Hi-Lite project

Final meeting

Presented by David LESENS

Wednesday, 29 May 2013

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Together pioneering excellence

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Overview

- Introduction
- Astrium Space Transportation Case study
  - Numerical algorithm
  - Event driven
- Conclusion

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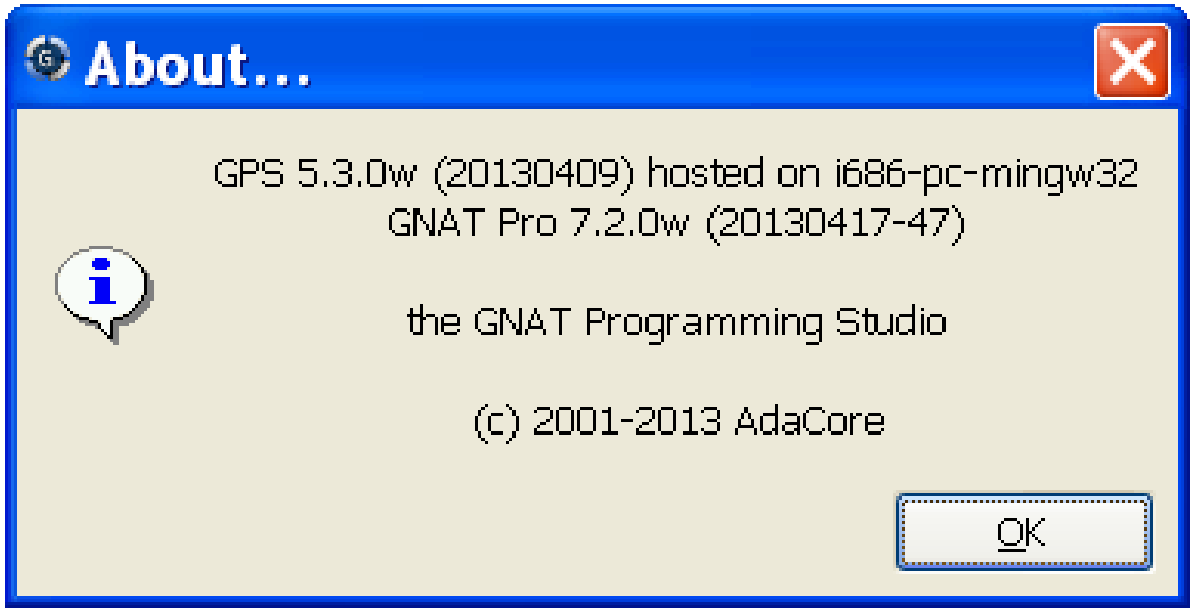
Tools



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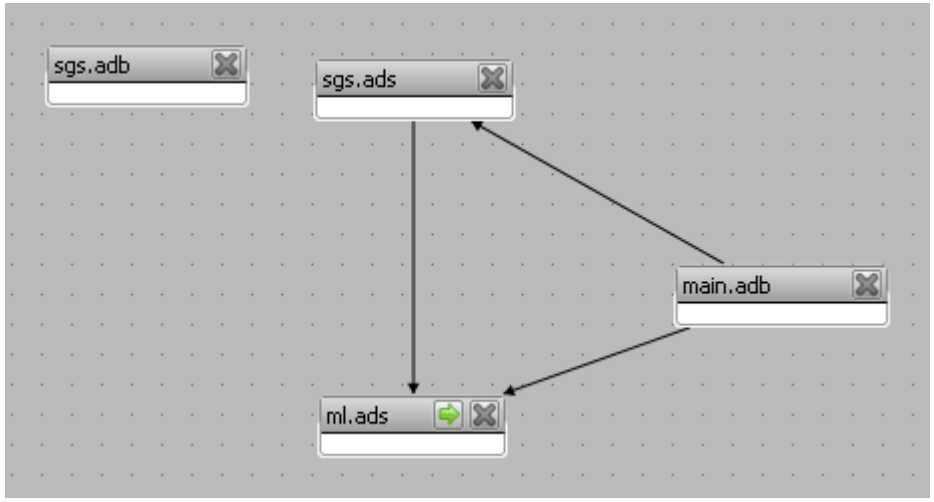
Architecture



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GPS - (Sgs project) - ml.ads

File Edit Navigate VCS Project Build Debug Tools Prove SPARK Window Help

default

\\muhome2\M023206\Offline Folder\HiLite\CASE_STUDY\TMTC\SGS\src\ml.ads

```
27    -- A signed integer type on 32 bits
28    type T_Int32 is range (-2 ** 31) .. (2 ** 31 - 1);
29    -- A signed integer type on 64 bits
30    type T_Int64 is range (-2 ** 63) .. (2 ** 63 - 1);
31
32    for T_Int32'Size use 32;
33    for T_Int64'Size use 64;
34
35    subtype T_Uint32 is T_Int32 range 0 .. (2 ** 31 - 1);
36    subtype T_Uint64 is T_Int64 range 0 .. (2 ** 63 - 1);
37
38    subtype T_Pos32 is T_Uint32 range 1 .. (2 ** 31 - 1);
39    subtype T_Pos64 is T_Uint64 range 1 .. (2 ** 63 - 1);
40
41    type T_Nat32 is range 0 .. (2 ** 32 - 1);
42    type T_Nat64 is range 0 .. (2 ** 63 - 1);
43
44    for T_Nat32'Size use 32;
45    for T_Nat64'Size use 64;
46
47    subtype T_Sign_Int32 is T_Int32 range -1 .. 1;
48
49    type T_Float32 is digits 6  range -3.40282E+38 .. 3.40282E+38;
50    type T_Float64 is digits 15 range -1.79769313486231E+308 .. 1.79769313486231E+308;
51    for T_Float32'Size use 32;
52    for T_Float64'Size use 64;
53
54    subtype T_Sign_Float32 is T_Float32 range -1.0 .. 1.0;
```

