'Cross-platform Make'
- Part of suite of productivity and quality tools
- Started by Kitware in 2000

CMake - What, Why, Who


Prog 1
Generates Source
DLL A
Ar B
Lib A
Lib B
Exe 1
Generates Source
Exe 2
Lib C

Makefiles

Maintainability

[illegible]

Abstraction

Visual Studio/Xcode Project

Maintainability [illegible] Abstraction

CMake

Maintainability Extensibility Abstraction Portability Technology

Where CMake shines

- Finding dependencies
- Portability
- Code generation
- Multi-language support

What is Modern CMake?

- New(er) APIs and mindset of writing CMake code
- Less code
- Cleaner code
- More target-focussed

The Good News

Mostly everything available to you already

	2012	2013		2014		2015			2016			2017
	October	May	October	June	December	March	July	November	March	July	November	April
CMake	<= 2.8.10	2.8.11	2.8.12	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8
Ubuntu	12.04		12.04						16.04		17.04	
Debian		Wheezy		Jessie							Sid	
Fedora							23		24	25		
Travis					Yes							
RHEL	5		6				7					

Defining a Buildsystem

⭐Modern CMake

```
cmake_minimum_required(VERSION 3.5)
project(myproject)

add_library(libsalutation STATIC salutation.cpp)

add_executable(hello hello.cpp)
target_link_libraries(hello
  libsalutation
)

add_executable(goodbye goodbye.cpp)
target_link_libraries(goodbye
  libsalutation
)
```

Policies

Policies

```
cmake_minimum_required(VERSION 2.8)
```

Policies

```
cmake_minimum_required(VERSION 2.8)
```

- Fail at runtime if version is too low
- Populate variable `CMAKE_MINIMUM_REQUIRED_VERSION`
- (Re)set runtime behavior of CMake with policies
- Should be first line of your CMake buildsystem (before `project`)

Policies

- Behavior deprecation mechanism
- In WARN state by default
- Set individually for fine control

	...
CMake 3.3	CMP0057
	CMP0056
CMake 3.2	CMP0055
CMake 3.1	CMP0054
	...

Policies

⭐Modern CMake

```
cmake_minimum_required(VERSION 3.0)
if (POLICY CMP0053)
  cmake_policy(SET CMP0053 NEW)
endif()
```

Not Modern CMake

```
cmake_policy(SET CMP0053 OLD)
```

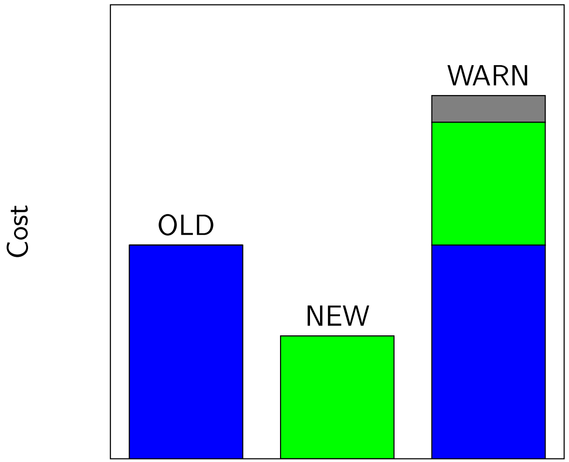
When to Set a Policy to OLD

`std::allOf(`

- You are close to your own release
- A new release of CMake just happened
- A policy warning is triggered for your code
- Your code relies on the OLD behavior
  - Or you suspect it might
- You don't pass the setting to dependents

`);`
Create a plan to migrate to the `NEW` behavior!

Policy warning is slower



Policies

UseCase: Require new features (higher version) but rely on OLD behavior

Not Modern CMake

```
cmake_minimum_required(VERSION 3.3)
cmake_policy(SET CMP0003 OLD)
target_include_directories(...)
```

Policies

UseCase: Allow old CMake but use `NEW` behavior where possible

⭐Modern CMake

```
cmake_minimum_required(VERSION 3.0)
foreach (pol CMP0053
             CMP0063
             CMP0065
    )
    if (POLICY ${pol})
        cmake_policy(SET ${pol} NEW)
    endif()
endforeach()
```

