Test-Driven Development (TDD)

EECS3311 A: Software Design
Fall 2018

CHEN-WEI WANG

DbC: Supplier

DbC is supported natively in Eiffel for **supplier**:

```
class ACCOUNT
create
      make
feature -- Attributes
      owner : STRING
      balance : INTEGER
feature -- Constructors
      make(nn: STRING; nb: INTEGER)
            require -- precondition
                  positive_balance: nb > 0
            do
                  owner := nn
                  balance := nb
            end
feature -- Commands
      withdraw(amount: INTEGER)
            require -- precondition
                  non_negative_amount: amount > 0
                  affordable_amount: amount <= balance -- problematic, why?
            do
                  balance := balance - amount
            ensure -- postcondition
                  balance_deducted: balance = old balance - amount
            end
invariant -- class invariant
      positive_balance: balance > 0
end
```

DbC: Contract View of Supplier

Any potential **client** who is interested in learning about the kind of services provided by a **supplier** can look through the *contract view* (without showing any implementation details):

```
class ACCOUNT
create
      make
feature -- Attributes
      owner : STRING
      balance : INTEGER
feature -- Constructors
      make(nn: STRING; nb: INTEGER)
            require -- precondition
                  positive_balance: nb > 0
            end
feature -- Commands
      withdraw(amount: INTEGER)
            require -- precondition
                  non_negative_amount: amount > 0
                  affordable_amount: amount <= balance -- problematic, why?
            ensure -- postcondition
                  balance_deducted: balance = old balance - amount
            end
invariant -- class invariant
      positive_balance: balance > 0
end
```

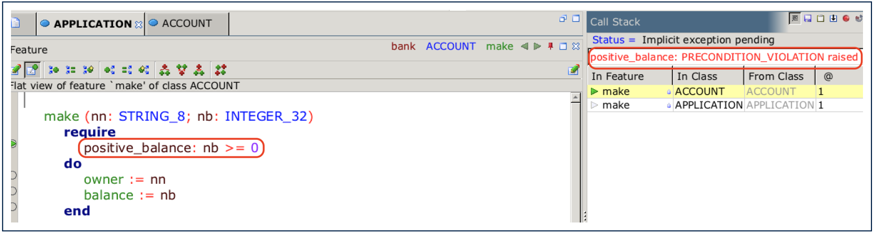
DbC: Testing Precondition Violation (1.1)

The **client** need not handle all possible contract violations:

```
class BANK_APP
inherit
  ARGUMENTS
create
  make
feature -- Initialization
  make
    -- Run application.
  local
    alan: ACCOUNT
  do
    -- A precondition violation with tag "positive_balance"
    create {ACCOUNT} alan.make ("Alan", -10)
  end
end
```

By executing the above code, the runtime monitor of Eiffel Studio will report a *contract violation* (precondition violation with tag `"positive_balance"`).

DbC: Testing for Precondition Violation (1.2)



Flat view of feature `make' of class ACCOUNT

```
make (nn: STRING_8; nb: INTEGER_32)
   require
      positive_balance: nb >= 0
   do
      owner := nn
      balance := nb
   end
```

Status = Implicit exception pending

positive_balance: PRECONDITION_VIOLATION raised

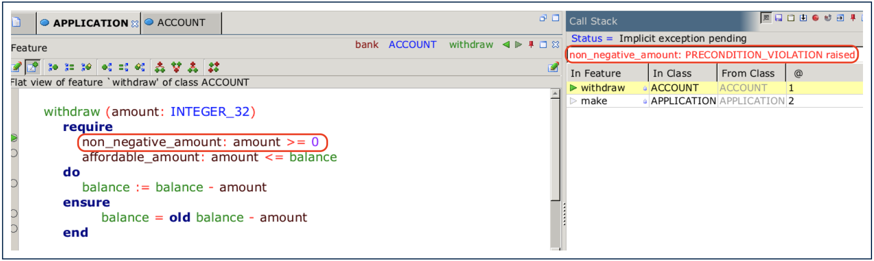
In Feature	In Class	From Class	@
make	ACCOUNT	ACCOUNT	1
make	APPLICATION	APPLICATION	1

