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Better Software: Simpler Faster

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C++ Refactoring and TDD with Eclipse CDT and CUTE

http://ifs.hsr.ch/cdtrefactoring/updatesite/

http://ifs.hsr.ch/cute/updatesite/

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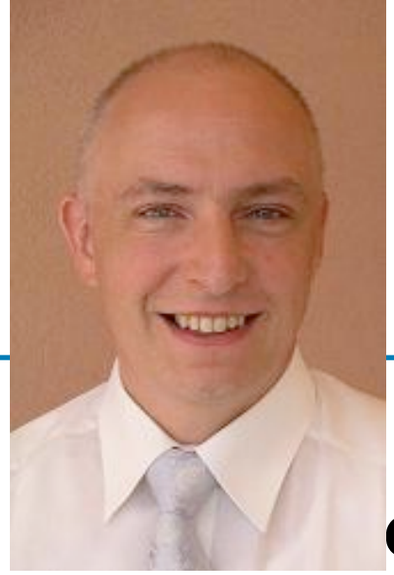

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- **Work Areas**
  - Refactoring Tools (C++, Ruby, Python, Groovy, PHP, JavaScript,...) for Eclipse
  - **Decremental Development (make SW 10% its size!)**
  - Modern Software Engineering
  - Patterns
    - POSA 1 and Security Patterns
- **Background**
  - Diplom-Informatiker Univ. Frankfurt/M
  - Siemens Corporate Research Munich
  - itopia corporate information technology, Zurich (Partner)
  - Professor for Software HSR Rapperswil, Head Institute for Software

Credo:

- **People create Software**
  - communication
  - feedback
  - courage
- **Experience through Practice**
  - programming is a trade
  - Patterns encapsulate practical experience
- **Pragmatic Programming**
  - test-driven development
  - automated development
  - Simplicity: fight complexity

Assumptions

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- **I assume you are familiar with object-oriented concepts of class, constructor/destructor, member functions.**
- **I assume some basic familiarity with Unit Testing**
- **I assume you are familiar with standard C++ or intervene otherwise!**
  - if I use a C++ feature you do not know or understand, please interrupt! I'll take a detour.
  - Many C++ programmers got stuck with C++ of the 1990s, feel free to ask for an "upgrade" on the go.

Goals

- **You'll learn about (some) TDD patterns and TDD principles**
- **You'll get a brief intro to Test Doubles and Mock Objects**
- **You'll participate in Test-driven Design in C++ using Eclipse CDT, CUTE and our C++ Refactoring plug-in (at least as an Observer)**

- **I want to show you what we've created to ease C++ development with CDT.**

Unit-Testing Principles (already known?)

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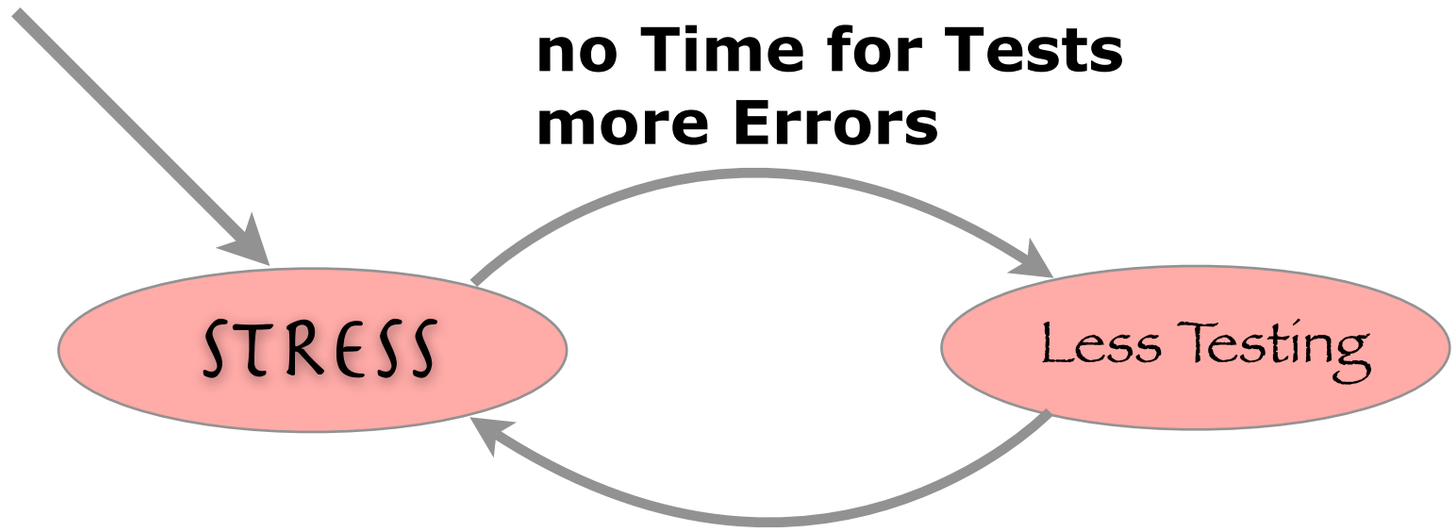
- Test anything that might break
- Test everything that does break
- New code is guilty until proven innocent
- Write at least as much test code as production code
- Run local tests with each compile
- Run all tests before check-in to repository

Vicious Circle: Testing - Stress



- **Automate tests and run them often!**

How do I write good Unit Tests?

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- Ask yourself the following questions: (among others about your coding)
- If the code is correct, how would I know?
- How can I test this?
- What else could go wrong?
- Could a similar problem happen elsewhere?

Why even more on Test Automation?