Some Policies do not issue warnings

⭐Modern CMake as of 3.8

CMP0025	Compiler id for Apple Clang is now AppleClang
CMP0047	Use QCC compiler id for the qcc drivers on QNX
CMP0056	Honor link flags in try_compile()
CMP0060	Link libraries by full path even in implicit dirs
CMP0061	CTest does not by default tell make to ignore errors
CMP0065	ENABLE_EXPORTS target property flags
CMP0066	Honor per-config flags in try_compile()
CMP0067	Honor language standard in try_compile()

- Use `-DCMAKE_POLICY_WARNING_CMP<NNNN>=ON` to enable it

Modern CMake Guidelines

- Maintain up-to-date policy settings

Usage Requirements

Defining a Buildsystem

⭐Modern CMake

```
cmake_minimum_required(VERSION 3.5)
project(myproject)

add_library(libsalutation STATIC salutation.cpp)

add_executable(hello hello.cpp)
target_link_libraries(hello
  libsalutation
)

add_executable(goodbye goodbye.cpp)
target_link_libraries(goodbye
  libsalutation
)
```

Defining a Buildsystem

Modern CMake

```
cmake_minimum_required(VERSION 3.5)
project(myproject)

add_subdirectory(libraries)

add_subdirectory(executables)
```

Defining a Buildsystem

Not Modern CMake

```
include_directories(${salutation_INCLUDES})

add_executable(hello hello.cpp)
target_link_libraries(hello
libsalutation
)

add_executable(goodbye goodbye.cpp)
target_link_libraries(goodbye
libsalutation
)
```

Defining a Buildsystem

Not Modern CMake

```
add_executable(hello hello.cpp)
target_link_libraries(hello
  libsalutation)
target_include_directories(hello
  PRIVATE ${salutation_INCLUDES})

add_executable(goodbye goodbye.cpp)
target_link_libraries(goodbye
  libsalutation)
target_include_directories(goodbye
  PRIVATE ${salutation_INCLUDES})
```

Defining a Buildsystem

⭐Modern CMake 2.8.11

```
add_executable(hello hello.cpp)
target_link_libraries(hello
  libsalutation
)

add_executable(goodbye goodbye.cpp)
target_link_libraries(goodbye
  libsalutation
)
```

Build properties

⭐Modern CMake

- Target-based buildsystem definition
- Single point of dependency specification
- Targets provide information to dependers
    - Requirements to compile
    - Requirements to link

Defining a Buildsystem

Modern CMake 2.8.11

```
add_library(salutation salutation.cpp)
target_include_directories(salutation
  PUBLIC ${CMAKE_CURRENT_SOURCE_DIR}/include
)
```

Transitive compile dependency

Modern CMake 2.8.11

```
target_include_directories(<target>
   <PUBLIC|PRIVATE|INTERFACE>
   [items...]
)
```

Transitive compile dependency

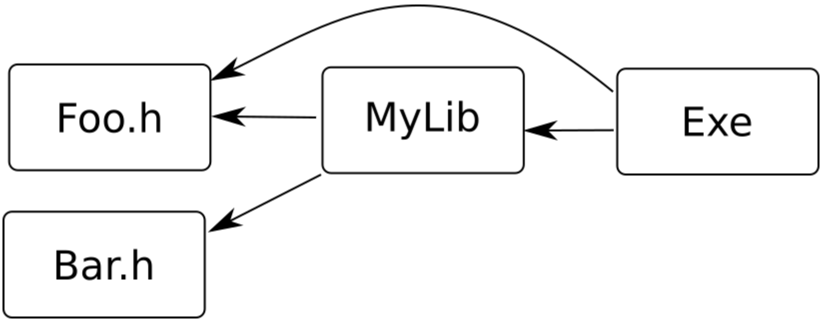
```cpp
#include <FooDependency>

class MyClass : public FooDependency
{
      MyClass();
};
```

```cpp
#include <BarDependency>

MyClass::MyClass()
{
    doInitialize(BarDependency{});
}
```

Transitive compile dependency



Transitive compile dependency

PRIVATE	Needed by me, but **not** my dependers
PUBLIC	Needed by me **and** my dependers
INTERFACE	Needed **not** by me, **but** by my dependers

Defining a Buildsystem

⭐Modern CMake 2.8.11

```
add_library(salutation salutation.cpp)
target_include_directories(salutation
  PUBLIC ${CMAKE_CURRENT_SOURCE_DIR}/include
)
```