DbC: Testing for Precondition Violation (2.1)

```
class BANK_APP
inherit
  ARGUMENTS
create
  make
feature -- Initialization
  make
    -- Run application.
  local
    mark: ACCOUNT
  do
    create {ACCOUNT} mark.make ("Mark", 100)
    -- A precondition violation with tag "non_negative_amount"
    mark.withdraw(-1000000)
  end
end
```

By executing the above code, the runtime monitor of Eiffel Studio will report a *contract violation* (precondition violation with tag `"non_negative_amount"`).

DbC: Testing for Precondition Violation (2.2)



Flat view of feature `withdraw' of class ACCOUNT

```
withdraw (amount: INTEGER_32)
   require
      non_negative_amount: amount >= 0
      affordable_amount: amount <= balance
   do
      balance := balance - amount
   ensure
         balance = old balance - amount
   end
```

Status = Implicit exception pending

non_negative_amount: PRECONDITION_VIOLATION raised

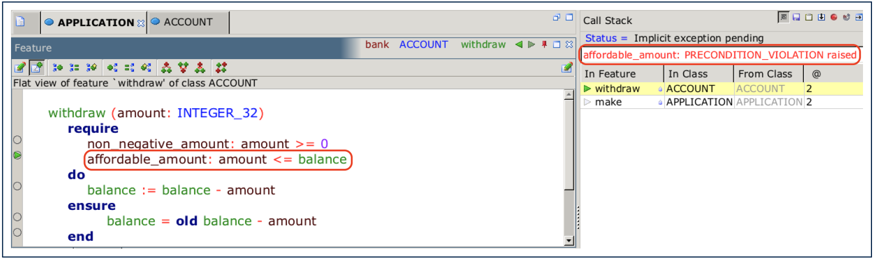
In Feature	In Class	From Class	@
▶ withdraw	ACCOUNT	ACCOUNT	1
▷ make	APPLICATION	APPLICATION	2

DbC: Testing for Precondition Violation (3.1)

```
class BANK_APP
inherit
 ARGUMENTS
create
 make
feature -- Initialization
 make
   -- Run application.
  local
   tom: ACCOUNT
  do
   create {ACCOUNT} tom.make ("Tom", 100)
   -- A precondition violation with tag "affordable_amount"
   tom.withdraw(150)
  end
end
```

By executing the above code, the runtime monitor of Eiffel Studio will report a *contract violation* (precondition violation with tag `"affordable_amount"`).

DbC: Testing for Precondition Violation (3.2)



Flat view of feature `withdraw' of class ACCOUNT

```
withdraw (amount: INTEGER_32)
   require
      non_negative_amount: amount >= 0
      affordable_amount: amount <= balance
   do
      balance := balance - amount
   ensure
         balance = old balance - amount
   end
```

Status = Implicit exception pending

affordable_amount: PRECONDITION_VIOLATION raised

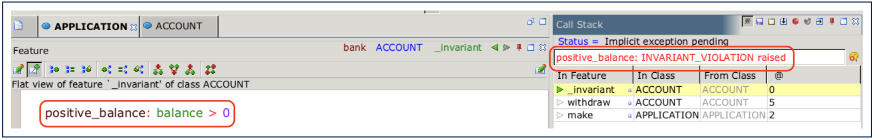
In Feature	In Class	From Class	@
▶ withdraw	ACCOUNT	ACCOUNT	2
▷ make	APPLICATION	APPLICATION	2

DbC: Testing for Class Invariant Violation (4.1)

```
class BANK_APP
inherit
 ARGUMENTS
create
 make
feature -- Initialization
 make
   -- Run application.
 local
   jim: ACCOUNT
 do
   create {ACCOUNT} tom.make ("Jim", 100)
   jim.withdraw(100)
   -- A class invariant violation with tag "positive_balance"
 end
end
```

By executing the above code, the runtime monitor of Eiffel Studio will report a *contract violation* (class invariant violation with tag `"positive_balance"`).