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- **Writing good automated tests is hard.**
- **Beginners are often satisfied with "happy-path" tests**
  - error conditions and reactions aren't defined by the tests
- **Code depending on external stuff (DB, IO, etc) is hard to test. How can you test it?**
- **Will good tests provide better class design?**
- **How can tests be designed well?**

Principle of Automated Tests Triple-A (AAA)

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1. **Arrange**
   - initialize system(s) under test
2. **Act**
   - call functionality that you want to test
3. **Assert**
   - assert that results are as you expect

Remember: "Triple-A: arrange, act, assert"

Terminology xunitpatterns.com

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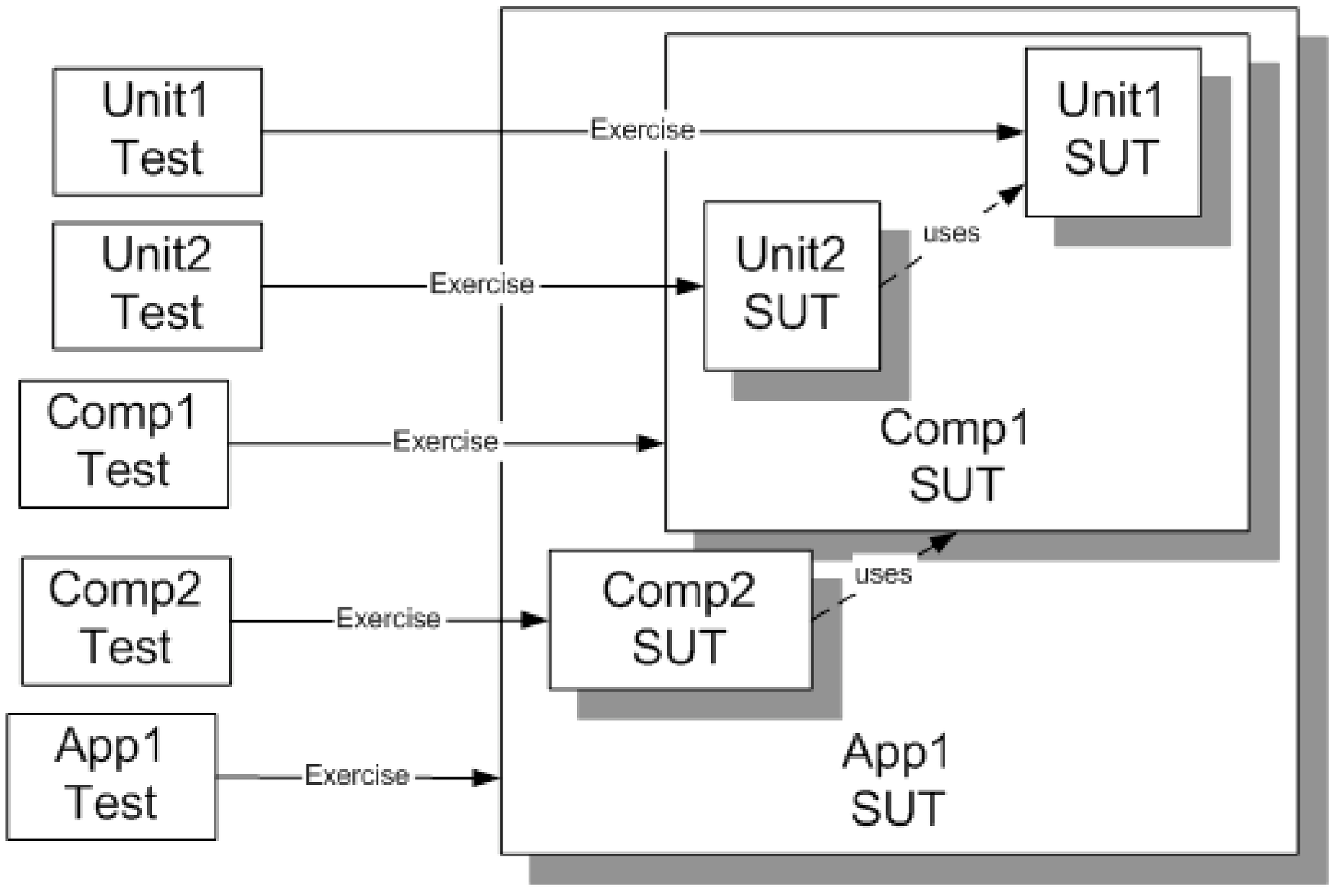
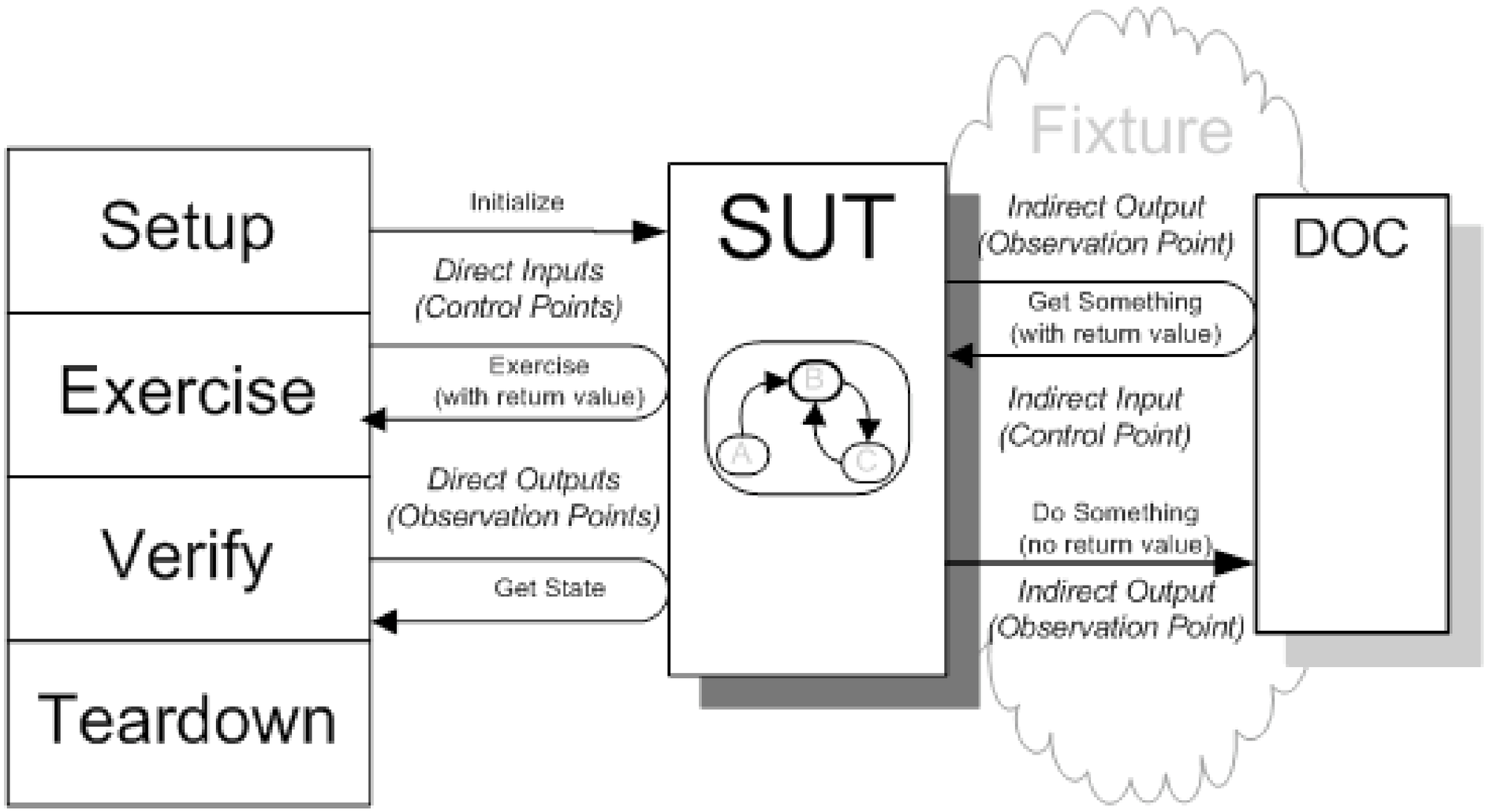
- **SUT system under test**