Transitive Scope

Modern CMake 2.8.11

```
target_include_directories(myTarget
  PUBLIC    "/something/public"
  PRIVATE   "/something/private"
  INTERFACE "/something/interface"
  PUBLIC    "/another/public"
  PRIVATE   "/another/private"
)
```

include_directories command

Not Modern CMake

```
include_directories(some_dir)

add_library(libA)

add_library(libB)
```

include_directories command

Not Modern CMake

```
add_library(libA)

include_directories(some_dir)

add_library(libB)
```

include_directories command

Not Modern CMake

```
add_library(libA)

add_library(libB)

include_directories(some_dir)
```

include_directories command

Not Modern CMake

```
add_library(libA)

add_subdirectory(dir1)

include_directories(some_dir)

add_library(libB)

add_subdirectory(dir2)
```

include_directories command

Not Modern CMake

```
add_library(libA)

subdirs(dir1)

include_directories(some_dir)

add_library(libB)

add_subdirectory(dir2)
```

Lack of transitivity

Not Modern CMake

```
set(app_INCLUDES
  ${lib1_INCLUDES}
  ${lib2_INCLUDES}
  ${lib3_INCLUDES})

set(app_LIBRARIES ...)

include_directories(${app_INCLUDES})

add_subdirectory(dir1)
add_subdirectory(dir2)
add_subdirectory(dir3)

add_subdirectory(app)
```

Compile Definitions

`add_definitions` command has all the same problems as `include_directories` command.

Not Modern CMake

```
add_library(salutation salutation.cpp)
add_definitions(
  -DUSE_INTERNAL_SIMD
  -DUSE_MULTITHREADING)
```

Compile Definitions

⭐Modern CMake 2.8.11

```
add_library(salutation salutation.cpp)
target_include_directories(salutation
  PUBLIC ${CMAKE_CURRENT_SOURCE_DIR}/include
)
target_compile_definitions(salutation
  PRIVATE USE_INTERNAL_SIMD
  PUBLIC  USE_MULTITHREADING
)
```

Build properties

Support <PRIVATE|PUBLIC|INTERFACE> and transitivity

Include Directories (`-I/foo/bar`)	`target_include_directories`
Compile Definitions (`-DSOMEDEF`)	`target_compile_definitions`
Compile Options (`-fPIC`)	`target_compile_options`
Link Libraries (`-l/path/to/lib`)	`target_link_libraries`
Sources	`target_sources`

Modern CMake Guidelines

- Maintain up-to-date policy settings
- Write target-centric code
    - Use `target_` command variants
    - Specify usage requirements for targets

Lack of transitivity

Not Modern CMake

```
set(app_INCLUDES
  ${lib1_INCLUDES}
  ${lib2_INCLUDES}
  ${lib3_INCLUDES})

set(app_LIBRARIES ...)

include_directories(${app_INCLUDES})

add_subdirectory(dir1)
add_subdirectory(dir2)
add_subdirectory(dir3)

add_subdirectory(app)
```

Reliance on variables

Not Modern CMake

```
set(main_SRCS
  main.cpp)

add_executable(app ${main_SRCS})
target_include_directories(app
  PRIVATE ${app_INCLUDES})
target_compile_definitions(app
  PRIVATE ${app_DEFINES})
target_link_libraries(app
  ${app_LIBRARIES})
```

Reliance on variables

Not Modern CMake

```
set(main_SRCS
  main.cpp)

add_executable(app ${main_SRCS})
target_include_directories(app
  PRIVATE                ${some_directories})
target_compile_definitions(app
  PRIVATE               )
target_link_libraries(app
                  )
```

Reliance on variables

Eschew obfuscation; Espouse elucidation

⭐Modern CMake

```
add_executable(app main.cpp)
target_link_libraries(app
    lib2 lib3
)
```

Problems with Variables

- Variables are fragile
- Variables leak to other contexts
- Variables don't express scope of dependencies
- Variables are not checked for correctness or content

Modern CMake Guidelines

- Maintain up-to-date policy settings
- Write target-centric code
  - Use `target_` command variants
  - Specify usage requirements for targets
- Avoid unnecessary variables

Generator Expressions

Conditions

Not Modern CMake

```
set(main_SRCS
  main.cpp
)
if (WIN32)
  list(APPEND main_SRCS helper_win.cpp)
else()
  list(APPEND main_SRCS helper_posix.cpp)
endif()

add_executable(hello ${main_SRCS})
```