DbC: Testing for Class Invariant Violation (4.2)



Flat view of feature `_invariant' of class ACCOUNT

```
positive_balance: balance > 0
```

Status = Implicit exception pending

positive_balance: INVARIANT_VIOLATION raised

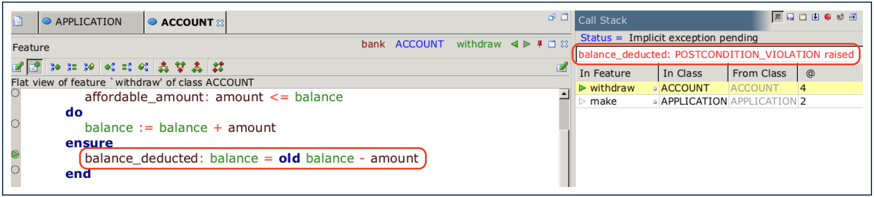
In Feature	In Class	From Class	@
▶ _invariant	ACCOUNT	ACCOUNT	0
▷ withdraw	ACCOUNT	ACCOUNT	5
▷ make	APPLICATION	APPLICATION	2

DbC: Testing for Class Invariant Violation (5.1)

```
class BANK_APP
inherit ARGUMENTS
create make
feature -- Initialization
 make
   -- Run application.
 local
   jeremy: ACCOUNT
 do
   -- Faulty implementation of withdraw in ACCOUNT:
   -- balance := balance + amount
   create {ACCOUNT} jeremy.make ("Jeremy", 100)
   jeremy.withdraw(150)
   -- A postcondition violation with tag "balance_deducted"
 end
end
```

By executing the above code, the runtime monitor of Eiffel Studio will report a *contract violation* (postcondition violation with tag `"balance_deducted"`).

DbC: Testing for Class Invariant Violation (5.2)



Flat view of feature `withdraw' of class ACCOUNT

```
        affordable_amount: amount <= balance
    do
        balance := balance + amount
    ensure
        balance_deducted: balance = old balance - amount
    end
```

Status = Implicit exception pending

balance_deducted: POSTCONDITION_VIOLATION raised

In Feature	In Class	From Class	@
withdraw	ACCOUNT	ACCOUNT	4
make	APPLICATION	APPLICATION	2

TDD: Test-Driven Development (1)

- How we have tested the software so far:
  - Executed each test case **manually** (by clicking `Run` in EStudio).
  - Compared **with our eyes** if ***actual results*** (produced by program) match ***expected results*** (according to requirements).
- Software is subject to numerous revisions before delivery.

  ⇒ Testing manually, repetitively, is tedious and error-prone.

  ⇒ We need *automation* in order to be cost-effective.
- *Test-Driven Development*
  - **Test Case**:
    - ***normal*** scenario (**expected** outcome)
    - ***abnormal*** scenario (**expected** contract violation).
  - **Test Suite**: Collection of test cases.

    ⇒ A test suite is supposed to measure "correctness" of software.

    ⇒ The larger the suite, the more confident you are.

TDD: Test-Driven Development (2)

- Start writing tests as soon as your code becomes *executable* :
  - with ***a unit of functionality*** completed
  - or even with ***headers*** of your features completed

```
class STACK[G]
create make
-- No implementation
feature -- Queries
  top: G do end
feature -- Commands
  make do end
  push (v: G) do end
  pop do end
end
```

```
class TEST_STACK
...
  test_lifo: BOOLEAN
    local s: STACK[STRING]
    do create s.make
       s.push ("Alan") ; s.push ("Mark")
       Result := s.top ~ "Mark"
       check Result end
       s.pop
       Result := s.top ~ "Alan"
    end
end
```

- Writing tests should ***not*** be an isolated, last-staged activity.
- Tests are a precise, executable form of *documentation* that can guide your design.

