RAPITA SYSTEMS LTD

ALTRAN

UNIVERSITY OF OXFORD

Automated Testing of SPARK Contracts

AUTOSAC NATEP Research Project

Ada Europe 2016

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Rolls-Royce

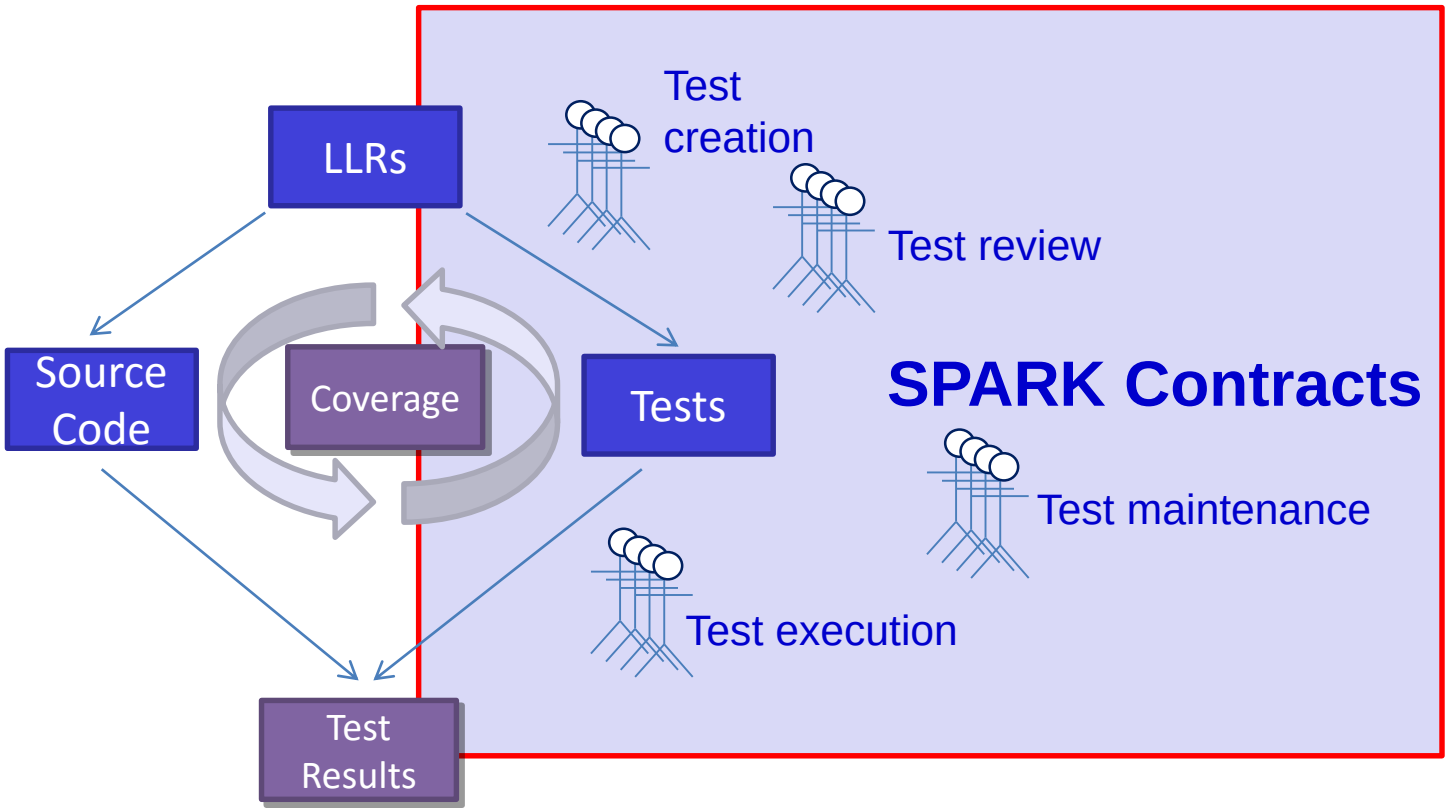
MBDA MISSILE SYSTEMS

Aerospace Growth Partnership

Department for Business Innovation & Skills

Automated Testing of SPARK Contracts

Reduce time and effort to test low-level requirements (LLRs) of safety-critical SPARK code