Conditions

Modern CMake 3.1

```
add_executable(hello main.cpp)
if (WIN32)
  target_sources(hello PRIVATE
    helper_win.cpp
  )
else()
  target_sources(hello PRIVATE
    helper_posix.cpp
  )
endif()
```

Conditions

⭐Modern CMake 3.1

```
add_executable(hello
  main.cpp
  $<$<BOOL:${WIN32}>:helper_win.cpp>
  $<$<NOT:$<BOOL:${WIN32}>>:helper_posix.cpp>
)
```

Conditions

Not Modern CMake

Warning: this code is buggy and non-portable!

```
set(main_SRCS
  main.cpp
)
if (CMAKE_BUILD_TYPE STREQUAL DEBUG)
  list(APPEND main_SRCS helper_debug.cpp)
else()
  list(APPEND main_SRCS helper_rel.cpp)
endif()

add_executable(hello ${main_SRCS})
```

Conditions

⭐Modern CMake 3.1

```
add_executable(hello
  main.cpp
  $<$<CONFIG:Debug>:helper_debug.cpp>
  $<$<NOT:$<CONFIG:Debug>>:helper_rel.cpp>
)
```

Generator Expressions

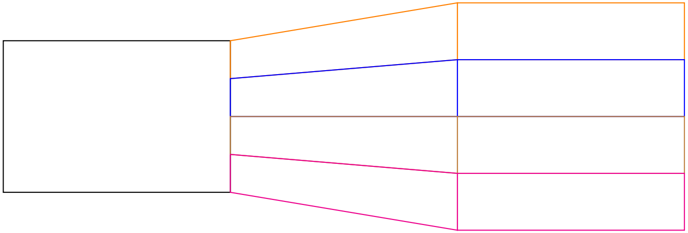
Configure

Compute

Generate

if()/else()/endif()

$<1:...>



Generator Expressions basics

\$<1:...>	...
\$<0:...>	
\$<Config:Debug>	1 (in Debug config)
\$<Config:Debug>	0 (in Debug config)
\$<\$<Config:Debug>:...>	... (in Debug config)
\$<\$<Config:Debug>:...>	(in Debug config)

Truthiness conversion

`$<$<BOOL:${WIN32}>:...>` at configure time produces `$<$<BOOL:1>:...>` or `$<$<BOOL:>:...>` at generate-time!

```
add_executable(hello
  main.cpp
  $<$<BOOL:${WIN32}>:helper_win.cpp>
  $<$<NOT:$<BOOL:${WIN32}>>:helper_posix.cpp>
)
```

Support for Generator Expressions

- `target_` commands
- `file(GENERATE)` command
- `add_executable`/`add_library` commands
- `install` command (partial)
- `add_custom_target` command (partial)
- `add_custom_command` command (partial)

There are others, but these are the most important

Imperative versus Transitive

⭐Modern CMake 2.8.11

```
# Compile with USE_THREADS if the
# WITH_THREADS property is ON
get_property(buildWithThreads TARGET hello
  PROPERTY WITH_THREADS)
if (buildWithThreads)
  target_compile_definitions(hello PRIVATE
    USE_THREADS)
endif()

set_property(TARGET hello
  PROPERTY WITH_THREADS ON)
```

Imperative versus Transitive

Modern CMake 2.8.11

```
# Compile with USE_THREADS if the
# WITH_THREADS property is ON
target_compile_definitions(hello PRIVATE
  $<$<TARGET_PROPERTY:WITH_THREADS>:USE_THREADS>)

set_property(TARGET hello
  PROPERTY WITH_THREADS ON)
```

Conditions

- "Generator Expression" conditions at Generate-time
- Test content after configure-time
    - Configuration
    - TARGET_PROPERTY
    - TARGET_POLICY
    - COMPILE_FEATURES
    - LOCATION
- Never use `CMAKE_BUILD_TYPE` in `if()`

Modern CMake Guidelines

- Maintain up-to-date policy settings
- Write target-centric code
  - Use `target_` command variants
  - Specify usage requirements for targets
- Avoid unnecessary variables
- Use generate-time conditions correctly

target_link_libraries

Defining a Buildsystem

⭐Modern CMake 2.8.11

```
add_executable(hello hello.cpp)
target_link_libraries(hello
  libsalutation
)

add_executable(goodbye goodbye.cpp)
target_link_libraries(goodbye
  libsalutation
)
```

target_link_libraries

```
target_link_libraries(someTarget <item>)
```

`<item>` can be:

- A CMake target
- A library name on disk
- A full library path
- A linker flag

target_link_libraries

```
target_link_libraries(someTarget aTargetName)
```

- Link to aTargetName
- Determine build order
- Consume usage requirements
  - Compiling
  - Linking
- Determine compatibility

target_link_libraries

```
target_link_libraries(someTarget oopsItsATypo)
```

- Check if it is a CMake target name
- Check if it is a link flag (starts with '-')
- Check if it is a path
- Assume it is a libraryname (add -loopsItsATypo)

CMake Target types

Executables	`add_executable`
Shared libraries	`add_library(SHARED)`
Static libraries	`add_library(STATIC)`
Object libraries	`add_library(OBJECT)`
Interface libraries	`add_library(INTERFACE)`
Alias libraries	`add_library(ALIAS)`

Interface targets

Suitable for header-only libraries

```
add_library(boost_mpl INTERFACE)
target_compile_definitions(boost_mpl
INTERFACE BOOST_MPL_CFG_NO_PREPROCESSED_HEADERS)
target_include_directories(boost_mpl
INTERFACE "3rdparty/boost/mpl")
```

```
add_executable(my_exe)
target_link_libraries(my_exe boost_mpl)
```

Interface targets

Suitable for header-only libraries

```
add_library(boost_mpl INTERFACE)
target_compile_definitions(boost_mpl
INTERFACE BOOST_MPL_CFG_NO_PREPROCESSED_HEADERS)
target_include_directories(boost_mpl
INTERFACE "3rdparty/boost/mpl")

add_library(boost_icl INTERFACE)
target_link_libraries(boost_icl
INTERFACE boost_mpl)
target_include_directories(boost_icl
INTERFACE "3rdparty/boost/icl")
```

```
add_executable(my_exe)
target_link_libraries(my_exe boost_icl)
```

Interface targets

Group build properties for convenient consumption

```
target_link_libraries(windows_specific
INTERFACE directX)
target_compile_definitions(windows_specific
INTERFACE USE_DIRECTX)
target_sources(windows_specific
INTERFACE network_win.cpp)

add_library(platform_specific INTERFACE)
target_link_libraries(platform_specific INTERFACE
$<$<BOOL:${WIN32}>:windows_specific>
$<$<NOT:$<BOOL:${WIN32}>>:posix_specific>
)
```

Interface targets

Modern CMake 3.1

```
target_link_libraries(mytarget
platform_specific
helper_library
)
```

Alias targets

⭐Modern CMake 2.8.12

```
add_library(detail::platform_specific
    ALIAS platform_specific)
)
```

```
target_link_libraries(mytarget
  detail::platform_specific
)
```

Alias targets

⭐Modern CMake 2.8.12

```
add_library(boost::mpl
    ALIAS boost_mpl)
)
```

```
target_link_libraries(mytarget
  boost::mpl
)
```

Dependencies

External dependencies

Modern CMake 3.1

```cmake
cmake_minimum_required(VERSION 3.5)
project(myproject)

find_package(Qt5Widgets REQUIRED)
find_package(Qt53D REQUIRED)

add_executable(hello main.cpp)
target_link_libraries(hello
  Qt5::Widgets Qt5::3DCore
)
```

External dependencies

⭐Modern CMake 3.1

```
cmake_minimum_required(VERSION 3.5)
project(myproject)

find_package(Qt5Widgets REQUIRED)

add_library(locallib STATIC locallib.cpp)
target_link_libraries(locallib PUBLIC
  Qt5::Widgets
)
add_executable(hello main.cpp)
target_link_libraries(hello
  locallib
)
```

Legacy pattern

Not Modern CMake

```
cmake_minimum_required(VERSION 3.5)
project(myproject)

find_package(Qt5Core REQUIRED)
find_package(Qt5Gui REQUIRED)
find_package(Qt5Widgets REQUIRED)

add_definitions(
  ${Qt5Core_DEFINITIONS}
  ${Qt5Gui_DEFINITIONS}
  ${Qt5Widgets_DEFINITIONS}
)
```

Legacy pattern

Not Modern CMake

```
include_directories(
  ${Qt5Core_INCLUDE_DIRS}
  ${Qt5Gui_INCLUDE_DIRS}
  ${Qt5Widgets_INCLUDE_DIRS}
)

set(CMAKE_CXX_FLAGS
  "${CMAKE_CXX_FLAGS} ${Qt5Core_CXX_FLAGS} \
    ${Qt5Gui_CXX_FLAGS} ${Qt5Widgets_CXX_FLAGS}")
```