TDD: Test-Driven Development (3)

- The *ESpec* (Eiffel Specification) library is a framework for:
  - Writing and accumulating ***test cases***

    Each list of *relevant test cases* is grouped into an `ES_TEST` class, which is just an Eiffel class that you can execute upon.
  - Executing the ***test suite*** whenever software undergoes a change

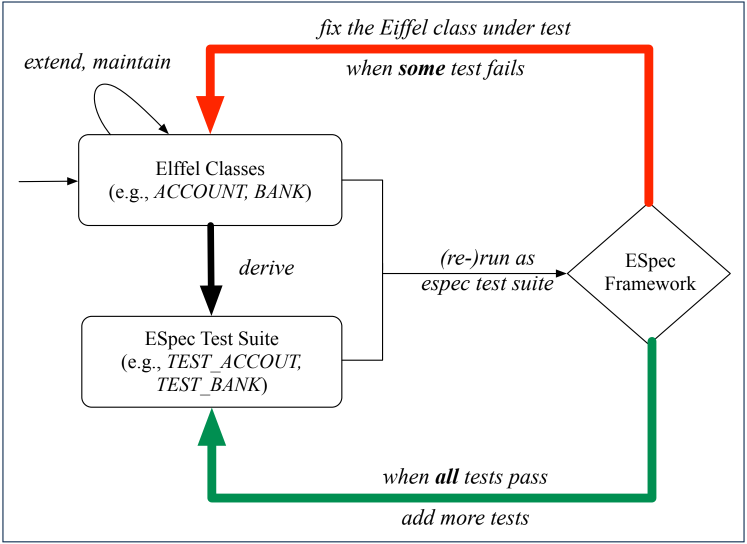
    e.g., a bug fix

    e.g., extension of a new functionality
- ESpec tests are *helpful client* of your classes, which may:
  - Either attempt to use a feature in a ***legal*** way (i.e., ***satisfying*** its precondition), and report:
    - ***Success*** if the result is as expected
    - ***Failure*** if the result is ***not*** as expected:

      e.g., state of object has not been updated properly

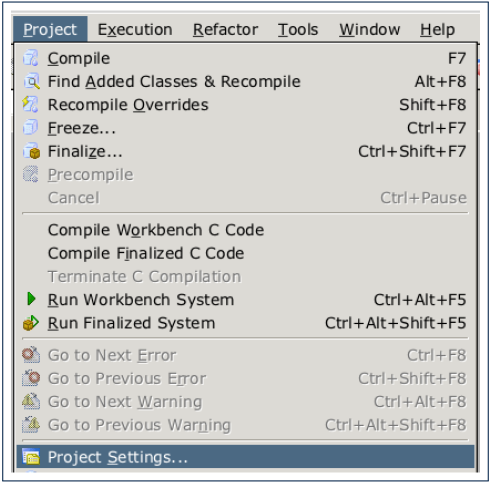
      e.g., a ***postcondition violation*** or ***class invariant violation*** occurs
  - Or attempt to use a feature in an ***illegal*** way (e.g., ***not satisfying*** its precondition), and report:
    - ***Success*** if precondition violation occurs.
    - ***Failure*** if precondition violation does ***not*** occur.

TDD: Test-Driven Development (4)



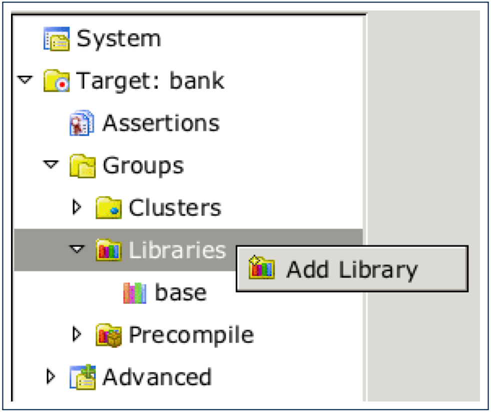
Adding the ESpec Library (1)

Step 1: Go to Project Settings.