Types definitions

Unknown VCS (Modified) | Insert | Writable | Modified | 1:1

Dependency Browser | ml.ads | ml.adb | sgs.ads | sgs.adb

Messages

Messages | Locations

GPS - (Sgs project) - ml.ads

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```
92
93      ----------------------------------------------------------------------
94
95       function Float32_To_Int32 (X : in T_Float32) return T_Int32
96       with
97        Pre  => (X >= T_Float32(T_Int32'First) and then
98                 X + 1.0 <= T_Float32(T_Int32'Last)),
99        Post => Float32_To_Int32'Result = T_Int32 (X);
100
101     function Float32_To_Int32 (X : T_Float32) return T_Int32
102     is (T_Int32 (X));
103
104     ----------------------------------------------------------------------
105
106     function Int32_To_Float32 (X : T_Int32) return T_Float32
107     is (T_Float32 (X));
108
109     ----------------------------------------------------------------------
110
111     function Sign_Strict_Float32 (X : T_Int32) return T_Sign_Float32;
112
113     function Sign_Strict_Float32 (X : T_Int32) return T_Sign_Float32
114     is (if X >= 0 then 1.0 else -1.0);
115
116     ----------------------------------------------------------------------
117
118     function Absolute (X : T_Int32) return T_Int32
119     with
120       Pre => (X >= -T_Int32'Last);
```

Contracts

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Dependency Browser | ml.ads | ml.adb | sgs.ads | sgs.adb

Messages

Messages | Locations

GPS - (Sgs project) - ml.ads

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```
177    function Cos (X : T_Float32) return T_Float32
178    with
179      Pre => (X >= -C_2Pi32) and then
180      (X <= C_2Pi32),
181      Post => (Cos'Result >= -1.0) and then
182      (Cos'Result <= 1.0);
183
184    ----------------------------------------------------------------
185
186    function Arctan (X : T_Float32) return T_Float32
187    with
188      Post => (Arctan'Result >= -C_Halfpi32) and then
189      (Arctan'Result <= C_Halfpi32);
190
191    ----------------------------------------------------------------
192
193    function Saturate (X     : T_Float32;
194                       X_Min : T_Float32;
195                       X_Max : T_Float32) return T_Float32
196    with
197      Pre => (X_Min < X_Max);
198
199    function Saturate (X     : T_Float32;
200                       X_Min : T_Float32;
201                       X_Max : T_Float32) return T_Float32
202    is (if X < X_Min then X_Min
203        elsif X > X_Max then X_Max
204        else X);
```

Contracts

Unknown VCS (Modified) | Insert | Writable | Modified | 1:1

Dependency Browser | ml.ads | ml.adb | sgs.ads | sgs.adb

Messages

Messages | Locations

GPS - (Sgs project) - ml.adb

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```
16  -- Author: David Lesens
17  --                                                                    --
18  ------------------------------------------------------------------------
19
20  with Ada.Numerics.Generic_Elementary_Functions;
21
22  package body Ml is
23
24       package Num32 is new Ada.Numerics.Generic_Elementary_Functions (T_Float32);
25
26     ----------------------------------------------------------------------
27
28     function Arctan (X : T_Float32) return T_Float32
29     is (Num32.Arctan (X));
30
31     ----------------------------------------------------------------------
32
33     function Cos (X : T_Float32) return T_Float32
34     is (Num32.Cos (X));
35
36     ----------------------------------------------------------------------
37
38     function Sin (X : T_Float32) return T_Float32
39     is (Num32.Sin (X));
40
41     ----------------------------------------------------------------------
42
43  end Ml;
```

Trigonometric functions

Insert | Writable | Unmodified | 1:1

Dependency Browser | ml.ads | ml.adb | sgs.ads | sgs.adb

Messages

Messages | Locations

GPS - (Sgs project) - sgs.adb

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```
175                 + (
176                   C_SGS_SADM_STEP_ANG_VALUE
177                   *
178                     (
179                      SGS_SADE_MOTOR_STEPS_MOVED(SADE_I,SADM_J)
180                      + (
181                        SGS_SADE_MOTOR_U_STEPS_MOVED(SADE_I,SADM_J)/ C_SGS_SADM_MICRO_STEPS_NUMBER
182                       )
183                     )
184                 )
185               ));
186
187           else    -- SGS_MOTORj_TURNING_SENS(T-3) = CLOCK_WISE
188
189              SGS_MOTOR_MEASURED_ANGLE_STATE(T_2)(SADM_J) := ( S_NORMALISE_0_360(
190                (SGS_MOTOR_MEASURED_ANGLE_STATE(T_3)(SADM_J))
191                - (
192                  C_SGS_SADM_STEP_ANG_VALUE
193                  *
194                    (
195                     SGS_SADE_MOTOR_STEPS_MOVED(SADE_I,SADM_J)
196                     + (
197                       SGS_SADE_MOTOR_U_STEPS_MOVED(SADE_I,SADM_J)/ C_SGS_SADM_MICRO_STEPS_NUMBER
198                      )
199                    )
200                 )
201               ));
202
```

Insert | Writable | Unmodified | 1:1

Dependency Browser | ml.ads | ml.adb | sgs.ads | sgs.adb

Messages

Messages | Locations

Numerical algorithms

Results

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See PDF

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Space engineering

Spacecraft on-board control procedures

EUROPEAN COOPERATION
ECSS
FOR SPACE STANDARDIZATION

- On-board control procedure
  - Software program designed to be executed by an OBCP engine, which can easily be loaded, executed, and also replaced, on-board the spacecraft
- OBCP code
  - Complete representation of an OBCP, in a form that can be loaded on-board for subsequent execution
- OBCP engine
  - Application of the on-board software handling the execution of OBCPs
- OBCP language
  - Programming language in which OBCP source code is expressed by human programmers

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GPS - (Mvm project) - Project