Test Case Structure: Four Phase Test



- **compare that to AAA ---> another similarity**
- **Source: xunitpatterns.com**

Test-Driven Development

Exploiting Unit Tests...

Test-Driven Development [Beck-TDD]

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- **There are several books on test-driven design (or TDD)**
  - Kent Beck, Dave Astels, Gerard Meszaros
- **TDD is not a testing technique, but a coding and design technique**
  - nevertheless TDD patterns help you writing tests, regardless if you follow TDD or not
- **TDD relies heavily on Refactoring**
  - we (IFS) try hard to provide you with such Refactoring automation for C++ as well as you might be used to with Java or Ruby. (plus Refactoring for Python (PyDev), Groovy, PHP, JavaScript)

TDD [Kevlin Henney]

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- **TDD has emerged from the many practices that form Extreme Programming's core**
  - Focused on code-centric practices in the micro process rather than driving the macro process
- **TDD can be used in other macro-process models**
  - TDD is not XP, and vice versa
  - TDD is not just unit testing
- **BDD (Behaviour Driven Design)**
  - Follow-up to TDD
  - since TDD is not about Testing

TDD Practices and Characteristics

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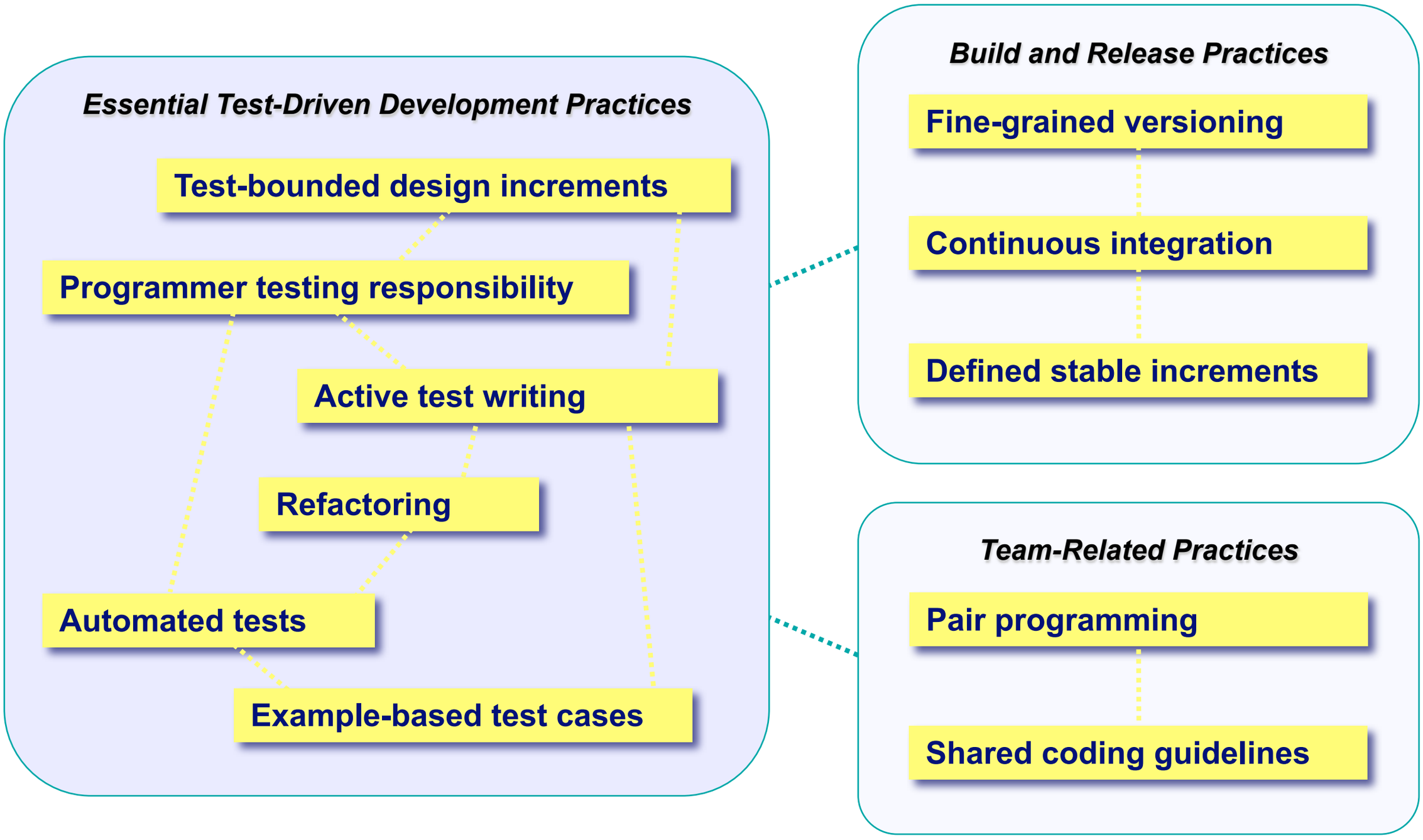

provided by [Kevlin Henney]