Automation using SPARK Contracts

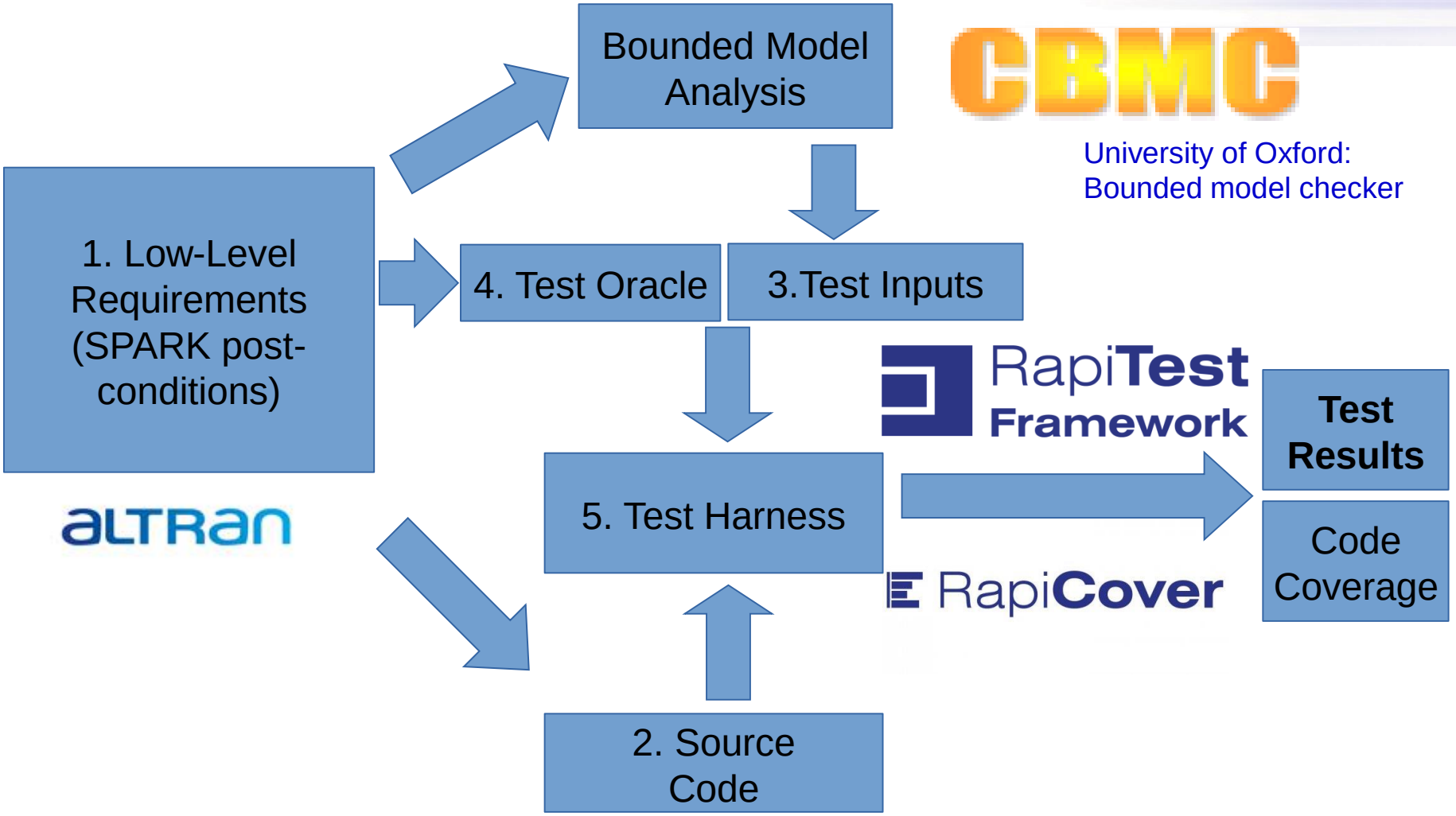
SPARK contracts can describe a subprogram specification well

We can use them for:

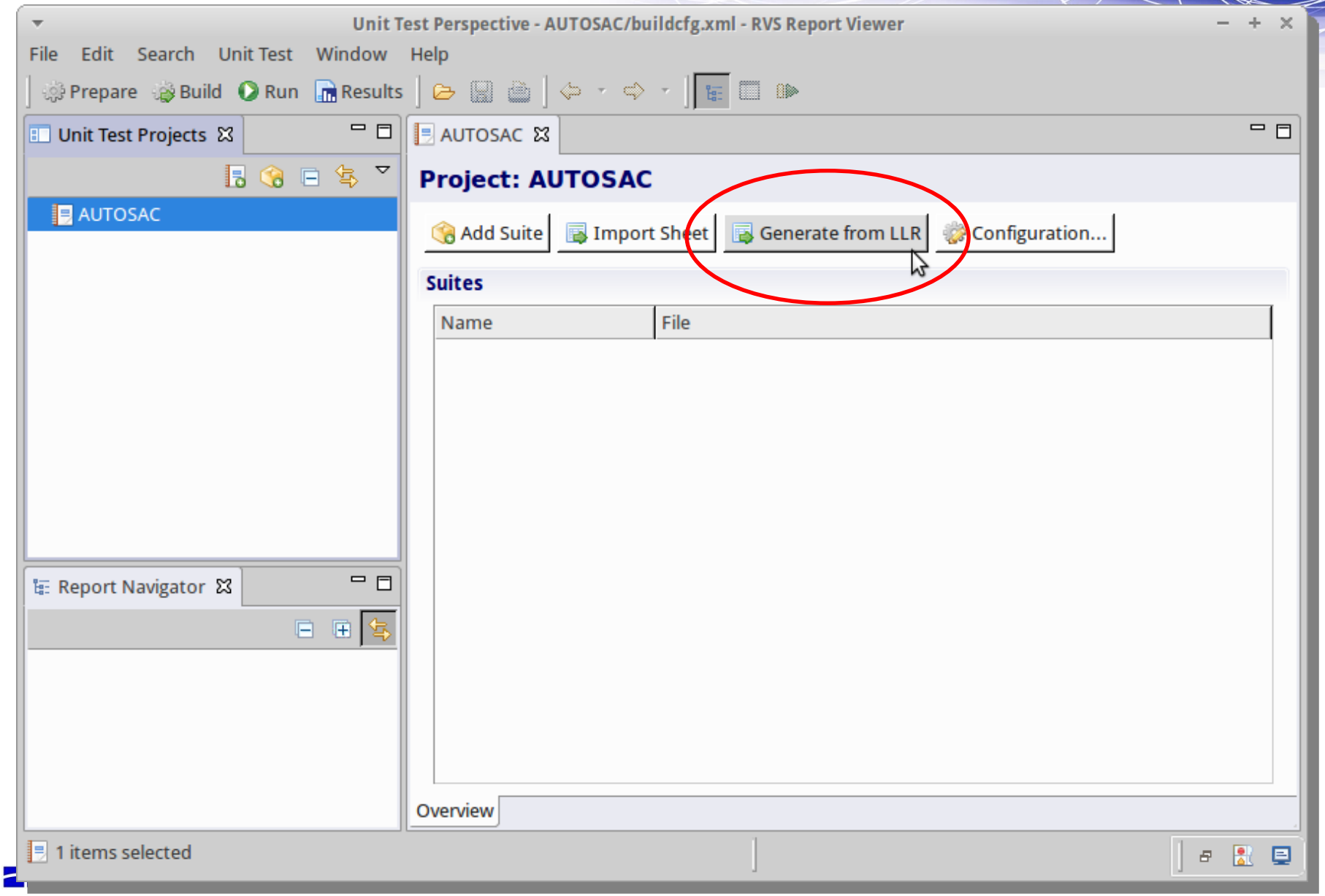
- Low-level requirements (LLR)
- Auto-generation of unit tests based on LLR
- Verification of Test Results

```
function Days_In_Month ( M : Month_T; Year : Year_T)
return Days_In_Month_T
with Post =>
  Days_In_Month'Result =
     (case M is
      when September | April | June | November => 30,
      when February =>
            (if Year mod 100 = 0 then
                (if Year mod 400 =0 then 29 else 28)
             else
                (if Year mod 4 = 0 then 29 else 28)),
      when others => 31);
```

