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Changing Legacy Code with Confidence:

Practical Advice for Maintaining and Migrating Working Code

Brian Ruth (he/him) brian.ruth@garmin.com

Part 0: Legacy Code

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Legacy code has value

- It works*
- It may not have tests, but has been tested
- Documents all the decisions and problems encountered in its lifetime
- It is currently making the company money
- One person's bug is another's critical feature

*well enough, for some definition of "works"

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The Legacy of Code

- Best practices and languages change
- Developers cycle through projects
- Features added/removed/re-added changed
- New developers may not have a firm understanding of project structure*
- Supporting tools change

*for some definition of "structure"

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Goals of this talk

- Preserve working code
- Introduce testing
- Gradual improvement
- Make code self documenting
- Instill confidence in changes
- Develop for maintenance

*for some definition of "structure"

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The Cost of Testing

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Whether or not you write an automated test, you need to make sure the code you are writing works.

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Testing Strategies

Test Everything
on every feature

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Test the change
you just made

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Write Automated
tests and run them
continuously

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Testing Strategies

Test Everything on every feature

Test the change you just made

Write Automated tests and run them continuously

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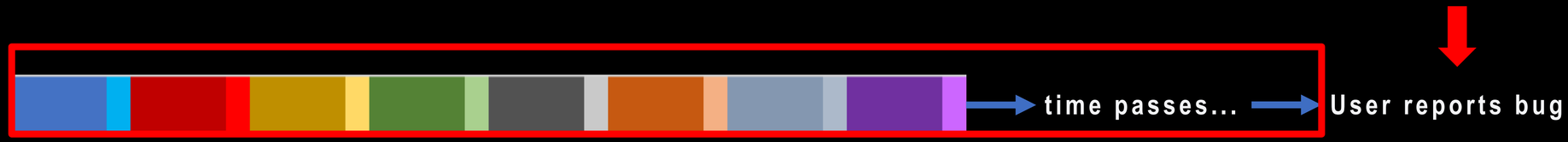
Testing Strategies

Test Everything
on every feature

Test the change
you just made



Write Automated
tests and run them
continuously

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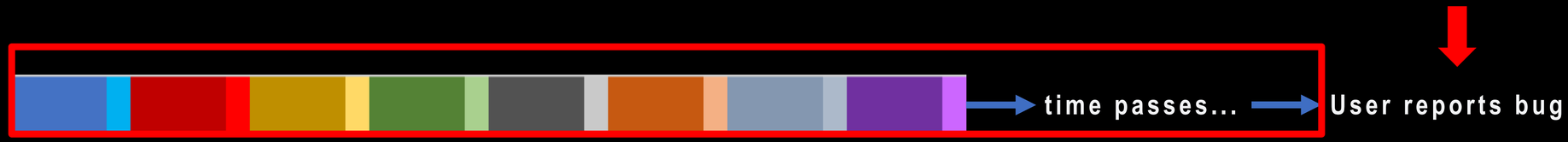
Testing Strategies

Test Everything on every feature

Test the change you just made



Write Automated tests and run them continuously

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Testing Strategies

Test Everything
on every feature

Test the change
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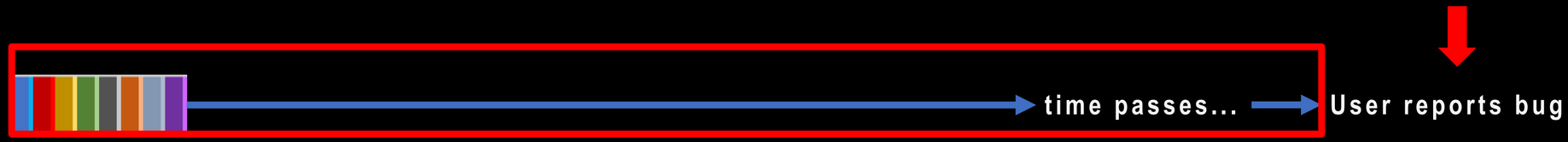

Write Automated
tests and run them
continuously

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Automated testing...

- reduces development time[1]
- reduces field defects[2]
- reduces costs over project lifetime[3]

1. https://tinyurl.com/vkj8tbxu
2. https://tinyurl.com/4nkrt5vv
3. https://tinyurl.com/3ccxscrs

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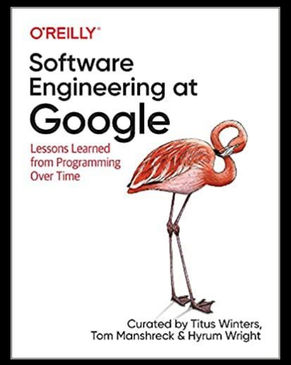
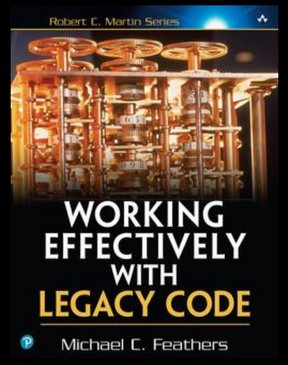
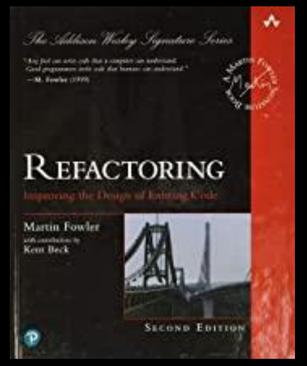
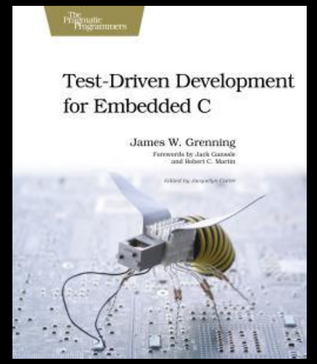
There are many resources available









accu
professionalism in programming

IEEE

acm Association for Computing Machinery

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Keep in mind...

- This requires determination
- Code performance may be sacrificed
- Best practices will be violated
- You will fix other people's code
- You will own the changes you make
- Soft skills required
- Everything is a judgement call

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- This requires determination
- Code performance may be sacrificed
- Best practices will be violated
- You will fix other people's code
- You will own the changes you make
- Soft skills required
- Everything is a judgement call
- This never ends

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Can't we just use tools?

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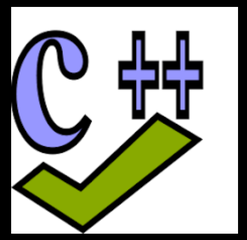
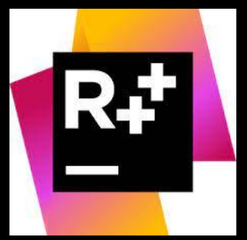
Many Tools Exist





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However...