TDD Patterns
Writing Tests & Habits

- **Isolated Tests**
  - write tests that are independent of other tests
- **Test List**
  - use a list of to-be-written tests as a reminder
  - only implement one failing test at a time
- **Test First**
  - write your tests before your production code
- **Assert First**
  - start writing a test with the assertion
  - only add the acting and arrangement code when you know what you actually assert

Demo TDD V1
Generate Roman Numbers

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- **generate roman numbers as strings from an integer representation**
  - start with the following list of tests
  - create a new CUTE projects
  - write test, implement function, refactor, repeat
  - make up new tests as you go and see need

THE LIST FOR ROMAN NUMBERS (V0)

1 → I

0 → EMPTY STRING

2 → II

...

"Red-bar" Patterns
Finding Tests to write

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- **One Step Test**
  - solve a development task test-by-test
    - no backlog of test code, only on your test list
    - select the simplest/easiest problem next
- **Starter Test**
  - start small, e.g., test for an empty list
  - refactor while growing your code
- **Explanation Test**
  - discuss design through writing a test for it
- **Learning Test**
  - understand existing code/APIs through writing tests exercising it

Demo TDD V2
(3+4)*6 → 42

- **Expression Evaluator for simple Arithmetic**
- **Test-First Development with CUTE**
- **Incremental Requirements Discovery**

The List for Eval (V0)

"" → error

"0" → 0

"2" → 2

"1+1" → 2

"Red Bar" Patterns (2)

- **Regression Test**
  - For every bug report write tests showing the bug
- **Break**
  - Enough breaks are essential. When you are tired you loose concentration and your judgement gets worse. This results in more errors, more work, and makes you more fatigue. (vicious circle!)
- **Do Over**
  - If you recognize your design and tests lead nowhere, DELETE your code! A fresh start earlier is often better.

"Green Bar" - Patterns Make your Tests succeed

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- **Fake It ('Til You Make It)**
  - It is OK to "hack" to make your test succeed.
  - Refactor towards the real solution ASAP
- **Triangulate**
  - How can you select a good abstraction?
  - try to code two examples, and then refactor to the "right" solution
- **Obvious Implementation**
  - Nevertheless, when it's easy, just do it.
- **One to Many**
  - Implement functions with many elements first for one element (or none) correctly

TDD Patterns Habits

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- **Child Test**
  - If a test case gets too large, “remove” it, redo the core, get “green-bar”, and then introduce the “full” case again, get “green-bar”
- **Broken Test**
  - If you have to stop programming or take a break, leave a broken test to remind you where you left.
    - but only do Clean Check-in!
- **Clean Check-in**
  - Do only (and may be always) check-in your code and tests when you have a green bar.

Test Double Pattern xunitpatterns.com

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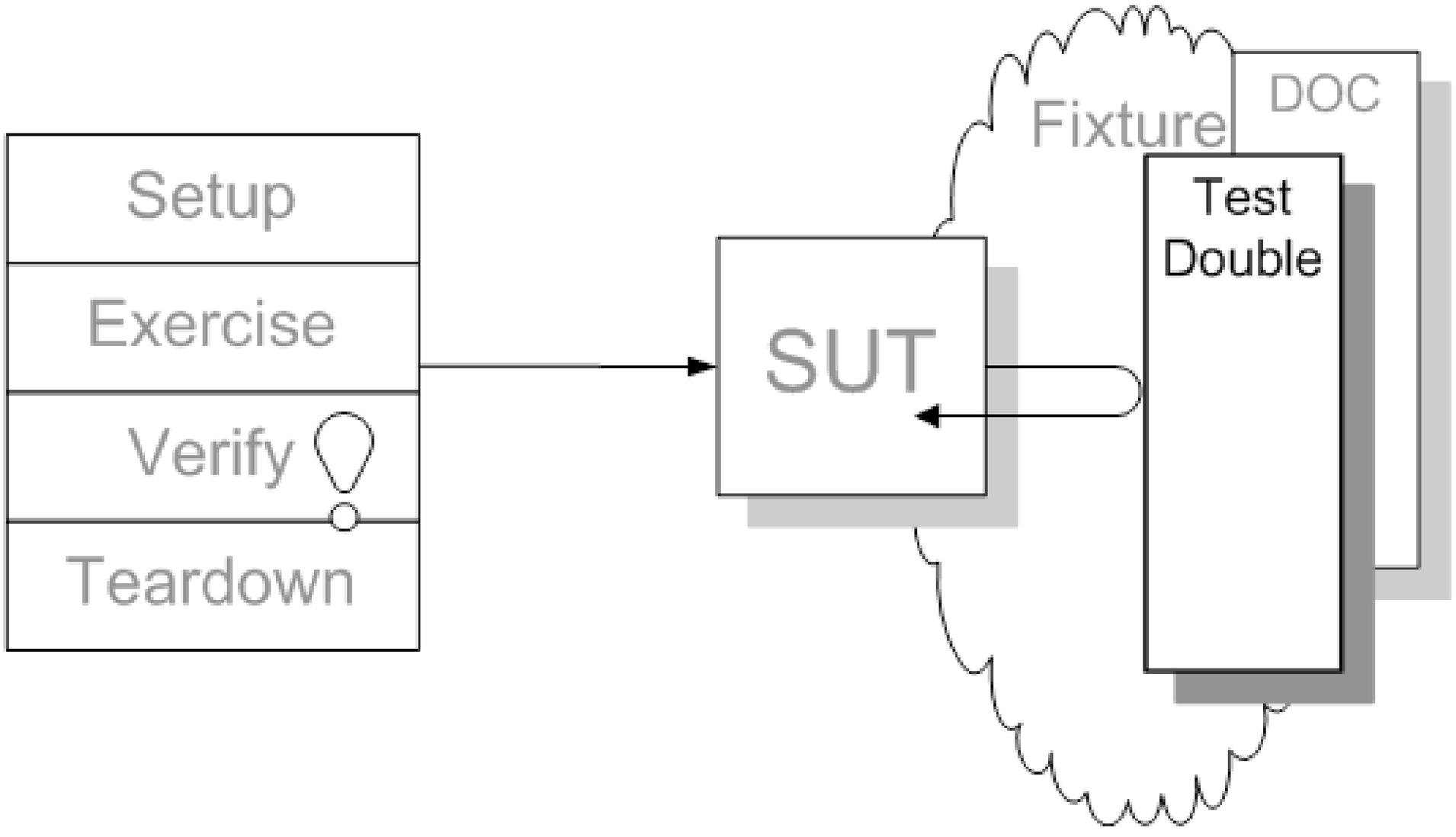
- How can we verify logic independently when code it depends on is unusable?
- How can we avoid Slow Tests?