Project
Execution
Refactor
Tools
Window
Help
Compile F7
Find Added Classes & Recompile Alt+F8
Recompile Overrides Shift+F8
Freeze... Ctrl+F7
Finalize... Ctrl+Shift+F7
Precompile
Cancel Ctrl+Pause
Compile Workbench C Code
Compile Finalized C Code
Terminate C Compilation
Run Workbench System Ctrl+Alt+F5
Run Finalized System Ctrl+Alt+Shift+F5
Go to Next Error Ctrl+F8
Go to Previous Error Ctrl+Shift+F8
Go to Next Warning Ctrl+Alt+F8
Go to Previous Warning Ctrl+Alt+Shift+F8
Project Settings...

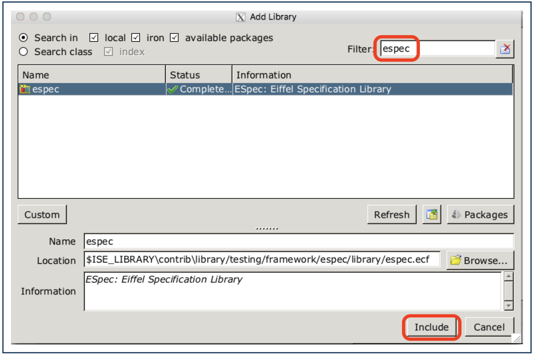
Adding the ESpec Library (2)

Step 2: Right click on `Libraries` to add a library.



Adding the ESpec Library (3)

Step 3: Search for `espec` and then include it.



Add Library

● Search in ☑ local ☑ iron ☑ available packages

○ Search class ☑ index

Filter: espec

Name	Status	Information
espec	✓ Complete...	ESpec: Eiffel Specification Library

Name: espec

Location: $ISE_LIBRARY\contrib\library/testing/framework/espec/library/espec.ecf

Information: *ESpec: Eiffel Specification Library*

This will make two classes available to you:

- `ES_TEST` for adding test cases
- `ES_SUITE` for adding instances of `ES_TEST`.
  - To run, an instance of this class must be set as the `root`.

ES_TEST: Expecting to Succeed (1)

```
class TEST_ACCOUNT
inherit ES_TEST
create make
feature -- Add tests in constructor
  make
    do
      add_boolean_case (agent test_valid_withdraw)
    end
feature -- Tests
  test_valid_withdraw: BOOLEAN
    local
      acc: ACCOUNT
    do
      comment("test: normal execution of withdraw feature")
      create {ACCOUNT} acc.make ("Alan", 100)
      Result := acc.balance = 100
      check Result end
      acc.withdraw (20)
      Result := acc.balance = 80
    end
end
```

`ES_TEST`: Expecting to Succeed (2)

- **L2**: A test class is a subclass of `ES_TEST`.
- **L10 – 20** define a `BOOLEAN` test *query*. At runtime:
  - ***Success***: Return value of `test_valid_withdraw` (final value of variable **`Result`**) evaluates to *true* upon its termination.
  - ***Failure***:
    - The return value evaluates to *false* upon termination; or
    - Some contract violation (which is *unexpected*) occurs.
- **L7** calls feature `add_boolean_case` from `ES_TEST`, which expects to take as input a *query* that returns a Boolean value.
  - We pass *query* `test_valid_withdraw` as an input.
  - Think of the keyword `agent` acts like a function pointer.
    - `test_invalid_withdraw` alone denotes its return value
    - **`agent`** `test_invalid_withdraw` denotes address of *query*
- **L14**: Each test feature ***must*** call **`comment(...)`** (inherited from `ES_TEST`) to include the description in test report.
- **L17**: Check that *each* intermediate value of `Result` is ***true***.