- Not everyone will use them
- Not all code will work with them
- They require maintenance too
- Can be intrusive or leave artifacts in code
- Not available on all platforms
- Understand what the tools are automating

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Part I: Getting Started

Add A Test

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Add A Test: Hijack a Function

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Complicated Dependencies

```
class ActiveAssetsPage : public UI::Page {
 public:
   ActiveAssetsPage(UI::Page& parent, SQLDB dbId);
   void OnShow() override;
 private:
   UIList mAssetList
   std::vector<Asset> mFilteredAssets;
   AssetDatabase mDB;
};
```

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Complicated Dependencies

```
class ActiveAssetsPage : public UI::Page {
 public:
   ActiveAssetsPage(UI::Page& parent, SQLDB dbId);
   const Asset& GetNextAsset(AssetId id, AssetFilter filter) const;
   void OnShow() override;
 private:
   UIList mAssetList
   std::vector<Asset> mFilteredAssets;
   AssetDatabase mDB;
};
```

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Complicated Dependencies

```
class ActiveAssetsPage : public UI::Page {
 public:
   ActiveAssetsPage(UI::Page& parent, SQLDB dbId);
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   void OnShow() override;
 private:
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};
```

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Complicated Dependencies

```
class ActiveAssetsPage : public UI::Page {
 public:
   ActiveAssetsPage(UI::Page& parent, SQLDB dbId);
   const Asset& GetNextAsset(AssetId id, AssetFilter filter) const;
   void OnShow() override;
 private:
   UIList mAssetList
   std::vector<Asset> mFilteredAssets;
   AssetDatabase mDB;
};
```

```
void ActiveAssetsPage::OnShow() {
 #if ENABLE_TEST
 TestGetNextAsset(*this, mDB);
 #else
  //normal UI OnShow stuff
 #endif
}
```

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Complicated Dependencies

```
#if ENABLE_TEST
static void TestGetNextAsset(ActiveAssetPage& page, AssetDatabase& db) {
  const auto print_assert = ()(bool test, int line) {
    std::cout << (test ? "PASSED" : "FAILED) << " on line " << line;
  };
```

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Complicated Dependencies

```
#if ENABLE_TEST
static void TestGetNextAsset(ActiveAssetPage& page, AssetDatabase& db) {
  const auto print_assert = ()(bool test, int line) {
    std::cout << (test ? "PASSED" : "FAILED) << " on line " << line;
  };

  db.clear();
  print_assert(INVALID_ID == page.GetNextAssetInList( 0_id, AT::All ).id, __LINE__ );
```

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Complicated Dependencies

```
#if ENABLE_TEST
static void TestGetNextAsset(ActiveAssetPage& page, AssetDatabase& db) {
  const auto print_assert = ()(bool test, int line) {
    std::cout << (test ? "PASSED" : "FAILED) << " on line " << line;
  };

  db.clear();
  print_assert(INVALID_ID == page.GetNextAssetInList( 0_id, AT::All ).id, __LINE__ );

  Asset a1(0_id);
  a.type = AT::Dog;
  db.AddAsset(a1);
  print_assert(0_id == page.GetNextAssetInList( 0_id, AT::All ).id, __LINE__ );
  print_assert(INVALID_ID == page.GetNextAssetInList(0_id, AT::Cat), __LINE__);
  print_assert(0_id == page.GetNextAssetInList(0_id, AT::Dog), __LINE__);
```

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Complicated Dependencies

```
#if ENABLE_TEST
static void TestGetNextAsset(ActiveAssetPage& page, AssetDatabase& db) {
  const auto print_assert = ()(bool test, int line) {
    std::cout << (test ? "PASSED" : "FAILED) << " on line " << line;
  };

  db.clear();
  print_assert(INVALID_ID == page.GetNextAssetInList( 0_id, AT::All ).id, __LINE__ );

  Asset a1(0_id);
  a.type = AT::Dog;
  db.AddAsset(a1);
  print_assert(0_id == page.GetNextAssetInList( 0_id, AT::All ).id, __LINE__ );
  print_assert(INVALID_ID == page.GetNextAssetInList(0_id, AT::Cat), __LINE__);
  print_assert(0_id == page.GetNextAssetInList(0_id, AT::Dog), __LINE__);

  for(AssetId i = 1_id; i < 20_id; i++) {
    Asset a(i);
    a.type = AT::Cat;
    db.AddAsset(i);
  }

  print_assert(1_id == page.GetNextAssetInList( 0_id, AT::All ).id, __LINE__ );
  print_assert(1_id == page.GetNextAssetInList( 0_id, AT::Cat ).id, __LINE__ );
  print_assert(2_id == page.GetNextAssetInList( 1_id, AT::Cat ).id, __LINE__ );
  print_assert(1_id == page.GetNextAssetInList( 19_id, AT::Cat ).id, __LINE__ );
  print_assert(0_id == page.GetNextAssetInList( 19_id, AT::All ).id, __LINE__ );
  print_assert(0_id == page.GetNextAssetInList( 19_id, AT::Dog ).id, __LINE__ );
  print_assert(0_id == page.GetNextAssetInList( 1_id, AT::Dog ).id, __LINE__ );
}
#endif
```

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Discovery Testing

What does this function do?

```
proc_rf_msg(buff, true, false, 7);
```

```
proc_rf_msg(uint8* buff, bool is_full, bool is_actvty, size_t sz);
```

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Discovery Testing

```
void hndl_new_pkt(rf_pkt* pkt, size_t size) {

...

proc_rf_msg(buff, true, false, 7);
```

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Discovery Testing

```
void hndl_new_pkt(rf_pkt* pkt, size_t size) {

...

//proc_rf_msg(buff, true, false, 7);
```

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Discovery Testing

```
void hndl_new_pkt(rf_pkt* pkt, size_t size) {

...

//proc_rf_msg(buff, true, false, 7);
proc_rf_msg(nullptr, false, false, 0);
```

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Discovery Testing

```
void hndl_new_pkt(rf_pkt* pkt, size_t size) {

...

//proc_rf_msg(buff, true, false, 7);
proc_rf_msg(nullptr, false, false, 0);

activity activity;
activity.start_loc = {32.2226, 110.9747};
activity.end_loc = {39.8175, 104.7509};
proc_rf_msg(&activity, true, true, sizeof(activity)};
...
}
```

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Discovery Testing

```
void hndl_new_pkt(rf_pkt* pkt, size_t size) {

...

//proc_rf_msg(buff, true, false, 7);
proc_rf_msg(nullptr, false, false, 0);

activity activity;
activity.start_loc = {32.2226, 110.9747};
activity.end_loc = {39.8175, 104.7509};
proc_rf_msg(&activity, true, true, sizeof(activity)};
...
}

void proc_rf_msg(void* buf, bool is_verified, bool is_activity, size_t buf_size) {
...

if(is_activity) {
 activity* activ = (activity)buf;
 int activity_distance = 0;
 //convoluted code doing something with distance
 //complicated code to calculate elevation
 // incomprehensible code to calculate calories burned
 activ.calories = kcals;
 }
 ...
}
```

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Discovery Testing

```
static int test_distance = 0;

void hndl_new_pkt(rf_pkt* pkt, size_t size) {
...
//proc_rf_msg(buff, true, false, 7);
proc_rf_msg(nullptr, false, false, 0);

activity activity;
activity.start_loc = {32.2226, 110.9747};
activity.end_loc = {39.8175, 104.7509};
proc_rf_msg(&activity, true, true, sizeof(activity)};
...
}

void proc_rf_msg(void* buf, bool is_verified, bool is_activity, size_t buf_size) {
...

if(is_activity) {
 activity* activ = (activity)buf;
 int activity_distance = 0;
 //convoluted code doing something with distance
 test_distance = dist;
 //complicated code to calculate elevation
 // incomprehensible code to calculate calories burned
 activ.calories = kcals;
 }
 ...
}
```