Test Double Patterns [Beck-TDD]

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- **Mock Object**
  - Decouple a class under test from its environment
- **Self Shunt**
  - Use the test case class itself as a Mock Object
- **Log String**
  - test temporal dependencies of calls by concatenating call info in a string, e.g., using Self Shunt
- **Crash Test Dummy**
  - How do you tests exceptions that are hard to force, but might occur during production?
  - Use a dummy/Mock Object that throws an exception instead of the real object.

Mock Object xunitpatterns

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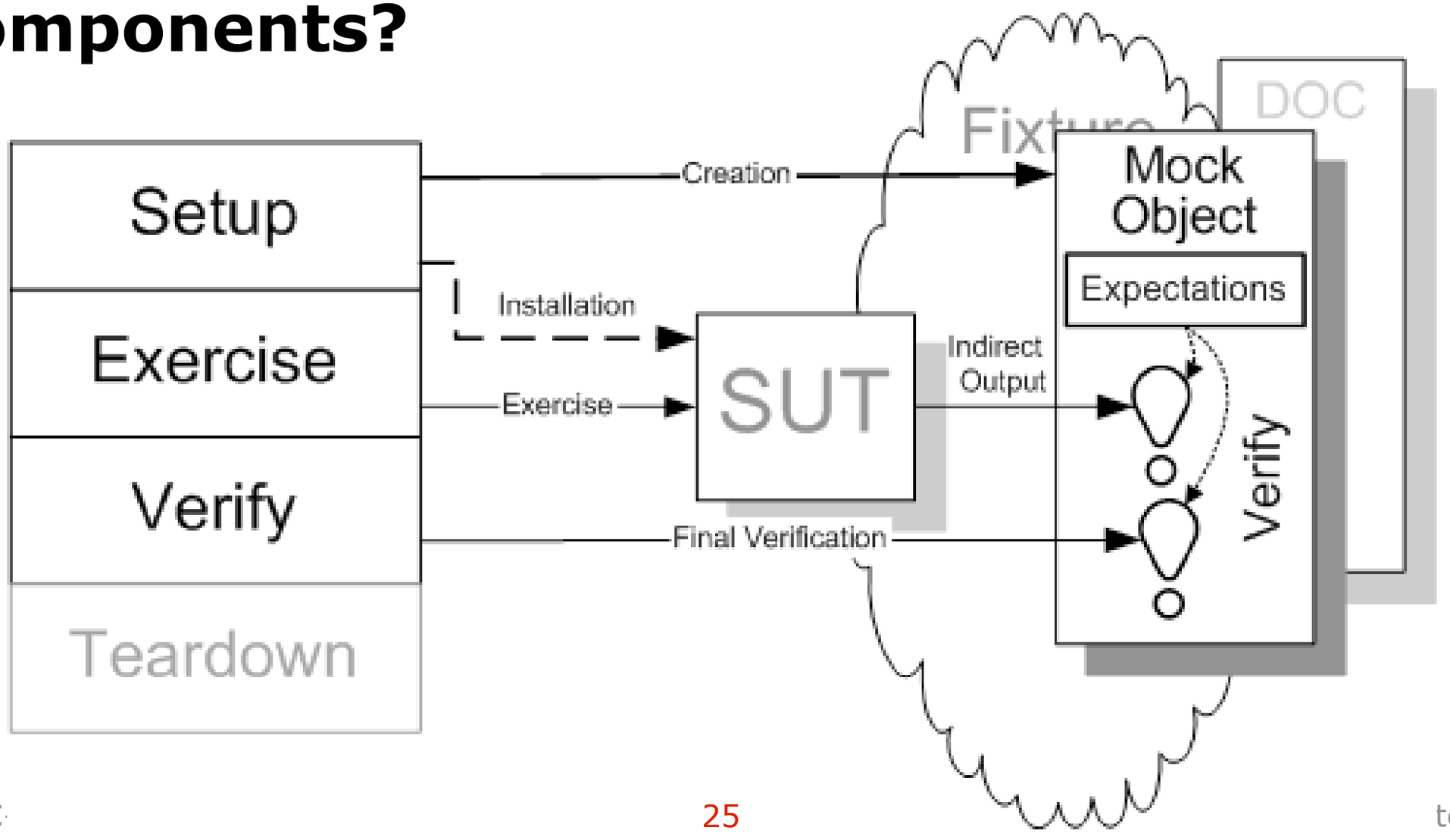
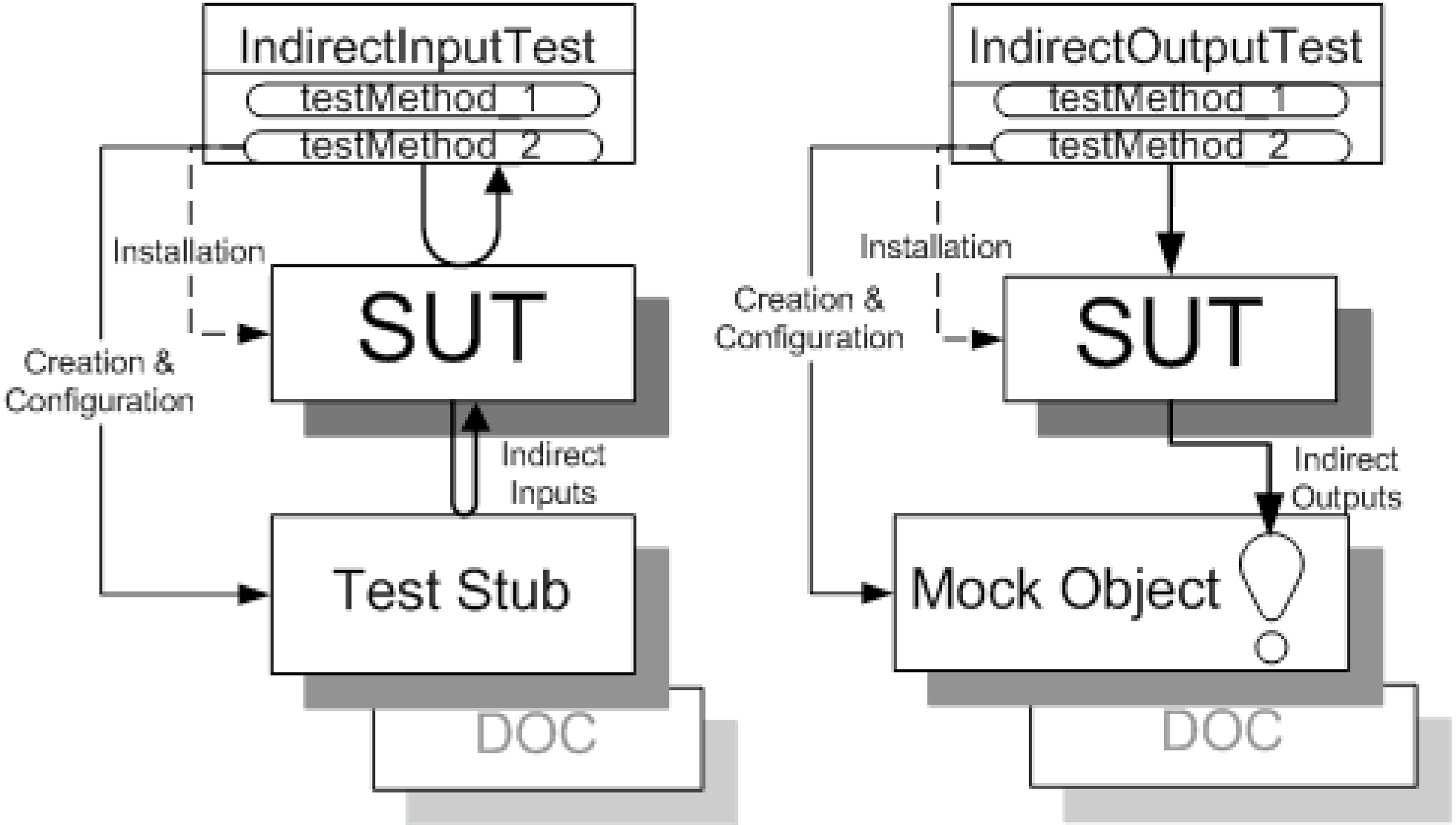
- How do we implement Behavior Verification for indirect outputs of the SUT?
- How can we verify logic independently when it depends on indirect inputs from other software components?