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Project

- Mvm
  - .
  - OBJ
  - src
  - src\instance
  - src\MVM
  - src\MVM\debug
  - src\MVM\generic
  - testing
  - testing\um
  - OBJ
  - AUnit

- ✓ Generic (flight software)
- ✓ Debug
- ✓ Instances (for testing and formal proof)
- ✓ Tests
- ✓ User manual

Messages

Messages Locations

GPS - (Mvm project) - Messages

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default

Project

- Mvm
  - .
    - mvm-data-pool.adb
    - mvm-data-pool.ads
    - mvm-data.ads
    - mvm-g_events.adb
    - mvm-g_events.ads
    - mvm-g_expressions.adb
    - mvm-g_expressions.ads
    - mvm-g_fdir.adb
    - mvm-g_fdir.ads
    - mvm-g_fu-efu.adb
    - mvm-g_fu-efu.ads
    - mvm-g_fu-fsm.adb
    - mvm-g_fu-fsm.ads
    - mvm-g_fu.ads
    - mvm-g_fus.adb
    - mvm-g_fus.ads
    - mvm-g_obcpe.adb
    - mvm-g_obcpe.ads
    - mvm-g_parameter-g_command-g_call.ads
    - mvm-g_parameter-g_command-g_commands.ads
    - mvm-g_parameter-g_command.adb
    - mvm-g_parameter-g_command.ads
    - mvm-g_parameter.ads

Size of the case study

Messages

Messages Locations

GPS - (Mvm project) - Messages

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Project

- mvm-g_fu-fsm.ads
- mvm-g_fu.ads
- mvm-g_fus.adb
- mvm-g_fus.ads
- mvm-g_obcpe.adb
- mvm-g_obcpe.ads
- mvm-g_parameter-g_command-g_call.ads
- mvm-g_parameter-g_command-g_commands.ads
- mvm-g_parameter-g_command.adb
- mvm-g_parameter-g_command.ads
- mvm-g_parameter.ads
- mvm-g_vaps.adb
- mvm-g_vaps.ads
- mvm-g_variables.adb
- mvm-g_variables.ads
- mvm-ml-bits.adb
- mvm-ml-bits.ads
- mvm-ml.adb
- mvm-ml.ads
- mvm-obit.adb
- mvm-obit.ads
- mvm-variable.adb
- mvm-variable.ads
- mvm.ads
- ..\..\..\OBJ

Size of the case study

Messages

Messages Locations

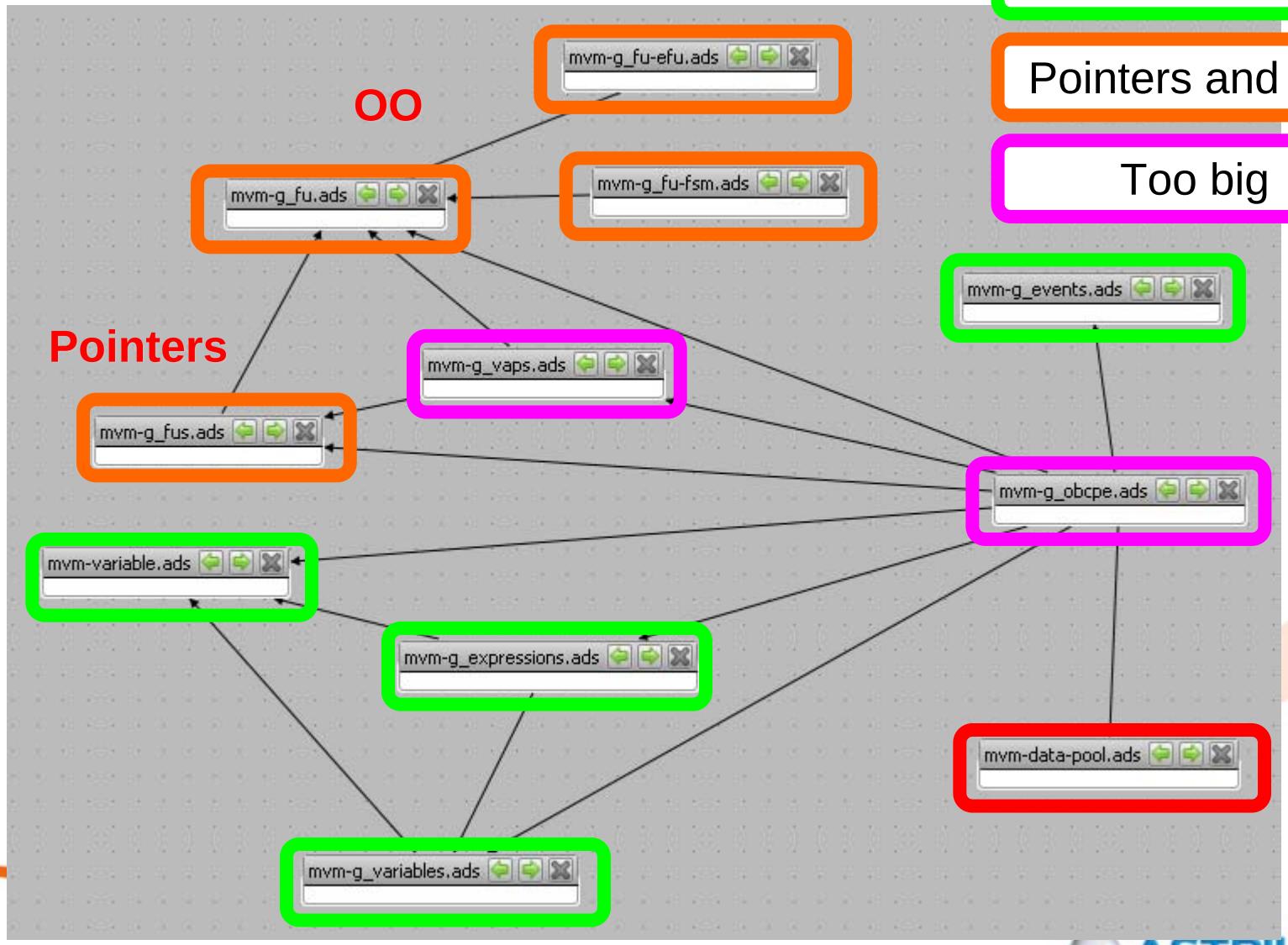
MVM (simplified) architecture

Not in SPARK

Proved

Pointers and OO

Too big



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GPS - (Mvm project) - mvm-ml-bits.adb