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Discovery Testing

```
static int test_distance = 0;

void hndl_new_pkt(rf_pkt* pkt, size_t size) {
...
//proc_rf_msg(buff, true, false, 7);
proc_rf_msg(nullptr, false, false, 0);

activity activity;
activity.start_loc = {32.2226, 110.9747};
activity.end_loc = {39.8175, 104.7509};
proc_rf_msg(&activity, true, true, sizeof(activity)};
if(test_distance != 1012) {
 printf("FAILED test_distance: %d", test_distance);
}
...
}

void proc_rf_msg(void* buf, bool is_verified, bool is_activity, size_t buf_size) {
...

if(is_activity) {
 activity* activ = (activity)buf;
 int activity_distance = 0;
 //convoluted code doing something with distance
 test_distance = dist;
 //complicated code to calculate elevation
 // incomprehensible code to calculate calories burned
 activ.calories = kcals;
 }
 ...
}
```

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Add A Test: A New main

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Create a new build target

- Create a location to store tests, something like PRJ/TESTS
- Create a test package and new build manifest based on the simulator manifest

```
<manifest
  name="unit-test-only"
  version="1.0"
  format-version="7">
    <include path="./manifest-simulator.pkg.xml"/>
    <include path="../../PRJ/TESTS/tests.pkg.xml"/>
</manifest>
```

- Create a build flag like PRD_UNIT_TEST_BUILD to enable testing

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Create a new build target (continued)

- Enable the PRD_UNIT_TEST_BUILD flag and copy all the flags from the simulator
- Add a new build configuration copied from the simulator to the project's INI file and point to the test files

```
[simulator]
sys.cobra          = configs/simulator.flags.cfg

[unit-tests]
parent             = simulator
sys.target         = test
sys.config         = configs/test.flags.cfg
sys.pkgtool        = PRD//manifest-test.pkg.xml
```

- At this point, test that we can build the test product

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Add the test framework

- Download your favorite test framework
- And to the unit test package manifest

```
<manifest
  name="unit-test-only"
  version="1.0"
  format-version="7">
    <include path="./manifest-simulator.pkg.xml"/>
    <include
      path="../../modules/external/googletest/googletest.pkg.xml"
      scope="public"/>
    <include path="../../PRJ/TESTS/tests.pkg.xml"/>
</manifest>
```

- And set appropriate configuration flags

```
PARENT CONFIG simulator.flags.cfg
OUTPUT PATH
XML PATH ..\..\PRJ\TESTS\tests.config.xml
XML PATH ..\..\modules\external\googletest\googletest.config.xml

GOOGLEMOCK_CONFIG_ENABLED                          true          FALSE
GOOGLETEST_CONFIG_ENABLED                          false         TRUE
GOOGLETEST_CONFIG_USE_ENTRY_POINT                  false         FALSE
PRD_UNIT_TEST_BUILD                                false         TRUE
```

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Hijack the Simulator's main

- Conditionally remove the simulator's main from the test build's manifest

```
<!-- need to exclude the main function from the simulator since the test suite has its own -->
<if condition="not defined PRD_UNIT_TEST_BUILD or PRD_UNIT_TEST_BUILD == FALSE">
  <source path='main.cpp' />
</if>
```

- Add a new main for the testing framework

```
#include <gtest/gtest.h>

// This class is setup and torn down once for the
// entire test suite
class TestEnvironment : public ::testing::Environment {
 public:
  void SetUp() override {}

  void TearDown() override {}
};

int main(int argc, char** argv) {
  ::testing::InitGoogleTest(&argc, argv);
  ::testing::AddGlobalTestEnvironment(new TestEnvironment);
  return RUN_ALL_TESTS();
}
```

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Our First Test

- **Add a test file with a failing test**

PRJ/TESTS/FirstTest.cpp

```
#include <gtest/gtest.h>

TEST(FirstTest, DoesThisCompile) {
  EXPECT_TRUE(false);
}
```

- **Build our test**

```
$> waf --product=unit_tests --mode=development
```

- **Run our test**

```
$> out/unit-tests/development/test.exe
```

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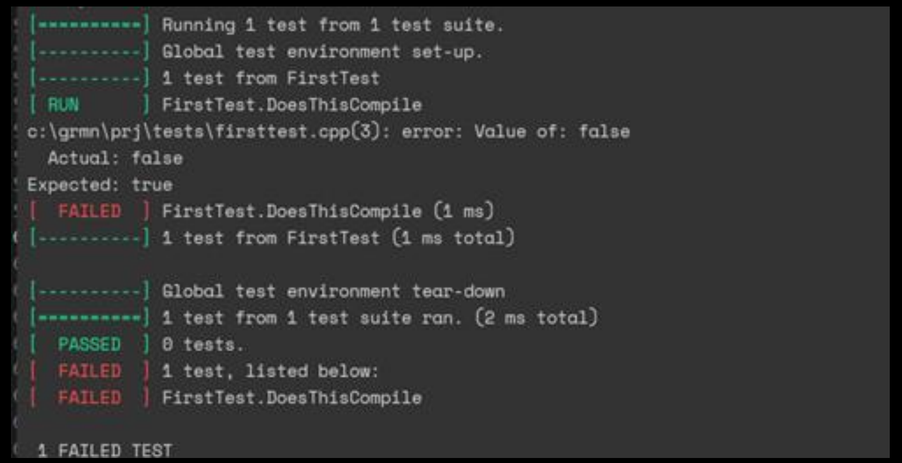
Our First Test

- **Add a test file with a failing test**

PRJ/TESTS/FirstTest.cpp

```
#include <gtest/gtest.h>

TEST(FirstTest, DoesThisCompile) {
  EXPECT_TRUE(false);
}
```



- **Build our test**

```
$> waf --product=unit_tests --mode=development
```

- **Run our test**

```
$> out/unit-tests/development/test.exe
```

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Add A Test: Bottom Up

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Start out similarly to A New Main

- Create an empty build configuration
- Add the PRD_UNIT_TEST_BUILD build flag
- Add the test framework

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Separate out Testable from Non-Testable

```
<!-- All testable translation units go here -->
<!-- UNIT_TEST_BUILD == TRUE -->

<source path ='share_code.cpp' />

<!-- All un-testable translation units go here -->
<ifeq name="UNIT_TEST_BUILD" value="FALSE">
 <!-- Everything else -->
</ifeq>
```