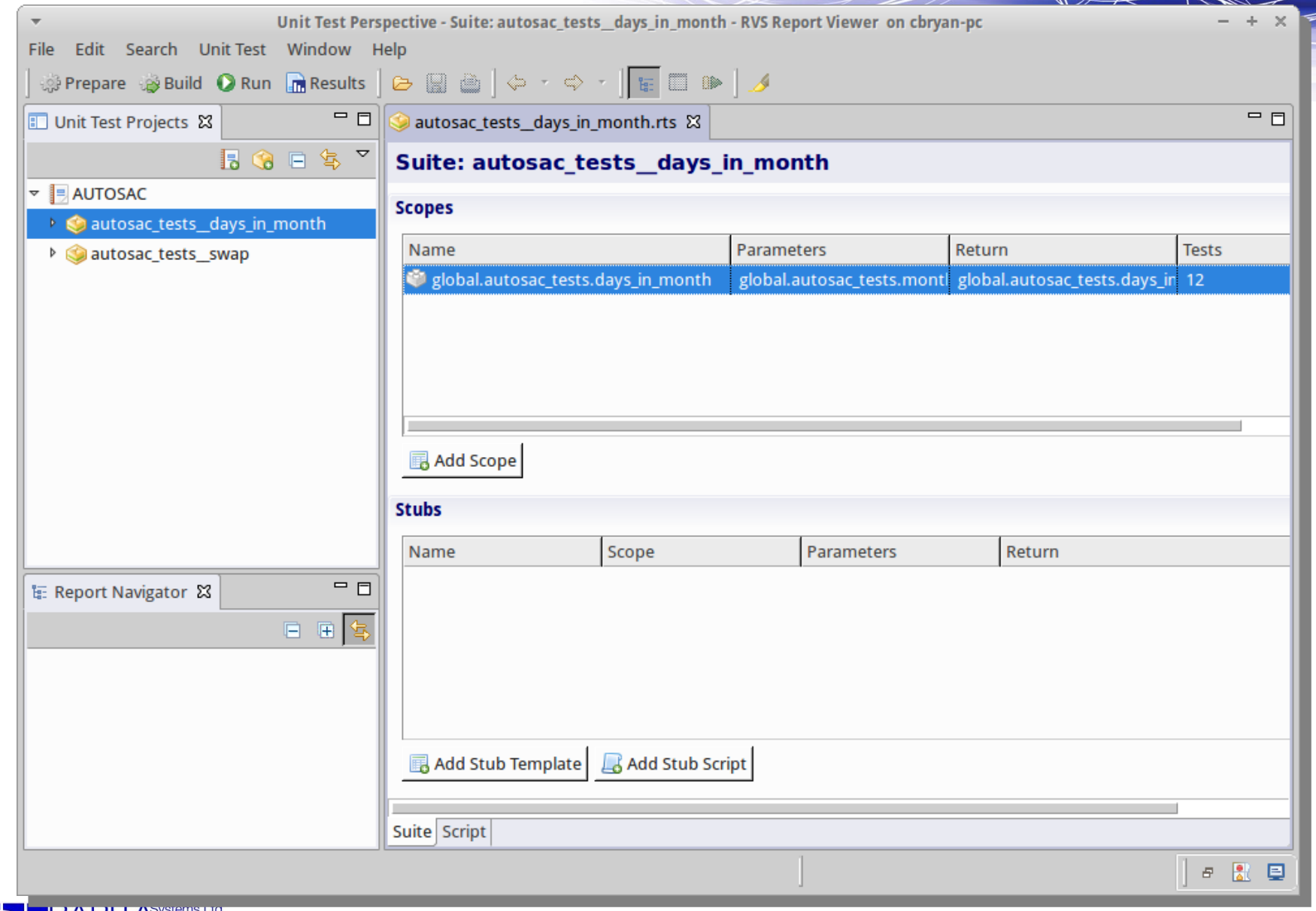
AUTOSAC Tool chain



Integration with RapiTest Framework



Tests have been generated by CMBC



Exploring “coverage” of the post-condition

CBMC

- Bounded model checker from University of Oxford.

“Explores post-condition to provide test inputs that cover all the post condition”

1. Coverage of the post-condition

- **i.e. generates test inputs that should exercise each part of post condition**

```
Case M is when September | April | June | November => 30,
```

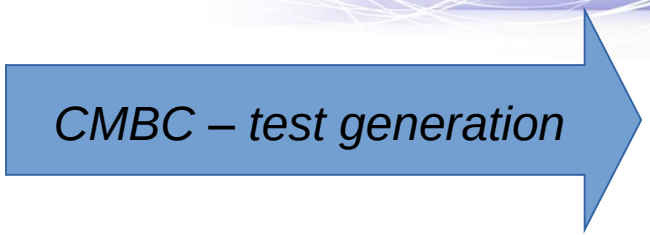
- **Generates a test input for either: Sept, April, June or November.**