`ES_TEST`: Expecting to Succeed (3)

- Why is the `check Result end` statement at **L7** necessary?
  - When there are two or more *assertions* to make, some of which (except the last one) may ***temporarily falsify*** return value **Result**.
  - As long as the last *assertion* assigns ***true*** to **Result**, then the entire *test query* is considered as a ***success***.
    ⇒ A ***false positive*** is possible!
- For the sake of demonstrating a false positive, imagine:
  - Constructor `make` ***mistakenly*** deduces 20 from input amount.
  - Command `withdraw` ***mistakenly*** deducts nothing.

```
1  test_query_giving_false_positive: BOOLEAN
2   local acc: ACCOUNT
3   do comment("Result temporarily false, but finally true.")
4      create {ACCOUNT} acc.make ("Jim", 100) -- balance set as 80
5      Result := acc.balance = 100 -- Result assigned to false
6      acc.withdraw (20) -- balance not deducted
7      Result := acc.balance = 80 -- Result re-assigned to true
8      -- Upon termination, Result being true makes the test query
9      -- considered as a success ==> false positive!
10  end
```

Fix? [insert ***check Result end***] between **L6** and **L7**.

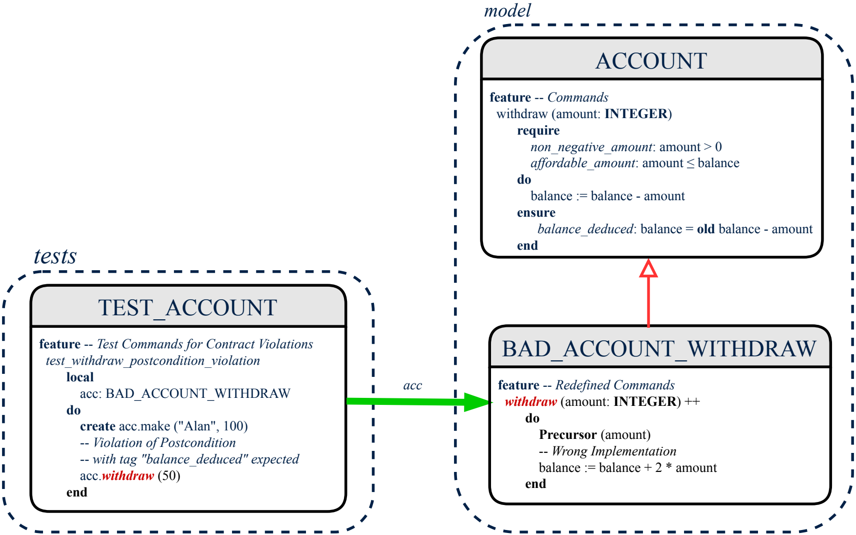
ES_TEST: Expecting to Fail Precondition (1)

```
class TEST_ACCOUNT
inherit ES_TEST
create make
feature -- Add tests in constructor
 make
  do
   add_violation_case_with_tag ("non_negative_amount",
    agent test_withdraw_precondition_violation)
  end
feature -- Tests
 test_withdraw_precondition_violation
  local
   acc: ACCOUNT
  do
   comment("test: expected precondition violation of withdraw")
   create {ACCOUNT} acc.make ("Mark", 100)
   -- Precondition Violation
   -- with tag "non_negative_amount" is expected.
   acc.withdraw (-1000000)
  end
end
```

ES_TEST: Expecting to Fail Precondition (2)

- **L2**: A test class is a subclass of ES_TEST.
- **L11 – 20** define a test *command*. At runtime:
  - ***Success***: A precondition violation (with tag "non_negative_amount") occurs at **L19** before its termination.
  - ***Failure***:
    - No contract violation with the expected tag occurs before its termination; or
    - Some other contract violation (with a different tag) occurs.
- **L7** calls feature `add_violation_case_with_tag` from ES_TEST, which expects to take as input a *command*.
  - We pass *command* test_invalid_withdraw as an input.
  - Think of the keyword agent acts like a function pointer.
    - `test_invalid_withdraw` alone denotes a call to it
    - `agent test_invalid_withdraw` denotes address of *command*
- **L15**: Each test feature ***must*** call `comment(...)` (inherited from ES_TEST) to include the description in test report.