Difference Test-Stub and Mock-Object



- **xunitpatterns.com**

Testing for Exceptions

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- **There is a standard Schema to test some code if it raises a specific exception:**

```
void testAnException() {
   std::vector<int> v; // arrange
   try {
      v.at(0); // act
      FAILM("expected out_of_range exception"); // assert
   }
   catch(std::out_of_range &) { }
}
```

- **CUTE encapsulates this to**

```
void testAnException() {
   std::vector<int> v;
   ASSERT_THROWS(v.at(0),std::out_of_range);
}
```

Example Crash-Test Dummy in C++

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```
struct out_of_memory:std::exception{};

template <typename T>
struct failingallocator :  std::allocator<T> {
    typedef typename std::allocator<T>::pointer pointer;
    typedef typename std::allocator<T>::size_type size_type;
    pointer allocate(size_type n, std::allocator<void>::const_pointer hint=0){
       //return std::allocator<T>::allocate(n,hint);
       throw out_of_memory();
    }
}; // “Crash-Test-Dummy” allocator

void testFailingAllocation(){
    std::vector<int,failingallocator<int> > v;
    ASSERT_THROWS(v.reserve(5),out_of_memory);
}
void testFailingAllocationCtor(){
    std::vector<int,failingallocator<int> > v(5); // will throw in ctor!
}
void runSuite(){
    cute::suite s;
    s.push_back(CUTE(testFailingAllocation));
    s.push_back(CUTE_EXPECT(CUTE(testFailingAllocationCtor),out_of_memory));
...
```

Why Test Doubles and Mock Objects? [PragUnit]

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- The real object has **nondeterministic behavior** (it produces unpredictable results, like a stock-market quote feed.)
- The real object is **difficult to set up**.
- The real object has **behavior that is hard to trigger** (for example, a network error).
- The real object is **slow**.
- The real object has (or is) a **user interface**.
- The test needs to **ask** the real object about **how it was used** (for example, a test might need to confirm that a callback function was actually called).
- The real object **does not yet exist** (a common problem when interfacing with other teams or new hardware systems).

TDD Expression Evaluator

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- **Thanks to Hubert Matthews for his last year workshop where I tried TDD on this problem.**

- **Wanted:**
  - A volunteer keeping track of tests to write: The List
  - Your help in implementing and refactoring
    - just call, ask, and answer
    - I am your (sometimes intelligent) typing machine (and guide)

How to write CUTE Tests?

optional slides...

Test Fixtures

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- **Often several test cases require identical arrangements of testee objects**
- **Reasons**
  - "expensive" setup of objects
  - no duplication of code (DRY principle)
- **Mechanisms**
  - JUnit provides setup() and teardown() methods
  - CPPUnitLite does not provide this
    - other CPPUnit variants do as virtual functions
  - CUTE employs **constructor** and **destructor** of a testing class with per test object incarnation
    - no need for inheritance and virtual member functions
    - just employ C++ standard mechanisms

Test Fixture with CUTE

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```
#include "cute.h"
#include "cute_equals.h"
struct ATest {
   CircularBuffer<int> buf;
   ATest():buf(4){}
   void testEmpty(){   ASSERT(buf.empty());}
   void testNotFull(){      ASSERT(!buf.full());}
   void testSizeZero(){     ASSERT_EQUAL(0,buf.size());}
};

#include "cute_testmember.h"
....

s.push_back(CUTE_SMEMFUN(ATest,testEmpty));
s.push_back(CUTE_SMEMFUN(ATest,testNotFull));
s.push_back(CUTE_SMEMFUN(ATest,testSizeZero));
...
```