Legacy pattern

Not Modern CMake

```
add_library(locallib SHARED
  locallib.cpp
)
target_link_libraries(locallib
  ${Qt5Core_LIBRARIES} ${Qt5Gui_LIBRARIES}
  ${Qt5Widgets_LIBRARIES}
)
set(locallib_LIBRARIES locallib
  ${Qt5Core_LIBRARIES} ${Qt5Gui_LIBRARIES}
  ${Qt5Widgets_LIBRARIES}
)
```

Old style packages populate variables

Not Modern CMake

```cmake
find_package(Foo REQUIRED)

add_executable(hello main.cpp)
target_include_directories(hello
  PRIVATE ${Foo_INCLUDE_DIRS}
)
target_compile_definitions(hello
  PRIVATE ${Foo_COMPILE_DEFINITIONS}
)
target_link_libraries(hello
  ${Foo_LIBRARIES}
)
```

Modern CMake packages define IMPORTED targets.

⭐Modern CMake

```
find_package(Foo REQUIRED)

add_executable(hello main.cpp)
target_link_libraries(hello
  Foo::Core
)
```

- Compare with syntax using `ALIAS` libraries.
- CMake code for `hello` doesn't change under refactoring

Modern CMake Guidelines

- Maintain up-to-date policy settings
- Write target-centric code
  - Use `target_` command variants
  - Specify usage requirements for targets
- Avoid unnecessary variables
- Use generate-time conditions correctly
- Use `IMPORTED` targets for external dependencies

Creating Packages

```
add_library(mylib ...)

install(TARGETS mylib
    EXPORT exp
    ARCHIVE DESTINATION lib)

install(EXPORT exp
    NAMESPACE ns:: DESTINATION share/cmake)
install(FILES mylibConfig.cmake
    DESTINATION share/cmake)
```

Modern CMake Guidelines

- Maintain up-to-date policy settings
- Write target-centric code
  - Use `target_` command variants
  - Specify usage requirements for targets
- Avoid unnecessary variables
- Use generate-time conditions correctly
- Use `IMPORTED` targets for external dependencies
- Install 'rich' targets and export packages

Where to get more information

- Avoid the wiki
- Use the documentation
- Use the cmake mailing list
- Use stack overflow

Thanks & Questions

Special thanks:

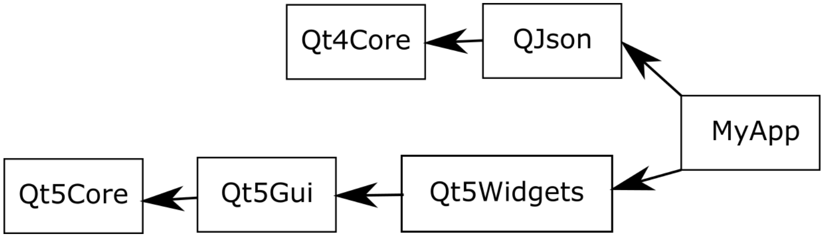
- Brad King
- Ben & Robert
- Reddit <3

Compatible interfaces

```
find_package(qjson REQUIRED)

add_executable(main main.cpp)
target_link_libraries(main
    Qt5::Widgets qjson::qjson)
```

Compatible interfaces



Compatible interfaces

```
set_property(TARGET Qt4::QtCore PROPERTY
    INTERFACE_QT_MAJOR_VERSION 4
)
set_property(TARGET Qt4::QtCore APPEND PROPERTY
    COMPATIBLE_INTERFACE_STRING QT_MAJOR_VERSION
)
# ...
set_property(TARGET Qt5::Core PROPERTY
    INTERFACE_QT_MAJOR_VERSION 5
)
set_property(TARGET Qt5::Core APPEND PROPERTY
    COMPATIBLE_INTERFACE_STRING QT_MAJOR_VERSION
)
```

Creating build-dir Packages

```
add_library(mylib ...)

install(TARGETS mylib
    EXPORT exp
    ARCHIVE DESTINATION lib)

export(EXPORT exp
    NAMESPACE ns:: FILE buildDirTargets.cmake)
```

- Non-relocatable (use `install(EXPORT)` for that)
- Suitable in cross-compiles or superbuilds.