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\\muhome2\M023206\Offline Folder\HiLite\CASE_STUDY\TMTC\MVM\src\MVM\generic\mvm-ml-bits.adb

```
3572
3573
3574
3575
3576
3577
3578
3579
3580
3581
3582
3583   function Buffer_32bit_To_Float32 (X : T_Bit_Buffer) return T_Float32 is
3584   begin
3585      return Cast_From_32bit_Buffer_To_Float32 (X);
3586   end Buffer_32bit_To_Float32;
3587
3588
3589
3590
3591
3592
3593
3594
3595
3596
3597
3598
3599
3600
```

Not in SPARK

Buffer_Bit_To_Boolean | Unknown VCS (Modified) | Insert | Writable | Modified | 3568:24

Messages | Locations | mvm-ml-bits.adb

GPS - (Mvm project) - mvm-data-pool.adb

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\\muhome2\M023206\Offline Folder\HiLite\CASE_STUDY\TMTC\MVM\src\MVM\generic\mvm-data-pool.adb

```
265
266    function Unchecked_Read_Float32 (Data_Id   : T_Data_Id;
267                                     Data_Pool : T_Data_Pool) return T_Float32 is
268       Definition : T_Data_Definition;
269    begin
270       Definition := Data_Pool.Definition (Data_Id);
271       return Mvm.Ml.Bits.Buffer_Bit_To_Float32
272         (Mvm.Ml.Bits.T_Bit_Buffer
273            (Data_Pool.Storage
274               (Definition.First_Bit .. Definition.Last_Bit)));
275    end Unchecked_Read_Float32;
276
277    ------------------------------------------------------------------------
278
279    function Unchecked_Read_Float64 (Data_Id   : T_Data_Id;
280                                     Data_Pool : T_Data_Pool) return T_Float64 is
281       Definition : T_Data_Definition;
282    begin
283       Definition := Data_Pool.Definition (Data_Id);
284       return Mvm.Ml.Bits.Buffer_Bit_To_Float64
285         (Mvm.Ml.Bits.T_Bit_Buffer
286            (Data_Pool.Storage
287               (Definition.First_Bit .. Definition.Last_Bit)));
288    end Unchecked_Read_Float64;
289
290    ------------------------------------------------------------------------
291
292    function Unchecked_Read_Int32 (Data_Id   : T_Data_Id;
293                                   Data_Pool : T_Data_Pool) return T_Int32 is
294       Definition : T_Data_Definition;
295    begin
296       Definition := Data_Pool.Definition (Data_Id);
```

Not in SPARK

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GPS - (Mvm project) - mvm-g_events.ads

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```
24  -- Status                                                          --
25  --                                                                  --
26  -- Development: Completed
27  -- Test        : Completed
28  -- Proof       : Completed
29  --
30  ----------------------------------------------------------------------
31
32  with Mvm.Obit;
33  use Mvm.Obit;
34
35  generic
36
37     -- The list of events
38     type T_Event_Id is (<>);
39
40     --*************************************************************************
41     --*                                                                       *
42     --*          00000    0    00000  0  0      0    00000  00000            *
43     --*          0   0   0 0   0      0 0      0 0   0      0                *
44     --*          00000  0   0  0      00      0   0  0      0                *
45     --*          0      00000  0      0 0     00000  0  00  0000             *
46     --*          0      0   0  0      0  0    0   0  0   0  0                *
47     --*          0      0   0  0      0   0   0   0  0   0  0                *
48     --*          0      0   0  00000  0    0  0   0  00000  00000            *
49     --*                                                                       *
50     --*************************************************************************
51  package Mvm.G_Events is
52
53     ---------------------------------------------------------------------
54
```

Generic

Unknown VCS (Modified) | Insert | Writable | Unmodified | 1:1

Messages | Locations

GPS - (Mvm project) - mvm-g_obcpe.ads

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\\muhome2\M023206\Offline Folder\HiLite\CASE_STUDY\TMTC\MVM\src\MVM\generic\mvm-g_obcpe.ads

```
generic

   type T_Plan_Id is (<>);
   type T_Event_Id is (<>);
   C_Max_Of_Plan_Steps : T_Pos32;
   type T_Variable_Id is (<>);
   type T_Fu_Id is (<>);
   type T_State_Id is (<>);
   type T_Fus_Command_Id is (<>);
   Max_Of_Parameter_Nb : T_Pos32;
   type T_Vap_Id is (<>);
   C_Max_Of_Vap_Steps : T_Pos32;
   type T_Data_Id is (<>);
   type T_Data_Pool_Storage is private;
   type T_Superstate_Types_Id is (<>);
   type T_Fus_Superstate_Id is (<>);

package Mvm.G_Obcpe is
```

Generic

Unknown VCS (Modified) | Insert | Writable | Modified | 34:20

Messages | Locations

GPS - (Mvm project) - mvm-g_events.ads

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\\muhome2\M023206\Offline Folder\HiLite\CASE_STUDY\TMTC\MVM\src\MVM\generic\mvm-g_events.ads