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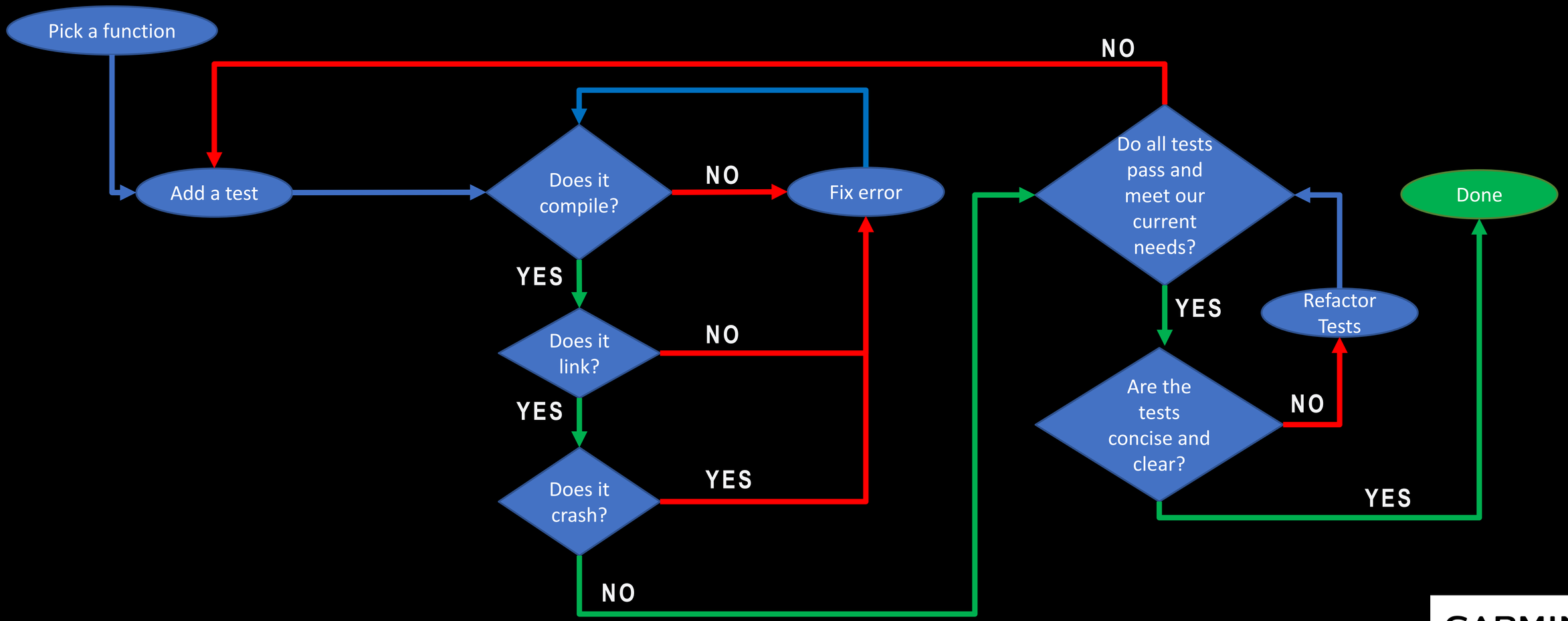
Bottom Up Testing Workflow



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Part II: Dealing with Dependencies

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Add them to the test project

- Isolated
  - avoid cascading dependencies
- Light-weight
  - avoid long running stuff like file or network access

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Create Type Only Headers

Header_to_test.hpp

```
#include "MLB_pub.hpp"

class CodeToTest {
  public:
    void SetModel( MLB::Model aModel);
    MLB::Model GetModel() const;

  private:
    MLB::Model mModel;
};
```

MLB_pub.hpp

```
#include "GPSReceiver.hpp"
#include "XMLParser.hpp"
// many more includes

namespace MLB{
// 200 lines of definitions, function declarations

  enum Model {
    AB_2020,
    TT_2251
    ...
  };

// and more code...
}
```

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Create Type Only Headers

Header_to_test.hpp

```
#include "MLB_pub_types.hpp"

class CodeToTest {
  public:
    void SetModel( MLB::Model aModel);
    MLB::Model GetModel() const;

  private:
    MLB::Model mModel;
};
```

MLB_pub_types.hpp

```
namespace MLB
 enum Model {
   AB_2020,
   TT_2251
   ...
 };
}
```

MLB_pub.hpp

```
#include "GPSReceiver.hpp"
#include "XMLParser.hpp"
// many more includes
#include "MLB_pub_types.hpp"

namespace MLB{
// all the stuff we don't need right now
}
```

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Stub out what you need

Settings.cpp

```
#include "FileSystem.hpp"


...

void Settings::SaveBacklightTimeout( Milliseconds ms) {
 //...

 if(WRITE_FAIL ==
   mSettingsFile.write(Setting::BackLight, ms.to_int()) {
  //error handling
 }
 // ...
}
```

FileSystem.hpp

```
#include "DiskDriver.h"
#include "JSONParser.hpp"
// many more includes

enum error_code { WRITE_FAIL, READ_FAIL, OK };

struct DataTag {
  Id id;
  size_t data_size;
};

class FileSystem : public DBInterface {
 //...
 error_code write( DataTag tag, const void* data);
 error_code read(DataTag tag, void* data) const;
 error_code scan(size_t offset);
 //...
};
```

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Stub out what you need

Settings.cpp

```
#include "FileSystem.hpp"


...

void Settings::SaveBacklightTimeout( Milliseconds ms) {
 //...

 if(WRITE_FAIL == mSettingsFile.write(Setting::BackLight,
ms.to_int()) {
  //error handling
 }
 // ...
}
```

FileSystem.hpp

```
#include "DiskDriver.h"
#include "JSONParser.hpp"
// many more includes

enum error_code { WRITE_FAIL, READ_FAIL, OK };

struct DataTag {
  Id id;
  size_t data_size;
};

class FileSystem : public DBInterface {
 //...
 error_code write( DataTag tag, const void* data);
 error_code read(DataTag tag, void* data) const;
 error_code scan(size_t offset);
 //...
};
```

STUBS/FileSystem.hpp

```
#include <map>
#include <vector>

enum error_code { WRITE_FAIL, READ_FAIL, OK };
using Id = int;
struct DataTag {
  Id id;
  size_t data_size;
};

class FileSystem {

 error_code write( DataTag tag, const void* data) {
  std::vector<byte> v(tag.data_size);
  memcpy(v.data(),data, tag.data_size);
  mStorage[tag.id] = v;
  return OK;
}

private:
 std::map<Id, std::vector<byte>> mStorage;
}
```