Member Functions as Tests in CUTE

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- `CUTE_SMEMFUN(TestClass,memfun)`
  - instantiates a new object of TestClass and calls memfun on it ("simple" member function)
- `CUTE_MEMFUN(testobject,TestClass,memfun)`
  - uses pre-instantiated testobject as target for memfun
    - this is kept by reference, take care of its scoping/lifetime
    - allows reuse of testobject for several tests and thus of a fixture provided by it.
  - allows for classes with complex constructor parameters
- `CUTE_CONTEXT_MEMFUN(context,TestClass,memfun)`
  - keeps a copy of context object and passes it to TestClass' constructor before calling memfun on it
    - avoids scoping problems
    - allows single-parameter constructors

Refactoring for Mocks in C++

Variations of Mock Objects classics

Principle of Mock objects

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- **A unit/system under test (SUT) depends on another component (DOC) that we want to separate out from our test.**
- **Reasons**
  - real DOC might not exist yet
  - real DOC contains uncontrollable behavior
  - want to test exceptional behavior by DOC that is hard to trigger
  - using the real DOC is too expensive or takes to long
  - need to locate problems within SUT not DOC
  - want to test usage of DOC by SUT is correct

Why the need for Mock Objects?

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- **Simpler Tests and Design**
  - especially for external dependencies
  - promote interface-oriented design
- **Independent Testing of single Units**
  - isolation of unit under testing
  - or for not-yet-existing units
- **Speed of Tests**
  - no external communication (e.g., DB, network)
- **Check usage of third component**
  - is complex API used correctly
- **Test exceptional behaviour**
  - especially when such behaviour is hard to trigger

Types of Mock Objects [Dave Astels]

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- **There exist different categories of Mock objects and different categorizers.**

- **Stubs**
  - substitutes for "expensive" or non-deterministic classes with fixed, hard-coded return values
- **Fakes**
  - substitutes for not yet implemented classes
- **Mocks**
  - substitutes with additional functionality to record function calls, and the potential to deliver different values for different calls

Interface-oriented Mock

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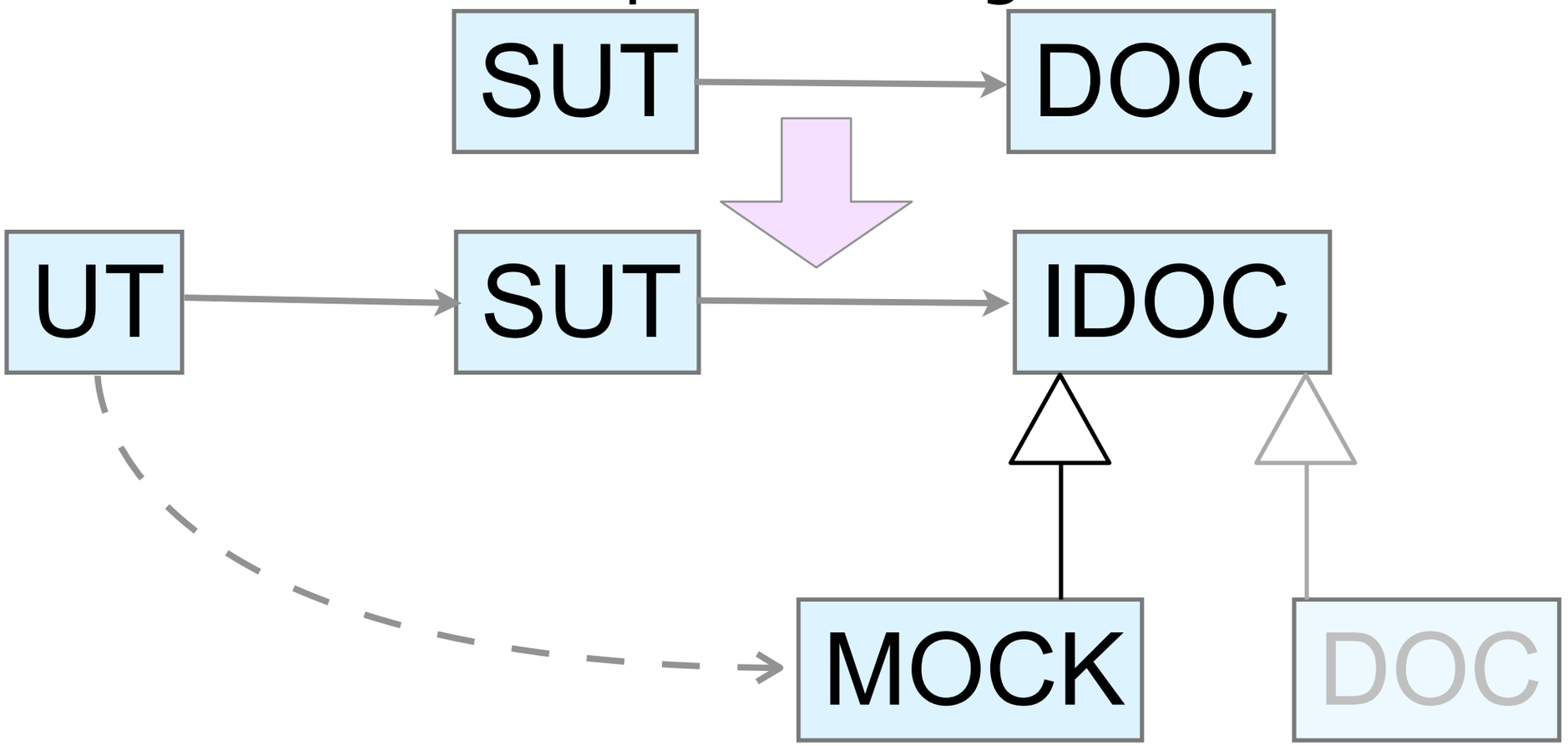
- **classic inheritance based mocking**
  - extract interface for DOC -> IDOC
  - make SUT use IDOC
  - create MOCK implementing IDOC and use it in UT



  - in C++ this means overhead for DOC (virtual functions)!