```
56
57    type T_Event
58      (
59       Event_Status        : T_Event_Status        := Inactive;
60       Type_Of_Monitoring  : T_Type_Of_Monitoring  := No_Window;
61       Type_Of_Time        : T_Type_Of_Time        := Absolute_Time)
62    is
63       record
64          case Event_Status is
65             when Inactive | Failed_To_Be_Detected => null;
66             when Not_Yet_Detected =>
67                Number_Of_Detection : T_Number_Of_Detection;
68                Threshold           : T_Number_Of_Detection;
69                case Type_Of_Monitoring is
70                when No_Window => null;
71                when Time_Window_Start_Not_Protected_End_Not_Protected
72                   | Time_Window_Start_Protected_End_Not_Protected
73                   | Time_Window_Start_Not_Protected_End_Protected
74                   | Time_Window_Start_Protected_End_Protected =>
75                   Start_Window : T_Numerical_Obit;
76                   End_Window   : T_Numerical_Obit;
77                   case Type_Of_Time is
78                      when Absolute_Time     => null;
79                      when Relative_To_Event => Origin_Event : T_Event_Id;
80                   end case;
81                end case;
82             when Detected =>
83                Detection_Time : T_Numerical_Obit;
84          end case;
85       end record;
86
```

Discriminant

Mvm.G_Events | Unknown VCS (Modified) | Insert | Writable | Modified | 50:62

Messages | Locations

GPS - (Mvm project) - mvm-g_events.ads

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\\muhome2\M023206\Offline Folder\HiLite\CASE_STUDY\TMTC\MVM\src\MVM\generic\mvm-g_events.ads

```
 85
 86    function Is_Valid (Event : T_Event) return Boolean is
 87      (case Event.Event_Status is
 88       when Inactive | Detected | Failed_To_Be_Detected => True,
 89       when Not_Yet_Detected =>
 90         (case Event.Type_Of_Monitoring is
 91          when No_Window                                          =>
 92            (Event.Number_Of_Detection < Event.Threshold),
 93          when Time_Window_Start_Not_Protected_End_Not_Protected   =>
 94            (Event.Number_Of_Detection < Event.Threshold and then
 95             Event.Start_Window <= Event.End_Window),
 96          when Time_Window_Start_Protected_End_Not_Protected
 97          | Time_Window_Start_Not_Protected_End_Protected
 98          | Time_Window_Start_Protected_End_Protected             =>
 99            (Event.Number_Of_Detection <= Event.Threshold and then
100               (Event.Start_Window <= Event.End_Window))))));
101
102    ------------------------------------------------------------------------
103
104    -- The detection statuses of all events
105    type T_Events is private;
106    function Is_Valid (Events : T_Events) return Boolean;
107
108    ------------------------------------------------------------------------
109
110    -- Returns an event status from its Id
111    function Get_Event (Event_Id : T_Event_Id;
112                        Events   : T_Events)
113                        return T_Event
114    with Pre => Is_Valid (Events);
115
```

Validity function

Private list

Mvm.G_Events | Unknown VCS (Modified) | Insert | Writable | Modified | 77:74

GPS - (Mvm project) - mvm-g_events.ads

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\\muhome2\M023206\Offline Folder\HiLite\CASE_STUDY\TMTC\MVM\src\MVM\generic\mvm-g_events.ads

```
   --*****************************************************************
private
   -- ***************************************************************** --

   ------------------------------------------------------------------------

   type T_Events is array (T_Event_Id) of T_Event;

   ------------------------------------------------------------------------

   function Is_Valid (Events : T_Events) return Boolean is
     (for all Event_Id in T_Event_Id => Is_Valid (Event => Events (Event_Id)));

   ------------------------------------------------------------------------

   function Init return T_Events is
     (T_Events'(others => T_Event'
                 (Event_Status       => Inactive,
                  Type_Of_Monitoring => No_Window,
                  Type_Of_Time       => Absolute_Time)));

   ------------------------------------------------------------------------

   function Get_Event (Event_Id : T_Event_Id;
                       Events   : T_Events)
                       return T_Event
   is (Events (Event_Id));

   ------------------------------------------------------------------------

   function Is_Event_Monitoring_Detected (Event_Id : T_Event_Id;
```

Private list

Validity function

Mvm.G_Events | Unknown VCS (Modified) | Insert | Writable | Modified | 105:15

GPS - (Mvm project) - mvm-g_events.ads

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```
456
457     -- Update the status of all events following time passing
458     procedure Check_Monitoring (Events       : in out T_Events;
459                                 Current_Time :        Mvm.Obit.T_Obit)
460     with
461       Pre  => Is_Valid (Events),
462       Post =>
463         (Is_Valid (Events) and then
464            (for all Event_Id in T_Event_Id =>
465               (case Get_Event (Event_Id, Events'Old).Event_Status is
466                when Inactive | Detected | Failed_To_Be_Detected =>
467                  (Get_Event (Event_Id, Events) = Get_Event (Event_Id, Events'Old)),
468                when Not_Yet_Detected                                =>
469                  (Get_Event (Event_Id, Events).Event_Status = Failed_To_Be_Detected or else
470                   Get_Event (Event_Id, Events).Event_Status = Not_Yet_Detected or else
471                   Get_Event (Event_Id, Events).Event_Status = Detected))));
472
473     ------------------------------------------------------------------------
474
475     -- Returns true iff the event has been detected
476     function Is_Event_Monitoring_Detected (Event_Id : T_Event_Id;
477                                            Events   : T_Events)
478                                            return Boolean with
479       Pre => Is_Valid (Events),
480       Post =>
481         (Is_Event_Monitoring_Detected'Result =
482              (case Get_Event (Event_Id, Events).Event_Status is
483               when Inactive | Not_Yet_Detected | Failed_To_Be_Detected => False,
484               when Detected                                           => True));
485
486     ------------------------------------------------------------------------
```

Subprogram on the whole list

Set_Event_Detection | Unknown VCS (Modified) | Insert | Writable | Modified | 439:47