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Isolate a Global

RFC_pub.h

```
extern Window next_window;
```

rfc_dd.cpp

```
Window next_window = INV_WINDOW;

//8 uses in this file
```

Conditionally included if BUILD == DD_BUILD

rfc_hh.cpp

```
Window next_window = MY_WINDOW;

//93 uses in this file
```

Conditionally included if BUILD == HH_BUILD

rfc_common.cpp

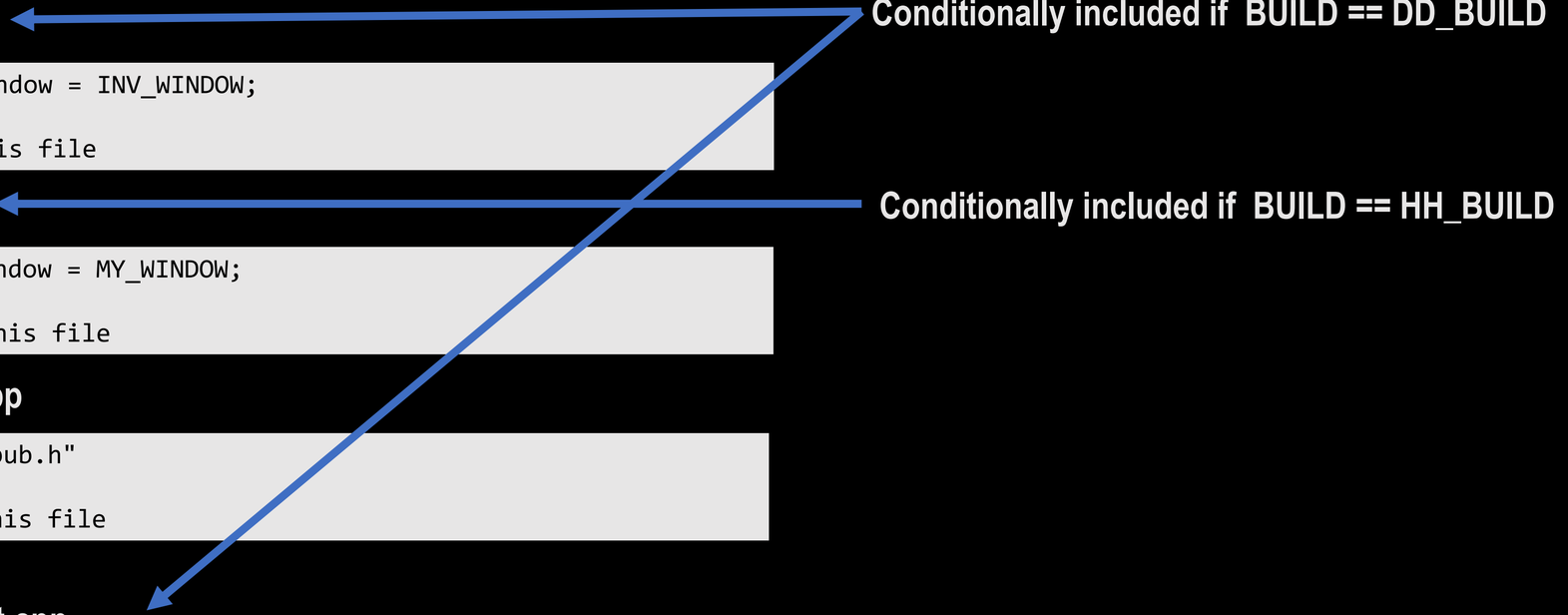
```
#include "RFC_pub.h"

//19 uses in this file
```

rfc_bark_detect.cpp

```
#include "RFC_pub.h"

//2 uses in this file
```



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Isolate a Global

RFC_pub.h

```
extern Window next_window;
```

rfc_dd.cpp

```
Window next_window = INV_WINDOW;

//8 uses in this file
```

rfc_hh.cpp

```
Window next_window = MY_WINDOW;

//93 uses in this file
```

rfc_common.cpp

```
#include "RFC_pub.h"

//19 uses in this file
```

rfc_bark_detect.cpp

```
#include "RFC_pub.h"

//2 uses in this file
```

RFC_pub.h

```
void SetNextWindow(Window nextWindow);
Window GetNextWindow();
```

rfc_dd.cpp

```
#include "RFC_pub.h"

//All assignments use Set, all reads use Get
```

rfc_hh.cpp

```
#include "RFC_pub.h"
//All assignments use Set, all reads use Get
```

rfc_common.cpp

```
#include "RFC_pub.h"

namespace {
 Window next_window = RFC_INV_WINDOW;
}
void SetNextWindow(Window nextWindow) { next_window = nextWindow; }
Window GetNextWindow() { return next_window; }

//All assignments use Set, all reads use Get
```

rfc_bark_detect.cpp

```
#include "RFC_pub.h"

//All assignments use Set, all reads use Get
```

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Testing with Time

BackLightManager.hpp

```
class BackLightManager {
public:
 void SetTimeout(Milliseconds timeout);
 bool IsBacklightOn() const;
 void TurnBacklightOn();

private:
 StartBackgroundProcessingThread();
 Milliseconds mTimeout = 1_hr;
 bool mBackLightOn = false;
}
```

BackLightManager.cpp

```
#include "Timer/TimerAPI.h"

BackLightManager::TurnBacklightOn() {
 mBacklightOn = true;
 StartBackgroundProcessingThread();
}

void BackLightManager::StartBackgroundProcessingThread() {
  StartThread([this]() {
    const auto start_time = get_tick();
    const auto off_time = start_time + mTimeout;
    while(start_time + get_tick() < off_time) {
     //do some other stuff or sleep or whatever
    }
    mBackLightOn = false;
  });
}
```

modules/Timer/TimerAPI.c

```
#include "TimerAPI.h"
// many more includes

uint32_t get_tick() {
  //OS stuff to get the real time
  return tick;
};
```

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Testing with Time

PRJ/TESTS/TimerAPI_test.hpp

```
extern "C" {
 //force C linking for link time sub
 #include "../../modules/Timer/TimerAPI.h"
}

void TEST_set_tick(uint32_t newTime);
```

PRJ/TESTS/TimerAPI_test.cpp

```
#include "TimerAPI_test.hpp"

static uint32_t time = 0;

void TEST_set_tick(uint32_t newTime) {
 time = newTime;
}

uint32_t get_tick() { return newTime; }
```

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Testing with Time

PRJ/TESTS/TimerAPI_test.hpp

```
extern "C" {
 //force C linking for link time sub
 #include "../../modules/Timer/TimerAPI.h"
}

void TEST_set_tick(uint32_t newTime);
```

PRJ/TESTS/TimerAPI_test.cpp

```
#include "TimerAPI_test.hpp"

static uint32_t time = 0;

void TEST_set_tick(uint32_t newTime) {
 time = newTime;
}

uint32_t get_tick() { return newTime; }
```

ProjectManifest

```
<!-- All testable translation units go here -->
<!-- UNIT_TEST_BUILD == TRUE -->

 <!-- TEST SUBSTITUTIONS -->
 <ifeq name="UNIT_TEST_BUILD" vale="TRUE">
    <source path='PRJ/TESTS/TimerAPI_test.cpp'/>
    <else>
      <source path='modules/Timer/TimerAPI.c"/>
    </else>
 </ifeq>

<!-- All un-testable translation units go here -->
<ifeq name="UNIT_TEST_BUILD" value="FALSE">
 <!-- Everything else -->
</ifeq>
```

GARMIN.

Testing with Time

BacklightTesting.cpp

```
#include "TimerAPI_test.hpp"

TEST(BackLightTests, BacklightTurnsOffAfterTime){

  uint32_t testTime = 100;
  TEST_set_tick(testTime);

  BackLightManager blm;
  blm.SetTimeout(1_hr);

  blm.TurnBacklightOn();
  testTime += 3590000;
  TEST_set_tick(testTime);
  EXPECT_TRUE(blm.IsBacklightOn());
  testTime += 100010;
  TEST_set_tick(testTime);
  EXPECT_FALSE(blm.IsBacklightOn());
}
```

PRJ/TESTS/TimerAPI_test.hpp

```
extern "C" {
 //force C linking for link time sub
 #include "../../modules/Timer/TimerAPI.h"
}

void TEST_set_tick(uint32_t newTime);
```

PRJ/TESTS/TimerAPI_test.cpp

```
#include "TimerAPI_test.hpp"

static uint32_t time = 0;

void TEST_set_tick(uint32_t newTime) {
 time = newTime;
}

uint32_t get_tick() { return newTime; }
```

ProjectManifest

```
<!-- All testable translation units go here -->
<!-- UNIT_TEST_BUILD == TRUE -->

 <!-- TEST SUBSTITUTIONS -->
 <ifeq name="UNIT_TEST_BUILD" vale="TRUE">
    <source path='PRJ/TESTS/TimerAPI_test.cpp'/>
    <else>
      <source path='modules/Timer/TimerAPI.c"/>
    </else>
 </ifeq>

<!-- All un-testable translation units go here -->
<ifeq name="UNIT_TEST_BUILD" value="FALSE">
 <!-- Everything else -->
</ifeq>
```

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Part III: The Scout Rule

“Try and leave this world a little better than you found it”

–Robert Bayden-Powell

Final Letter to the Scouts

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A Note on Refactoring...