ES_TEST: Expecting to Fail Postcondition (1)



ACCOUNT

```
feature -- Commands
 withdraw (amount: INTEGER)
     require
        non_negative_amount: amount > 0
        affordable_amount: amount ≤ balance
     do
        balance := balance - amount
     ensure
          balance_deduced: balance = old balance - amount
     end
```

BAD_ACCOUNT_WITHDRAW

```
feature -- Redefined Commands
 withdraw (amount: INTEGER) ++
     do
        Precursor (amount)
        -- Wrong Implementation
        balance := balance + 2 * amount
     end
```

TEST_ACCOUNT

```
feature -- Test Commands for Contract Violations
 test_withdraw_postcondition_violation
     local
        acc: BAD_ACCOUNT_WITHDRAW
     do
        create acc.make ("Alan", 100)
        -- Violation of Postcondition
        -- with tag "balance_deduced" expected
        acc.withdraw (50)
     end
```

ES_TEST: Expecting to Fail Postcondition (2.1)

```
 1  class
 2    BAD_ACCOUNT_WITHDRAW
 3  inherit
 4    ACCOUNT
 5      redefine withdraw end
 6  create
 7    make
 8  feature -- redefined commands
 9    withdraw(amount: INTEGER)
10      do
11        Precursor(amount)
12        -- Wrong implementation
13        balance := balance + 2 * amount
14      end
15  end
```

- **L3–5**: `BAD_ACCOUNT_WITHDRAW.withdraw` inherits postcondition from `ACCOUNT.withdraw`: `balance = **old** balance - amount`.
- **L11** calls *correct* implementation from parent class `ACCOUNT`.
- **L13** makes overall implementation *incorrect*.

ES_TEST: Expecting to Fail Postcondition (2.2)

```
class TEST_ACCOUNT
inherit ES_TEST
create make
feature -- Constructor for adding tests
  make
    do
      add_violation_case_with_tag ("balance_deducted",
        agent test_withdraw_postcondition_violation)
    end
feature -- Test commands (test to fail)
  test_withdraw_postcondition_violation
    local
      acc: BAD_ACCOUNT_WITHDRAW
    do
      comment ("test: expected postcondition violation of withdraw")
      create acc.make ("Alan", 100)
      -- Postcondition Violation with tag "balance_deduced" to occur.
      acc.withdraw (50)
    end
end
```

Exercise

Recall from the “Writing Complete Postconditions” lecture:

```
class BANK
  deposit_on_v5 (n: STRING; a: INTEGER)
    do ... -- Put Correct Implementation Here.
    ensure
      ...
      others_unchanged :
        across old accounts.deep_twin as cursor
        all cursor.item.owner /~ n implies
             cursor.item ~ account_of (cursor.item.owner)
        end
    end
end
```

How do you create a “bad” descendant of BANK that violates this postcondition?

```
class BAD_BANK_DEPOSIT
inherit BANK redefine deposit end
feature -- redefined feature
  deposit_on_v5 (n: STRING; a: INTEGER)
    do Precursor (n, a)
        accounts[accounts.lower].deposit(a)
    end
end
```