GPS - (Mvm project) - mvm-g_events.adb

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default

\\muhome2\M023206\Offline Folder\HiLite\CASE_STUDY\TMTC\MVM\src\MVM\generic\mvm-g_events.adb

```
47
48
49
50
51
52
53
54
55  procedure Check_Monitoring (Event        : in out T_Event;
56                              Events       :        T_Events;
57                              Current_Time :        Mvm.Obit.T_Obit)
58  with
59    Pre  => Is_Valid (Event => Event),
60    Post =>
61      Is_Valid (Event => Event),
62       Contract_Cases => ((Event.Event_Status in Inactive | Detected | Failed_To_Be_Detected) =>
63                            (Event = Event'Old),
64                          (Event.Event_Status in Not_Yet_Detected)                            =>
65                            (Event.Event_Status = Not_Yet_Detected or else
66                             Event.Event_Status = Detected or else
67                             Event.Event_Status = Failed_To_Be_Detected));
68
69
70
71
72
73
74
75
76
77
```

Subprogram on a single element

Unknown VCS (Modified) | Insert | Writable | Saved | 1:1

GPS - (Mvm project) - mvm-g_events.adb

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\\muhome2\M023206\Offline Folder\HiLite\CASE_STUDY\TMTC\MVM\src\MVM\generic\mvm-g_events.adb

```
procedure Check_Monitoring (Events       : in out T_Events;
                            Current_Time :        Mvm.Obit.T_Obit) is
   Event : T_Event;
begin
   for Event_Id in T_Event_Id loop
      Event := Events (Event_Id);
      Check_Monitoring (Event        => Event,
                        Events       => Events,
                        Current_Time => Current_Time);
      pragma Assert (Is_Valid (Event => Event));
      pragma Assert (Is_Valid (Events => Events));
      Events (Event_Id) := Event;
      pragma Assert (Is_Valid (Events => Events));
      pragma Loop_Invariant
        (Is_Valid (Events => Events) and then
           (for all I in T_Event_Id range T_Event_Id'First .. Event_Id =>
              (case Events'Loop_Entry (I).Event_Status is
               when Inactive | Detected | Failed_To_Be_Detected =>
                 (Events (I) = Events'Loop_Entry (I)),
               when Not_Yet_Detected                            =>
                 (Events (I).Event_Status = Not_Yet_Detected or else
                  Events (I).Event_Status = Detected or else
                  Events (I).Event_Status = Failed_To_Be_Detected))) and then
           (if Event_Id /= T_Event_Id'Last then
              (for all I in T_Event_Id'Succ (Event_Id) .. T_Event_Id'Last =>
               Events (I) = Events'Loop_Entry (I))))));
   end loop;
end Check_Monitoring;

--------------------------------------------------------------------------
```

Additional assertion

Loop invariant

Check_Monitoring | Unknown VCS (Modified) | Insert | Writable | Modified | 120:20

At 1KHz

On 32 bits	On 64 bits	
2147483648	9,22337E+18	
2147483,648	9,22337E+15	seconds
596,5232356	2,56205E+12	hours
24,85513481	1,06752E+11	days
0,067910204	291672107	years
0,000679102	2916721,07	centuries

```
pragma Assert (Event.Number_Of_Detection <= Event.Threshold);

if Event.Number_Of_Detection < Event.Threshold then
   Event.Number_Of_Detection := Event.Number_Of_Detection + 1;
end if;

pragma Assert (Is_Valid (Event => Event));
if (Event.Type_Of_Time = Absolute_Time and then
    Numerical_Obit >= Event.End_Window) or else
  (Event.Type_Of_Time = Relative_To_Event and then
   Events (Event.Origin_Event).Event_Status = Detected and then
   Numerical_Obit >= Event.End_Window + Events (Event.Origin_Event).Detection_Time)
then
   if Event.Event_Status /= Detected then
      Event := T_Event'(Event_Status       => Detected,
                        Detection_Time     => Numerical_Obit,
                        Type_Of_Monitoring => No_Window,
                        Type_Of_Time       => Absolute_Time);
      pragma Assert (Is_Valid (Event => Event));
   end if;
else
```

Additional numerical protection

Mvm.G_Events | Unknown VCS (Modified) | Insert | Writable | Modified | 53:4

Messages | Locations | mvm-g_events.ads

GPS - (Mvm project) - mvm-g_expressions.ads

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default

\\muhome2\M023206\Offline Folder\HiLite\CASE_STUDY\TMTC\MVM\src\MVM\generic\mvm-g_expressions.ads

```
69
70    type T_Expression (Expression_Type : T_Expression_Type := Onboard_Time_Expression)
71    is
72       record
73          Data_Type : T_Data_Type;
74          case Expression_Type is
75             when Constant_Expression =>
76                Numerical_Value : Data.T_Numerical_Value;
77             when Onboard_Time_Expression =>
78                null;
79             when Equal_Expression | Different_Expression | Greater_Expression
80                | Greater_Or_Equal_Expression | Less_Expression
81                | Less_Or_Equal_Expression | And_Expression | Or_Expression
82                | Addition_Expression | Subtraction_Expression
83                | Multiplication_Expression | Division_Expression
84                | Not_Expression | Negation_Expression
85                | Abs_Expression | Square_Root_Expression  | Variable_Expression
86                | Cast_Nat64_To_Nat32 | Cast_Int32_To_Nat32
87                | Cast_Int64_To_Nat32 | Cast_Float32_To_Nat32
88                | Cast_Float64_To_Nat32 | Cast_Nat32_To_Nat64
89                | Cast_Int32_To_Nat64 | Cast_Int64_To_Nat64
90                | Cast_Float32_To_Nat64 | Cast_Float64_To_Nat64
91                | Cast_Nat32_To_Int32 | Cast_Nat64_To_Int32 | Cast_Int64_To_Int32
92                | Cast_Float32_To_Int32 | Cast_Float64_To_Int32
93                | Cast_Nat32_To_Int64 | Cast_Nat64_To_Int64 | Cast_Int32_To_Int64
94                | Cast_Float32_To_Int64 | Cast_Float64_To_Int64
95                | Cast_Nat32_To_Float32 | Cast_Nat64_To_Float32
96                | Cast_Int32_To_Float32 | Cast_Int64_To_Float32
97                | Cast_Float64_To_Float32 | Cast_Nat32_To_Float64
98                | Cast_Nat64_To_Float64 | Cast_Int32_To_Float64
```