2. Boundary coverage for inputs

(e.g. Integer’First, Integer’Last, and intermediate values etc)

3. Test cases that explore discontinuities in non-deterministic post conditions (future work)

Test generation



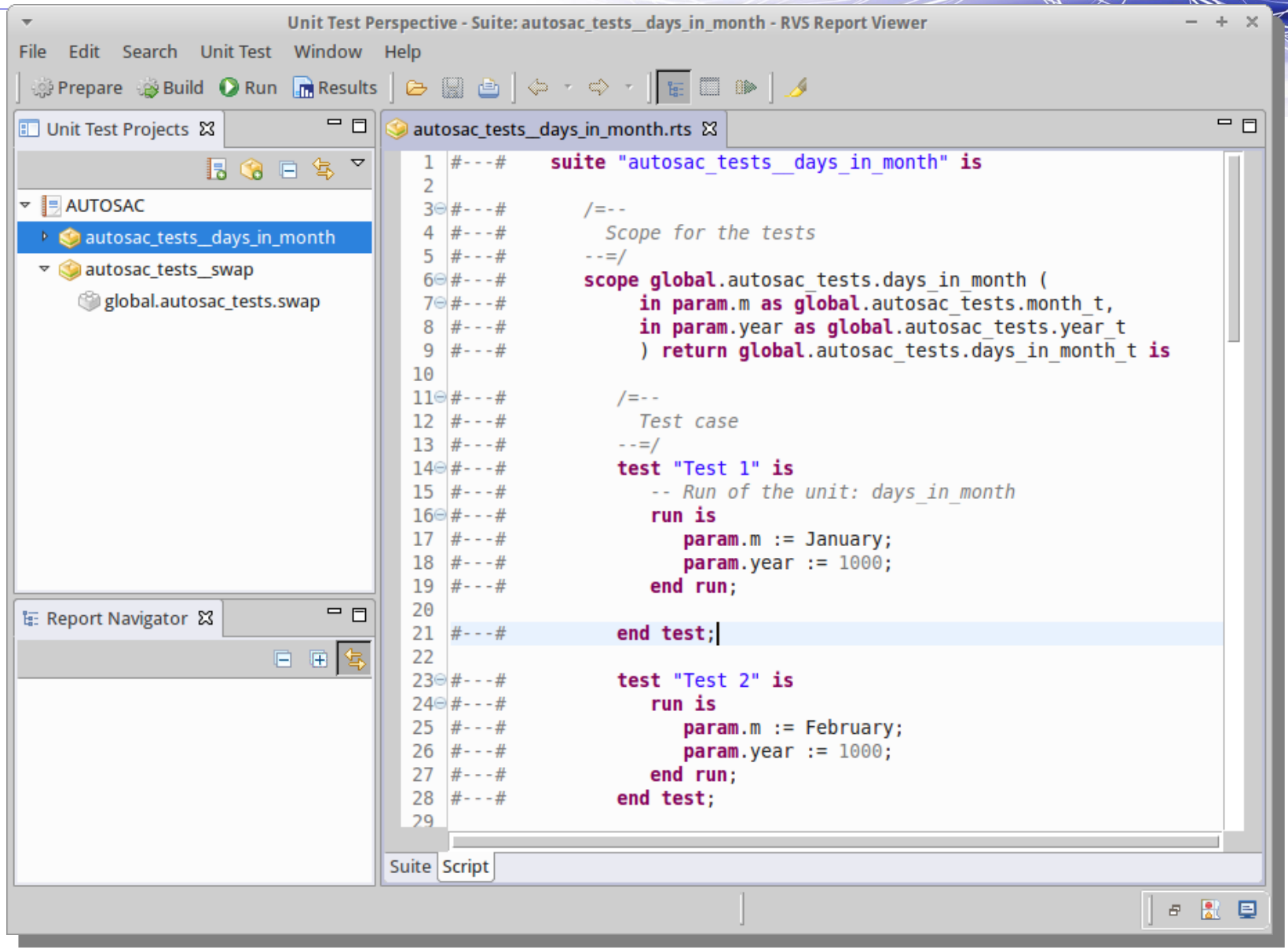
Ada Specification

```
function Days_In_Month (M : Month_T;
                        Year : Year_T)
return Days_In_Month_T
 with Post =>
 Days_In_Month'Result =
 (case M is
  when September | April | June | November =>
    30,
  when February =>
    (if Year mod 100 = 0 then
    (if Year mod 400 =0 then 29 else 28)
else
    (if Year mod 4 = 0 then 29 else 28)),
     when others => 31);
```