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Ways to maintain sanity

- Do NOT refactor AND add new functionality at the same time
- ALWAYS commit "working" code
- Make ONE change per commit
- Give yourself a TIME LIMIT

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New Code

- New code should be tested
- Make a new function or class, test in isolation, then integrate into existing code

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Data Accessors

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C.131: Avoid trivial getters and setters

Reason A trivial getter or setter adds no semantic value; the data item could just as well be `public`.

Note The key to this rule is whether the semantics of the getter/setter are trivial. While it is not a complete definition of "trivial", consider whether there would be any difference beyond syntax if the getter/setter was a public data member instead. Examples of non-trivial semantics would be: maintaining a class invariant or converting between an internal type and an interface type.

https://isocpp.github.io/CppCoreGuidelines/CppCoreGuidelines#Rh-get

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Data Only Struct

```
struct Position {
 float lat;
 float lon;
};
```

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Data Only Struct

```
struct Position {
 float lat;
 float lon;
};
```

```
struct GeoPacket {
 GPS_fix_type fix_type;
 Position position;
 float course_true_degrees;
 float elevation_meters;
 float speed_mps;
};
```

GARMIN®

Data Only Struct

```
struct Position {
 float lat;
 float lon;
};
```

```
struct GeoPacket {
 GPS_fix_type fix_type;
 Position position;
 float course_true_degrees;
 float elevation_meters;
 float speed_mps;
};
```

```
struct WeatherPacket {
  struct {
    GeoPacket geo;
    size_t count;
    WeatherRequest s[8];
  } request;

  boolean has_geo;
  GeoPacket geo;
};
```

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Data Only Struct

```
struct Position {
 float lat;
 float lon;
};
```

```
struct GeoPacket {
 GPS_fix_type fix_type;
 Position position;
 float course_true_degrees;
 float elevation_meters;
 float speed_mps;
};
```

```
struct WeatherPacket {
  struct {
    GeoPacket geo;
    size_t count;
    WeatherRequest s[8];
  } request;

  boolean has_geo;
  GeoPacket geo;
};
```

```
struct SatellitePayload {
  SatPayloadT type;

  union {
    ActivationPayload activation;
    GenericBinaryPayload binary;
    DBAck database_ack;

    LocateRespPld locate_response;

    MailCheckPayload mail_check;

    PresetMessage preset;
    ReferencePointPayload reference_point;
    MapShare shared_map;

    TextMessageText text_message;

    TrackingPacket tracking;

    WeatherPacket weather;
  } data;
};
```

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Data Only Struct

```
struct Position {
 float lat;
 float lon;
};
```

```
struct GeoPacket {
 GPS_fix_type fix_type;
 Position position;
 float course_true_degrees;
 float elevation_meters;
 float speed_mps;
};
```

```
struct WeatherPacket {
  struct {
    GeoPacket geo;
    size_t count;
    WeatherRequest s[8];
  } request;

  boolean has_geo;
  GeoPacket geo;
};
```

```
struct SatellitePayload {
  SatPayloadT type;

  union {
    ActivationPayload activation;
    GenericBinaryPayload binary;
    DBAck database_ack;

    LocateRespPld locate_response;

    MailCheckPayload mail_check;

    PresetMessage preset;
    ReferencePointPayload reference_point;
    MapShare shared_map;

    TextMessageText text_message;

    TrackingPacket tracking;

    WeatherPacket weather;
  } data;
};
```

```
void AddGeoWeatherReqPayload(StallitePayload& payload) {
  payload.type = SPT_WEATHER;
  payload.weather.has_geo = true;
  payload.weather.request.geo.position.lat = currentPos.lat;
  payload.weather.request.geo.position.lon = currentPos.lon;
}
```

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Data Only Struct

```
struct Position {
 float lat;
 float lon;
};
```

```
struct GeoPacket {
 GPS_fix_type fix_type;
 Position position;
 float course_true_degrees;
 float elevation_meters;
 float speed_mps;
};
```

```
struct WeatherPacket {
  struct {
    GeoPacket geo;
    size_t count;
    WeatherRequest s[8];
  } request;

  boolean has_geo;
  GeoPacket geo;
};
```

```
struct SatellitePayload {
  SatPayloadT type;

  union {

    TrackingPacket tracking;

    WeatherPacket weather;
  } data;
};
```

```
void AddGeoWeatherReqPayload(StallitePayload& payload) {
  payload.type = SPT_WEATHER;
  payload.weather.has_geo = true;
  payload.weather.request.geo.position.lat = currentPos.lat;
                                             currentPos.lon;
```

```
void AddGeoWeatherReqPayload(StallitePayload& payload) {
  GeoRequest geo;
  geo.SetPosition(currentPos);
  WeatherPayload weather;
  weather.SetRequest(geo);
  payload.Add(weather);
}
```

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Remember our extern isolation?

RFC_pub.h

```
void SetNextWindow(Window nextWindow);
Window GetNextWindow();
```

rfc_dd.cpp

```
#include "RFC_pub.h"

//All assignments use Set, all reads use Get
```

rfc_hh.cpp

```
#include "RFC_pub.h"
//All assignments use Set, all reads use Get
```

rfc_common.cpp

```
#include "RFC_pub.h"

namespace {
 Window next_window = RFC_INV_WINDOW;
}
void SetNextWindow(Window nextWindow) { next_window = nextWindow; }
Window GetNextWindow() { return next_window; }

//All assignments use Set, all reads use Get
```

rfc_bark_detect.cpp

```
#include "RFC_pub.h"

//All assignments use Set, all reads use Get
```

- Single definition
- Prevent accidental change when reading
- Ability to add diagnostics
- Reduce locations where variable is changed
- Ability to mock or override reads/writes
- Prevent proliferation to other files

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Tip: Adding Call Site Diagnostics

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If you can use C++20

BTPairingViewModel.h

```
void UpdatePairingState(PairingState newState);
```

BTPairingViewModel.cpp

```
void UpdatePairingState(PairingState newState) {
  ...
}
```

BTPairingViewModel.h

```
#include <source_location>

void UpdatePairingState(PairingState newState,
  std::source_location loc = std::source_location::current());
```

BTPairingViewModel.cpp

```
#include <source_location>

void UpdatePairingState(PairingState newState, std::source_location loc) {
  DBG_PRINT("call %s from %s:%d", __func__, loc.file_name(), loc.line());
  ...
}
```

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C or pre-C++20

BTPairingViewModel.h

```
void UpdatePairingState(PairingState newState);
```

BTPairingViewModel.h

```
void UpdatePairingStateTmp(PairingState newState);

static void UpdatePairingStateLog(PairingState newState, const char* file, int line){
 DBG_PRINT("call %s from %s:%d", __func__, file, line);
 UpdatePairingStateTmp(newState);
}

#define UpdatePairingState(state) UpdatePairingStateLog(state, __FILE__, __LINE__);
```

BTPairingViewModel.cpp

```
void UpdatePairingState(PairingState newState) {
...
}
```