Bigger structure

Mvm.G_Expressions | Unknown VCS (Modified) | Insert | Writable | Modified | 66:50

mvm-data-pool.adb | mvm-g_expressions.ads

Messages | Locations

GPS - (Mvm project) - mvm-g_expressions.ads

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default

\\muhome2\M023206\Offline Folder\HiLite\CASE_STUDY\TMTC\MVM\src\MVM\generic\mvm-g_expressions.ads

```
908
909    function Is_Valid (Expression     : T_Expression;
910                       Variable_Types : P_Variables.T_Variable_Types)
911                       return Boolean is
912      (P_Variables.Is_Valid (Variable_Types => Variable_Types) and then
913         (case Expression.Expression_Type is
914          when Variable_Expression          =>
915            (Expression.Data_Type =
916               Variable_Types (Expression.Left).Data_Type),
917          when Onboard_Time_Expression      =>
918            (Expression.Data_Type = Nat64_Type),
919          when Constant_Expression          =>
920            (Expression.Data_Type = Expression.Numerical_Value.Data_Type),
921          when Equal_Expression             =>
922            (Expression.Data_Type = Boolean_Type and then
923               (Variable_Types (Expression.Left).Data_Type =
924                  Variable_Types (Expression.Right).Data_Type)),
925          when Different_Expression         =>
926            (Expression.Data_Type = Boolean_Type and then
927               (Variable_Types (Expression.Left).Data_Type =
928                  Variable_Types (Expression.Right).Data_Type)),
          when Greater_Expression           =>
930            (Expression.Data_Type = Boolean_Type and then
931             Variable_Types (Expression.Left).Data_Type /= Boolean_Type and then
             Variable_Types (Expression.Right).Data_Type /= Boolean_Type and then
933               (Variable_Types (Expression.Left).Data_Type =
934                  Variable_Types (Expression.Right).Data_Type)),
935          when Greater_Or_Equal_Expression =>
936            (Expression.Data_Type = Boolean_Type and then
937             Variable_Types (Expression.Left).Data_Type /= Boolean_Type and then
```

Insert | Writable | Unmodified | 1:1

mvm-g_expressions.ads

Messages | Locations

Validity function

GPS - (Mvm project) - mvm-g_expressions.adb

File Edit Navigate VCS Project Build Debug Tools Prove SPARK Window Help

default

\\muhome2\M023206\Offline Folder\HiLite\CASE_STUDY\TMTC\MVM\src\MVM\generic\mvm-g_expressions.adb

```
1687
1688    ----------------------------------------------------------------------
1689
1690    procedure Compute (Expression   :     T_Expression;
1691                       Variables    :     T_Variables;
1692                       Current_Time :     Mvm.Obit.T_Obit;
1693                       Result       : out Data.T_Numerical_Value;
1694                       Is_Error     : out Boolean) is
1695    begin
1696       Is_Error := False;
1697       case Expression.Expression_Type is
1698          when Variable_Expression         =>
1699             Result := Compute_Variable (Expression => Expression, Variables => Variables);
1700             pragma Assert (Expression.Data_Type = Result.Data_Type);
1701          when Constant_Expression         =>
1702             Result := Compute_Constant (Expression => Expression, Variables => Variables);
1703             pragma Assert (Expression.Data_Type = Result.Data_Type);
1704          when Onboard_Time_Expression     =>
1705             Result := Compute_Onboard_Time (Expression => Expression, Variables => Variables, Current_Time
1706             pragma Assert (Expression.Data_Type = Result.Data_Type);
1707          when Equal_Expression            =>
1708             pragma Assert (Expression.Data_Type = Boolean_Type);
1709             pragma Assert (Get_Variable (Expression.Left, Variables).Data_Type =
1710                            Get_Variable (Expression.Right, Variables).Data_Type);
1711             Result := Compute_Equal (Expression => Expression, Variables => Variables);
1712             pragma Assert (Result.Data_Type = Boolean_Type);
1713             pragma Assert (Expression.Data_Type = Result.Data_Type);
1714          when Different_Expression        =>
1715             pragma Assert (Expression.Data_Type = Boolean_Type);
1716             pragma Assert (Get_Variable (Expression.Left, Variables).Data_Type =
```

Divide and Conquer

Insert | Writable | Unmodified | 1:1

mvm-g_expressions.adb

Messages | Locations

GPS - (Mvm project) - mvm-g_expressions.adb

File Edit Navigate VCS Project Build Debug Tools Prove SPARK Window Help

default

\\muhome2\M023206\Offline Folder\HiLite\CASE_STUDY\TMTC\MVM\src\MVM\generic\mvm-g_expressions.adb

```
90    function Compute_Equal (Expression : T_Expression;
91                            Variables  : T_Variables)
92                            return Data.T_Numerical_Value
93    with
94      Pre  =>
95        (Is_Valid (Expression => Expression, Variables  => Variables)
96         and then Expression.Expression_Type = Equal_Expression and then
97           (Get_Variable (Expression.Left, Variables).Data_Type =
98              Get_Variable (Expression.Right, Variables).Data_Type)),
99      Post => Compute_Equal'Result.Data_Type = Boolean_Type;
100
101   function Compute_Equal (Expression : T_Expression;
102                           Variables  : T_Variables)
103                           return Data.T_Numerical_Value is
104       Result : Data.T_Numerical_Value;
105   begin
106      pragma Assert (Get_Variable (Expression.Left, Variables).Data_Type =
107                        Get_Variable (Expression.Right, Variables).Data_Type);
108      case Get_Variable (Expression.Left, Variables).Data_Type is
109         when Boolean_Type =>
110            Result := Data.Create_Boolean_Value (P_Variables.Get_Boolean (Expression.Left, Variables) =
111                                                 P_Variables.Get_Boolean (Expression.Right, Variables));
112            pragma Assert (Result.Data_Type = Boolean_Type);
113         when Nat32_Type =>
114            Result := Data.Create_Boolean_Value (P_Variables.Get_Nat32 (Expression.Left, Variables) =
115                                                 P_Variables.Get_Nat32 (Expression.Right, Variables));
116            pragma Assert (Result.Data_Type = Boolean_Type);
117         when Int32_Type => Result := Data.Create_Boolean_Value (P_Variables.Get_Int32 (Expression.Left, V
118                                                                 P_Variables.Get_Int32 (Expression.Right
119            pragma Assert (Result.Data_Type = Boolean_Type);
```