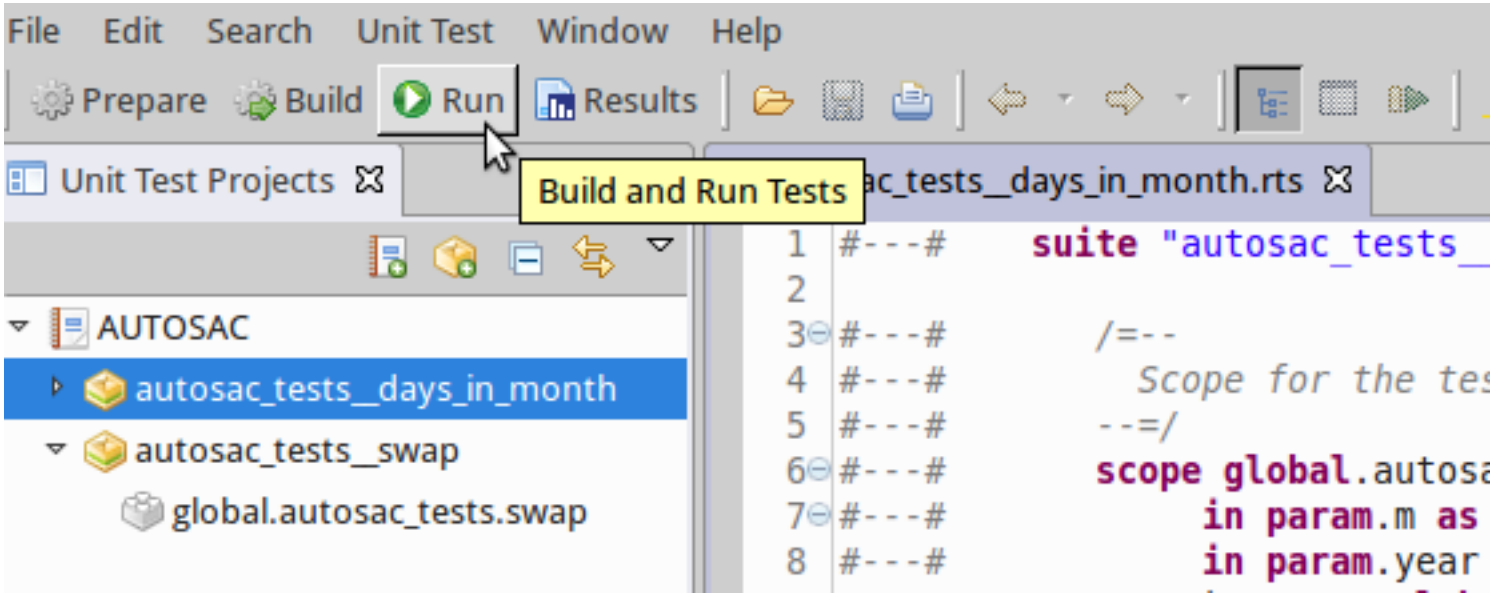
RapiTest Framework Script

```
suite "autosac_tests__days_in_month" is

scope global.autosac_tests.days_in_month (
     in param.m as global.autosac_tests.month_t,
     in param.year as global.autosac_tests.year_t)
 return global.autosac_tests.days_in_month_t is

     /=--
       Test case
     --=/
     test "Test 1" is
        -- Run of the unit: days_in_month
        run is
            param.m := January;
            param.year := 1000;
        end run;
      end test;
      test "Test 2" is
         run is
          param.m := February;
          param.year := 1000;
        end run;
     end test;
```