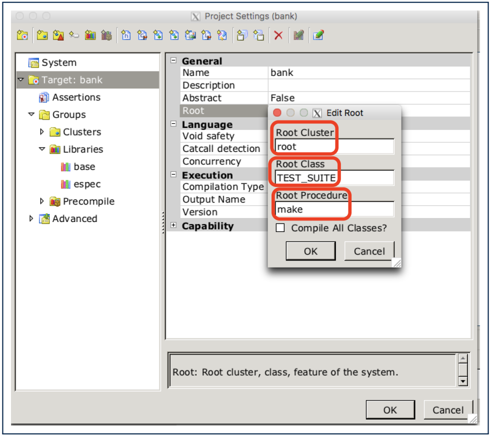
ES_SUITE: Collecting Test Classes

```
 1  class TEST_SUITE
 2  inherit ES_SUITE
 3  create make
 4  feature -- Constructor for adding test classes
 5    make
 6      do
 7        add_test (create {TEST_ACCOUNT}.make)
 8        show_browser
 9        run_espec
10      end
11  end
```

- **L2**: A test suite is a subclass of `ES_SUITE`.
- **L7** passes an **anonymous** object of type `TEST_ACCOUNT` to `add_test` inherited from `ES_SUITE`).
- **L8 & L9** have to be entered in this order!

Running `ES_SUITE` (1)

Step 1: Change the *root class* (i.e., entry point of execution) to be `TEST_SUITE`.



Name: bank

Description:

Abstract: False

Root:

Void safety

Catcall detection

Concurrency

Compilation Type

Output Name

Version

Root Cluster: root

Root Class: TEST_SUITE

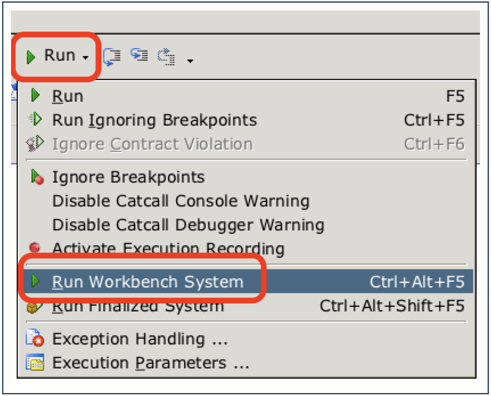
Root Procedure: make

□ Compile All Classes?

Root: Root cluster, class, feature of the system.

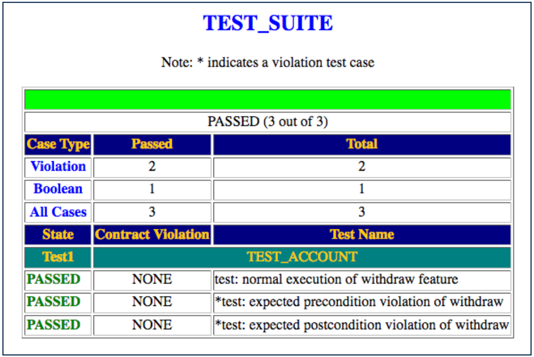
Running ES_SUITE (2)

Step 2: Run the **Workbench System**.


Run
Run F5
Run Ignoring Breakpoints Ctrl+F5
Ignore Contract Violation Ctrl+F6
Ignore Breakpoints
Disable Catcall Console Warning
Disable Catcall Debugger Warning
Activate Execution Recording
Run Workbench System Ctrl+Alt+F5
Run Finalized System Ctrl+Alt+Shift+F5
Exception Handling ...
Execution Parameters ...

Running `ES_SUITE` (3)

Step 3: See the generated test report.



TEST_SUITE

Note: * indicates a violation test case

🟩		
PASSED (3 out of 3)		
Case Type	**Passed**	**Total**
Violation	2	2
Boolean	1	1
All Cases	3	3
State	**Contract Violation**	**Test Name**
Test1	**TEST_ACCOUNT**	
PASSED	NONE	test: normal execution of withdraw feature
PASSED	NONE	*test: expected precondition violation of withdraw
PASSED	NONE	*test: expected postcondition violation of withdraw

Beyond this lecture...

- Study this tutorial series on DbC and TDD:

  `https://www.youtube.com/playlist?list=PL5dxAmCmjv_6r5VfzCQ5bTznoDDgh__KS`

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