BTPairingViewModel.cpp

```
void UpdatePairingStateTmp(PairingState newState) {
  ...
}
```

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Use Public Functions, Even In Private

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Following member variables

VHFDevice.hpp

```
class VHFDevice {
public:
 UpdateRate GetUpdateRate() const;
 void SetUpdateRate(UpdateRate rate);
 bool IsDeviceAsleep() const;

private:
 void NewPacketCallback(Packet pkt);
 UpdateRate mCurrentUpdateRate;
};
```

VHFDevice.cpp

```
void VHFDevice::NewPacketCallback ( Packet pkt) {
...
  if(pkt.updateRate == mCurrentUpdateRate) {
    return;
  }

  if(mCurrentUpdateRate == UpdateRate::Asleep) {
   WakeUp();
  }

  mCurrentUpdateRate = pkt.updateRate;
  if(pkt.updateRate == UpdateRate::Asleep) {
   VHFRadio_Set_Sleep_Enabled(1);
  }

  ...
}
```

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Following member variables

VHFDevice.hpp

```
class VHFDevice {
public:
 UpdateRate GetUpdateRate() const;
 void SetUpdateRate(UpdateRate rate);
 bool IsDeviceAsleep() const;

private:
 void NewPacketCallback(Packet pkt);
 UpdateRate mCurrentUpdateRate;
};
```

VHFDevice.cpp

```
void VHFDevice::NewPacketCallback ( Packet pkt) {
...
  if(pkt.updateRate == mCurrentUpdateRate) {
    return;
  }

  if(mCurrentUpdateRate == UpdateRate::Asleep) {
   WakeUp();
  }

  mCurrentUpdateRate = pkt.updateRate;
  if(pkt.updateRate == UpdateRate::Asleep) {
   VHFRadio_Set_Sleep_Enabled(1);
  }

  ...
}
```

VHFDevice.cpp

```
void VHFDevice::NewPacketCallback ( Packet pkt) {
...
  if(pkt.updateRate == GetUpdateRate()) {
    return;
  }

  if(IsDeviceAsleep()) {
   WakeUp();
  }

  SetUpdateRate(pkt.updateRate);
  ...
}
```

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And what does this gain us?

VHFDevice.cpp

```
void VHFDevice::NewPacketCallback ( Packet pkt) {
...
  if(pkt.updateRate == GetUpdateRate()) {
    return;
  }

  if(IsDeviceAsleep()) {
   WakeUp();
  }

  SetUpdateRate(pkt.updateRate);

  ...
}
```

- Single path for external and internal callers
- Dogfooding public API
- Changes to logic occur in one location
- Ability to override for testing

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Ease cognitive burden

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Is my bug in here somewhere?

```
void process_barks(uint8 dir_idx, packet& pkt) {
 ...
 validate_pkt(pkt);
 ...
 calculate_bark_rate(&pkt);
 ...
 send_notification(pkt);
 ...
}
```

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Does pkt get modified here?

```
void process_barks(uint8 dir_idx, const packet& pkt) {
 ...
 validate_pkt(pkt);
 ...
 calculate_bark_rate(&pkt);
 ...
 send_notification(pkt);
 ...
}
```

error: binding reference of type 'packet&' to 'const packet' discards qualifiers

error: invalid conversion from 'const packet*' to 'packet*'

Compiles, we can ignore this function

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Does pkt get modified here?

```
void process_barks(uint8 dir_idx, const packet& pkt) {
 ...
 validate_pkt(pkt);
 ...
 calculate_bark_rate(&pkt);
 ...
 send_notification(pkt);
 ...
}
```

error: binding reference of type 'packet&' to 'const packet' discards qualifiers

error: invalid conversion from 'const packet*' to 'packet*'

Compiles, we can ignore this function

```
void validate_pkt(const packet& pkt){
 ...
}

void calculate_bark_rate(const packet* pkt) {
...
}
```

error: assignment of member 'packet::is_valid' in read-only object

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Does pkt get modified here?

```
void process_barks(uint8 dir_idx, const packet& pkt) {
 ...
 validate_pkt(pkt);
 ...
 calculate_bark_rate(&pkt);
 ...
 send_notification(pkt);
 ...
}
```

error: binding reference of type 'packet&' to 'const packet' discards qualifiers

Compiles, we can ignore this function

Compiles, we can ignore this function

```
void validate_pkt(const packet& pkt){
 ...
}
```

error: assignment of member 'packet::is_valid' in read-only object

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Reduce possible bug locations

```
void process_barks(uint8 dir_idx, packet& pkt) {
 ...
 validate_pkt(pkt);
 ...
 calculate_bark_rate(&pkt);
 ...
 send_notification(pkt);
 ...
}
```

Need to look into this function since it does modify pkt

Compiles, we can ignore this function

Compiles, we can ignore this function

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Reduce scope and const

```
void validate_pkt(packet& pkt) {
  bark_cnt* bark_cnt;
  bark_cnt last_bark_cnt;
  uint32 now;
  bool bark_cnt_is_delta_based;
```

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Reduce scope and const

```
void validate_pkt(packet& pkt) {
  bark_cnt* bark_cnt;
  bark_cnt last_bark_cnt;
  uint32 now;
  bool bark_cnt_is_delta_based;
```

Reduce scope to first usage, then add const

```
const auto now = timer_function();

if (INVALID_INDEX!= pkt.dir_idx) {
  const auto last_bark_cnt = pkt.bark_cnt_last_bark_hd_rate_update;
  const auto* bark_cnt = &pkt.bark_info;
  const auto bark_cnt_is_delta_based = pkt.bark_hd_info_is_delta;
```

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Reduce scope and const

```
const auto now = timer_function();

if (INVALID_INDEX!= pkt.dir_idx) {
  const auto last_bark_cnt = pkt.bark_cnt_last_bark_hd_rate_update;
  const auto* bark_cnt = &pkt.bark_info;
  const auto bark_cnt_is_delta_based = pkt.bark_hd_info_is_delta;
```

104 lines later...

```
// add "potential" bark back
*bark_cnt += asset_item->potential_bark_to_ignore;
```

Cannot assign to variable 'bark_cnt' with const-qualified type 'const bark_cnt' (aka 'const unsigned short')

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Reduce scope and const

```
const auto now = timer_function();

if (INVALID_INDEX!= pkt.dir_idx) {
  const auto last_bark_cnt = pkt.bark_cnt_last_bark_hd_rate_update;
  auto* bark_cnt = &pkt.bark_info;
  const auto bark_cnt_is_delta_based = pkt.bark_hd_info_is_delta;
```

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Document understanding

```
/**
*Adds the specified track point to the temporary course
*/
void add_tpt_to_temp_course(HANDLE file_hndl, uint16 trkpt_cnt,
                                    const position* posn, uint16_t alt) {
  Record rcrd_mesg;
  if (trkpt_cnt == 0) {
    rcrd_mesg.start_position_lat = (int32_t)posn->lat;
    rcrd_mesg.start_position_long = (int32_t)posn->lon;
    total_distance = 0.0f;
  }

  /*--------------------------------------
  Keep track of cumulative
  --------------------------------------*/
  if (trkpt_cnt > 0) {
    int32_t alpha_scale = 0;
    const int32_t lat = (last_posn.lat + posn->lat) / 2;
    lon_scale(lat, &alpha_scale, NULL);

    const uint32_t delta_distance_sc =
                compute_dist(posn, &last_posn, &alpha_scale, NULL);
    const float delta_distance = (float)(SEMI_TO_MT * delta_distance_sc);
    total_distance += delta_distance;
  }
...
}
```