Test script in RapiTest Framework



Execute the unit-tests



Unit tests auto-generated

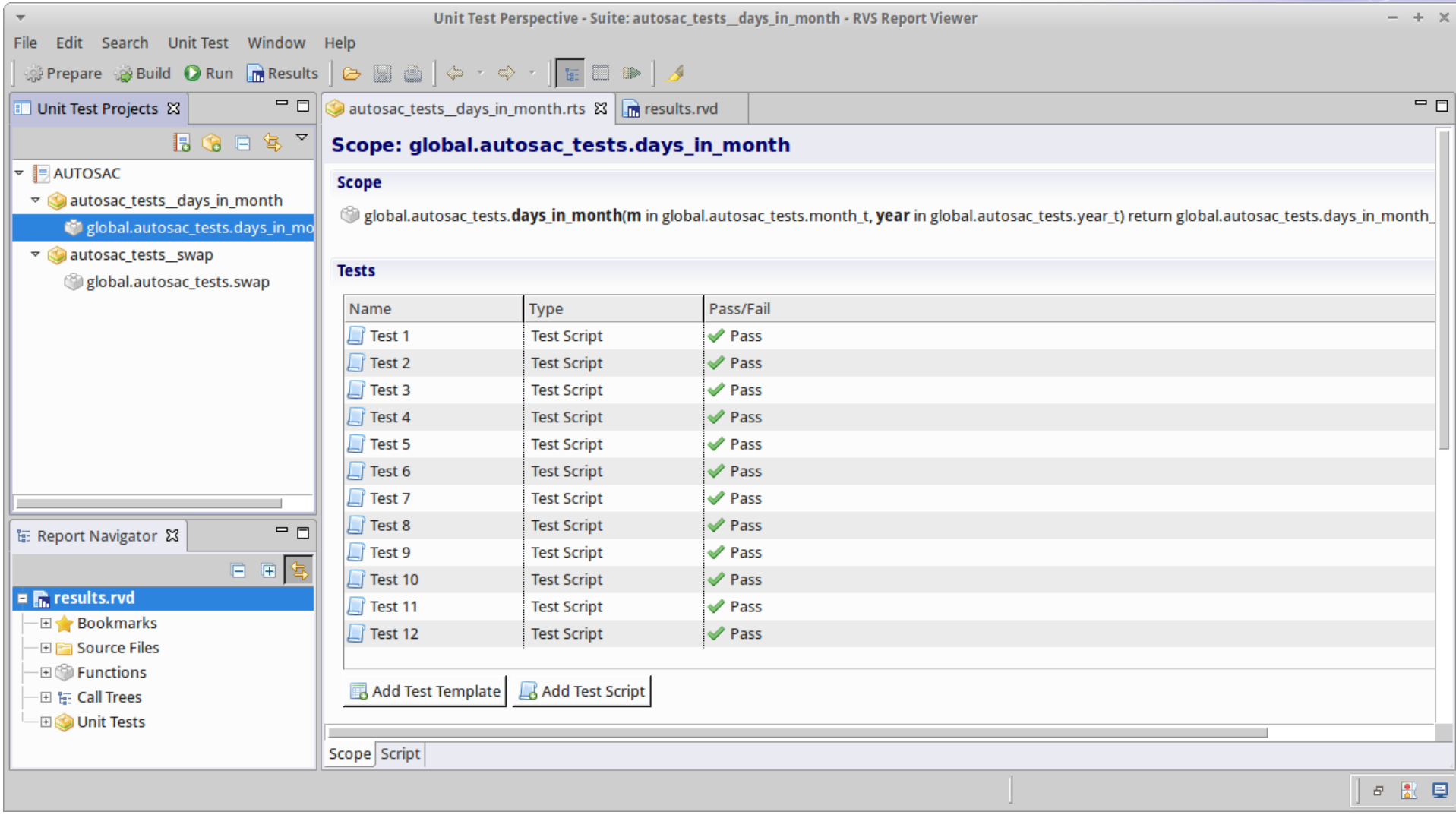
RapiTest Framework Script

```
suite "autosac_tests__days_in_month" is

scope global.autosac_tests.days_in_month (
     in param.m as global.autosac_tests.month_t,
     in param.year as global.autosac_tests.year_t)
 return global.autosac_tests.days_in_month_t is

     /=--
       Test case
     --=/
     test "Test 1" is
        -- Run of the unit: days_in_month
        run is
            param.m := January;
            param.year := 1000;
        end run;
      end test;
      test "Test 2" is
         run is
          param.m := February;
           param.year := 1000;
        end run;
     end test;
```

Driver Code

```
<...>

-- Adding tests
    RVS_RTS_Ext.Begin_Test(1738044706);
declare
     RVS_RTS_LOCAL_VAR_1733935649 :
     standard.autosac_tests.days_in_month_t :=
     standard.autosac_tests.days_in_month( m =>
     standard.autosac_tests.month_t`
        (autosac_tests.january),
     year => 1000 );
begin
      null; -- Any post-call assertions here...
end;


<...>
```

Test Results



Test results? Post Condition Is the Test Oracle

```
function Days_In_Month (M : Month_T;
                        Year : Year_T)
return Days_In_Month_T
 with Post =>
 Days_In_Month'Result =
 (case M is
  when September | April | June | November =>
    30,
  when February =>
    (if Year mod 100 = 0 then
    (if Year mod 400 =0 then 29 else 28)
else
    (if Year mod 4 = 0 then 29 else 28)),
     when others => 31);
```

Test success means post-condition evaluates true.