Demo/Exercise
Code in need for Mocking

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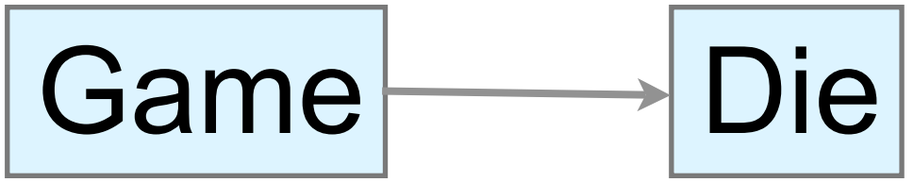
- **A very simple game, roll dice, check if you've got 4 and you win, otherwise you loose.**



- **We want to test class Die first:**

```
#include <cstdlib>

struct Die
{
   int roll() { return rand()%6 + 1; }
};
```

How to test Game?

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```
#include "Die.h"
class GameFourWins
{
   Die die;
public:
   GameFourWins();
   void play();
};
```

```
void GameFourWins::play(){
   if (die.roll() == 4) {
      cout << "You won!" << endl;
   } else {
      cout << "You lost!" << endl;
   }
}
```

Refactoring
Introduce Parameter

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```
#include "Die.h"
#include <iostream>

class GameFourWins
{
   Die die;
public:
   GameFourWins();
   void play(std::ostream &os = std::cout);
};
```

```
void GameFourWins::play(std::ostream &os){
   if (die.roll() == 4) {
      os << "You won!" << endl;
   } else {
      os << "You lost!" << endl;
   }
}
```

Test with a Mock ostream

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- **We now can use a ostrstream to collect the output of play() and check that against an expected value:**

```
void testGame() {
   GameFourWins game;
   std::ostringstream os;
   game.play(os);
   ASSERT_EQUAL("You lost!\n",os.str());
}
```

- **What is still wrong with that test?**

Simulation Mocks Interface-oriented

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- **deliver predefined values**
  - we need that for our Die class
- **Introduce an Interface**

```
struct DieInterface
{
   virtual ~DieInterface(){}
   virtual int roll() =0;
};

struct Die: DieInterface
{
   int roll() { return rand()%6+1; }
};
```

- **now we need to adjust Game as well to use DieInterface* instead of Die**

Simulation Mocks preparing SUT

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- Changing the interface, need to adapt call sites
- theDie must live longer than Game object

```
class GameFourWins
{
   DieInterface &die;
public:
   GameFourWins(DieInterface &theDie):die(theDie){}
   void play(std::ostream &os = std::cout);
};
```

- now we can write our test using an alternative implementation of DieInterface
- would using pointer instead of reference improve situation? what's different?

Simulation Mock Test it

- **This way we can also thoroughly test the winning case:**

```
struct MockWinningDice:DieInterface{
   int roll(){return 4;}
};

void testWinningGame() {
   MockWinningDice d;
   GameFourWins game(d);
   std::ostringstream os;
   game.play(os);
   ASSERT_EQUAL("You won!\n",os.str());
}
```

A C++ alternative using templates

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- **advantage: no virtual call overhead**
- **drawback: inline/export problem potential**

```
template <typename Dice=Die>
class GameFourWinsT
{
   Dice die;
public:
   void play(std::ostream &os = std::cout){
     if (die.roll() == 4) {
       os << "You won!" << std::endl;
     } else {
       os << "You lost!" << std::endl;
     }
   }
};
typedef GameFourWinsT<Die> GameFourWins;
```

Mock via template parameter

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- **The resulting test looks like this:**

```
struct MockWinningDice{
   int roll(){return 4;}
};
void testWinningGame() {
   GameFourWins<MockWinningDice> game;
   std::ostringstream os;
   game.play(os);
   ASSERT_EQUAL("You won!\n",os.str());
}
```

- **should we also mock the ostream similarly?**

Call Tracing Mocks

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- **We want also to count how often our dice are rolled. How to test this?**

```
struct MockWinningDice:DieInterface{
   int rollcounter;
   MockWinningDice():rollcounter(0){}
   int roll(){++rollcounter; return 4;}
};
void testWinningGame() {
   MockWinningDice d;
   GameFourWins game(d);
   std::ostringstream os;
   game.play(os);
   ASSERT_EQUAL("You won!\n",os.str());
   ASSERT_EQUAL(1,d.rollcounter);
   game.play(os);
   ASSERT_EQUAL(2,d.rollcounter);
}
```

Using C++ template Parameters for Mocking

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- **C++ template parameters can be used for mocking without virtual member function overhead and explicit interface extraction.**
  - no need to pass object in as additional parameter
  - unfortunately no default template parameters for template functions (yet)
- **You can mock**
  - Member Variable Types
  - Function Parameter Types
- **Mocking without template inline/export need is possible through explicit instantiations**

Summary Mock Objects

- **Mock Objects are important for isolating unit tests**
  - or speeding them up
- **They can lead to better, less-coupled design**
  - separation of concerns
- **Overdoing mocking can be dangerous**
  - go for simplicity!
- **C++ offers additional ways to introduce mock objects through templates**
  - also through #define and typedef!

Outlook/Questions

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- ...

References

- **[Beck-TDD]**
  - Kent Beck: Test-Driven Design
- **[PragUnit]**
  - Andy Hunt, Dave Thomas: Pragmatic Unit Testing
- **[Kevlin Henney]**
  - JUTLAND:
    Java Unit Testing: Light, Adaptable 'n' Discreet
- **[Dave Astels] - TDD**
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  - http://video.google.com/videoplay?docid=8135690990081075324 - on BDD
- **[Dan North] - Behaviour Driven Development**
  - http://dannorth.net/introducing-bdd/
  - http://behaviour-driven.org/
- **[Gerard Meszaros] - xUnit Test Patterns**
  - http://xunitpatterns.com
  - very good overview of the problems of and with test automation and their solutions