GARMIN®

Document understanding

```
/**
*Adds the specified track point to the temporary course
*/
void add_tpt_to_temp_course(HANDLE file_hndl, uint16 trkpt_cnt,
                                    const position* posn, uint16_t alt) {
  Record rcrd_mesg;
  if (trkpt_cnt == 0) {
    rcrd_mesg.start_position_lat = (int32_t)posn->lat;
    rcrd_mesg.start_position_long = (int32_t)posn->lon;
    total_distance = 0.0f;
  }

  /*--------------------------------------
  Keep track of cumulative
  --------------------------------------*/
  if (trkpt_cnt > 0) {
    int32_t alpha_scale = 0;
    const int32_t lat = (last_posn.lat + posn->lat) / 2;
    lon_scale(lat, &alpha_scale, NULL);

    const uint32_t delta_distance_sc =
                compute_dist(posn, &last_posn, &alpha_scale, NULL);
    const float delta_distance = (float)(SEMI_TO_MT * delta_distance_sc);
    total_distance += delta_distance;
  }
...
}
```

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Document understanding

```
/**
*Adds the specified track point to the temporary course
*/
void add_tpt_to_temp_course(HANDLE file_hndl, uint16 trkpt_cnt,
                                  const position* posn, uint16_t alt) {
  Record rcrd_mesg;
  if (trkpt_cnt == 0) {
    rcrd_mesg.start_position_lat = (int32_t)posn->lat;
    rcrd_mesg.start_position_long = (int32_t)posn->lon;
    total_distance = 0.0f;
  }

  /*--------------------------------------
  Keep track of cumulative
  --------------------------------------*/
  if (trkpt_cnt > 0) {
    int32_t alpha_scale = 0;
    const int32_t lat = (last_posn.lat + posn->lat) / 2;
    lon_scale(lat, &alpha_scale, NULL);

    const uint32_t delta_distance_sc =
                 compute_dist(posn, &last_posn, &alpha_scale, NULL);
    const float delta_distance = (float)(SEMI_TO_MT * delta_distance_sc);
    total_distance += delta_distance;
  }
...
}
```

```
enum distance_calc_type { DISTANCE_RESET, DISTANCE_ACCUMULATE };

/**
*Adds the specified track point to the temporary course
*and either reset or add to the total course distance
*/
static void add_tpt_to_temp_course(FFS_fhndl_type file_hndl,
                                   distance_calc_type distance_calc,
                                   const position *posn, uint16_t alt) {
  Record rcrd_mesg;
   if (distance_calc == DISTANCE_RESET) {
     rcrd_mesg.start_position_lat = (int32_t)posn->lat;
     rcrd_mesg.start_position_long = (int32_t)posn->lon;
     total_distance = 0.0f;
   } else if (distance_calc == DISTANCE_ACCUMULATE) {
    int32_t alpha_scale = 0;
    const int32_t lat = (last_posn.lat + posn->lat) / 2;
    lon_scale(lat, &alpha_scale, NULL);

    const uint32_t delta_distance_sc =
                 compute_dist(posn, &last_posn, &alpha_scale, NULL);
    const float delta_distance = (float)(SEMI_TO_MT * delta_distance_sc);
    total_distance += delta_distance;
  }

...
}
```

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RAII

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Prevent Maintenance Resource bugs

```
void updateColor(ID itemId, Color newColor) {
  ReserveMutex(&itemMutex);
  item* itemToChange = get_item_from_id(itemId);
  if(itemToChange == NULL) {
    ReleaseMutex(&itemMutex);
    return;
  }

  itemToChange->SetColor(newColor);
  ReleaseMutex(&itemMutex);
}
```

GARMIN®

Prevent Maintenance Resource bugs

```
void updateColor(ID itemId, Color newColor) {
  ReserveMutex(&itemMutex);
  item* itemToChange = get_item_from_id(itemId);
  if(itemToChange == NULL) {
     ReleaseMutex(&itemMutex);
    return;
  }

  itemToChange->SetColor(newColor);
  ReleaseMutex(&itemMutex);
}
```

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Prevent Maintenance Resource bugs

```
void updateColor(ID itemId, Color newColor) {
  ReserveMutex(&itemMutex);
  item* itemToChange = get_item_from_id(itemId);
  if(itemToChange == NULL) {
    ReleaseMutex(&itemMutex);
    return;
  }

  itemToChange->SetColor(newColor);
  ReleaseMutex(&itemMutex);
}
```

```
struct MutexLocker {
 MutexLocker(Mutex& mutex) : mMutex(mutex) {
   ReserveMutex(&mutex);
 }
  ~MutexLocker() { ReleaseMutex(&mMutex); }
 private:
   Mutex& mMutex;
}


void updateColor(ID itemId, Color newColor) {
  MutexLocker(&itemMutex);
  item* itemToChange = get_item_from_id(itemId);
  if(itemToChange == NULL) {
    return;
  }

  itemToChange->SetColor(newColor);
}
```

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Recognize Algorithms

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Recognize Algorithms

```
bool IsFileInFilesToKeep(const char* aPath) {
  bool found = false;
  for (const auto& file : filesToKeep) {
    if (strcmp(file, aPath) == 0) {
      found = true;
      break;
    }
  }
  return found;
}
```

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Recognize Algorithms

```
bool IsFileInFilesToKeep(const char* aPath) {
  bool found = false;
  for (const auto& file : filesToKeep) {
    if (strcmp(file, aPath) == 0) {
      found = true;
      break;
    }
  }
  return found;
}
```

```
bool IsFileInFilesToKeep(const char* aPath) {
  const auto found = std::find_if(begin(filesToKeep),end(filesToKeep),
                [aPath](const char* file) {
                  return strcmp(aPath, file) == 0;
                });
 return found != end(filesToKeep);
}
```

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Boolean arguments

```
class CourseMap {
 public:
  // Constructor/Destructor.
  CourseReviewMap(RecordId aId, bool aIsActivity = false);
  ...
 private:
  bool mActivity;
};
```

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Take out the guesswork

```
class CourseMap {
 public:
  // Constructor/Destructor.
  CourseReviewMap(RecordId aId, bool aIsActivity = false);
  ...
 private:
  bool mActivity;
};
```

```
enum struct NavType { Course, Activity };

class CourseMap {
 public:
  // Constructor/Destructor.
  CourseReviewMap(RecordId aId, NavType aNavType = NavType::Course);
  ...
 private:
  const NavType mNavType;
};
```

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Take out the guesswork, and prepare for the future

```
class CourseMap {
 public:
  // Constructor/Destructor.
  CourseReviewMap(RecordId aId, bool aIsActivity = false);
  ...
 private:
  bool mActivity;
};
```

```
enum struct NavType { Course, Activity, Track };

class CourseMap {
 public:
  // Constructor/Destructor.
  CourseReviewMap(RecordId aId, NavType aNavType = NavType::Course);
  ...
 private:
  const NavType mNavType;
};
```

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“Any fool can write code that a computer can understand. Good programmers write code that humans can understand.”

–Martin Fowler

Refactoring: Improving the Design of Existing Code

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Take the time to write code for maintainability

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Questions?

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