Q: how completely can the post condition describe the test result?

Test cases to explore discontinuities

```
function I_sqrt (M : Natural) return integer
with Post =>
I_sqrt'Result ** 2 <= M
and
(I_sqrt'Result + 1) ** 2 > M;
```

i_sqtr(63)=7

49 <= 63

64 > 63

Human tester might look at tests like:

- 0, 1, 2, 63, 64, 65, Integer'Last

How can a computer seek similar results?

- Currently CBMC would only produce one test case + out of range errors

(Future work)

Applicability to DO-178C

6.4.3c: This testing method should concentrate on demonstrating that each software component complies with its low-level requirements. Requirements based low-level testing ensures that the software components satisfy their low-level requirements. Typical errors revealed by this testing method include:

1 Failure of an algorithm to satisfy a software requirement;

2 Incorrect loop operations

3 Incorrect logic decisions

4 Failure to process correctly legitimate combinations of input conditions

5 Incorrect responses to missing or corrupted input data

6 Incorrect handling of exceptions, such as arithmetic faults or violations of array limits

7 Incorrect computation sequence

8 Inadequate algorithm precision, accuracy, or performance

Independence of compiler?

Common mode failure: the compiler ?

- Compiler generates test code
- AND compiler generates test-oracle (executing post-conditions). Normally the test results generated by a tester (greater independence)

Risk of common-mode failure in the compiler?

- The diversity of the specification and implementation would be enforced through coding standards that kept a separation and hence diversity between contracts and implementation.

End-to-end toolchain established and working on basic examples

- CMBC -> analysing SPARK post-conditions
- RapiTest Framework -> test scripts, execution, coverage etc.
- SPARK examples and case studies in preparation

Looking forward to seeing evaluation in case studies.

Conclusion

Basic idea:

- Use power of SPARK post conditions to generate tests
  - (Or at least get a head-start!)

How?

- SPARK -> CMBC ->RapiTest Framework

Benefit

- Reduce manual effort on creating tests, reviewing tests, executing tests, maintaining tests

Status

- Prototype – 2 case studies coming up

Looking for beta test…

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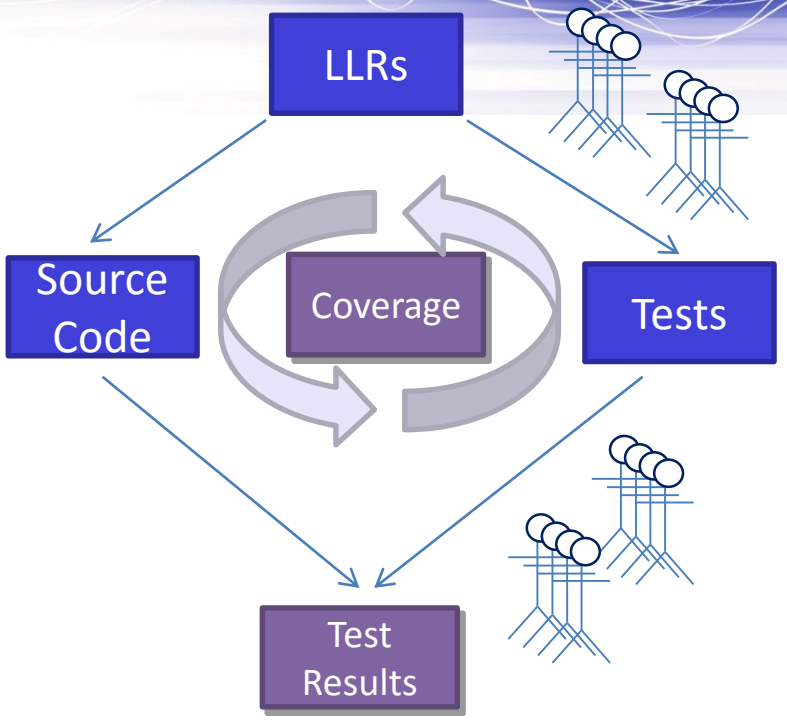

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