Divide and Conquer

Compute_Onboard_Time | Insert | Writable | Unmodified | 85:32

mvm-data-pool.adb | mvm-g_expressions.adb

Messages | Locations

GPS - (Mvm project) - mvm-g_fus.ads

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default

\\muhome2\M023206\Offline Folder\HiLite\CASE_STUDY\TMTC\MVM\src\MVM\generic\mvm-g_fus.ads

```
   --*****************************************************************************
   --*                                                                           *
   --*          OOOOO  OOOOO  OOOOO  O      O    O    OOOOO  OOOOO              *
   --*          O   O  O   O    O    O      O   O O     O    O                  *
   --*          OOOOO  OOOOO    O     O    O   O   O    O    O                  *
   --*          O      OO       O     O    O   OOOOO    O    OOOO               *
   --*          O      O O      O      O  O    O   O    O    O                  *
   --*          O      O  O     O      O  O    O   O    O    O                  *
   --*          O      O   O  OOOOO     O      O   O    O    OOOOO              *
   --*                                                                           *
   --*****************************************************************************
private
   -- ***************************************************************************

   type T_Fus is array (T_Fu_Id) of access T_Fu'Class;

   ----------------------------------------------------------------------------

   -- Check the validity of a FU
   function Is_Valid (Fus    : T_Fus;
                      Fu_Id  : T_Fu_Id) return Boolean is
     (P_Gfu.Is_Valid (Fus (Fu_Id).all));

   ----------------------------------------------------------------------------

   -- Check the validity of all FUs
   function Is_Valid (Fus : T_Fus) return Boolean is
     (for all Fu_Id in T_Fu_Id => Is_Valid (Fus, Fu_Id));

   ----------------------------------------------------------------------------

   -- Check the validity of a FU
```

Array of objects

Pointers

Insert | Writable | Unmodified | 1:1

Messages | Locations

GPS - (Mvm project) - mvm-g_fu.ads

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default

\\muhome2\M023206\Offline Folder\HiLite\CASE_STUDY\TMTC\MVM\src\MVM\generic\mvm-g_fu.ads

```
53    --*****************************************************************************
54    --*                                                                           *
55    --*          00000    0    00000  0  0      0    00000  00000                *
56    --*          0   0   0 0   0      0 0      0 0   0      0                     *
57    --*          00000  0   0  0      00      0   0  0      0                     *
58    --*          0      00000  0      0 0     00000  0  00  0000                  *
59    --*          0      0   0  0      0  0    0   0  0   0  0                     *
60    --*          0      0   0  0      0   0   0   0  0   0  0                     *
61    --*          0      0   0  00000  0    0  0   0  00000  00000                 *
62    --*                                                                           *
63    --*****************************************************************************
64 package Mvm.G_Fu is
65
66    ------------------------------------------------------------------------------
67
68    type T_Gfu is abstract tagged private;
69
70    ------------------------------------------------------------------------------
71
72    package P_Parameter is new Mvm.G_Parameter (Max_Of_Parameter_Nb => Max_Of_Parameter_Nb);
73
74    package P_Command is new P_Parameter.G_Command (T_Command_Id => T_Fus_Command_Id);
75
76    ------------------------------------------------------------------------------
77
78    -- Check validity
79    function Is_Valid (Fu : T_Gfu) return Boolean is abstract;
80
81    ------------------------------------------------------------------------------
82
83    function Is_Valid (Fu      : T_Gfu;
84                       Command : P_Command.T_Command) return Boolean
```

Abstract class

Mvm.G_Fu | Insert | Writable | Unmodified | 49:1

Messages | Locations

GPS - (Mvm project) - mvm-g_fu.ads

File Edit Navigate VCS Project Build Debug Tools Prove SPARK Window Help

default

\\muhome2\M023206\Offline Folder\HiLite\CASE_STUDY\TMTC\MVM\src\MVM\generic\mvm-g_fu.ads

```
179    --*                                                                  *
180    --*          00000  00000  00000  0      0    0    00000  00000      *
181    --*          0   0  0   0    0    0      0   0 0     0    0          *
182    --*          00000  00000    0     0    0   0   0    0    0          *
183    --*          0      00       0     0    0   00000    0    0000       *
184    --*          0      0 0      0      0  0   0   0    0    0          *
185    --*          0      0  0     0      0  0   0   0    0    0          *
186    --*          0      0   0  00000     0     0   0    0    00000      *
187    --*                                                                  *
188    --***********************************************************************
189 private
190    -- ***********************************************************************
191
192    ----------------------------------------------------------------------
193
194    type T_Gfu is abstract tagged record
195       Current_State_Id : T_Fus_State_Id;
196       Status           : T_Status;
197    end record;
198
199    ----------------------------------------------------------------------
200
201    function Get_Status_Id (Fu : T_Gfu) return T_Fu_Status_Id is
202      (Fu.Status.Status_Id);
203
204    ----------------------------------------------------------------------
205
206    function Get_State_Id (Fu : T_Gfu) return T_Fus_State_Id is
207      (Fu.Current_State_Id);
208
209    ----------------------------------------------------------------------
210
```

Abstract class

Mvm.G_Fu Insert | Writable | Unmodified 49:1

Messages Locations

GPS - (Mvm project) - mvm-g_fu-fsm.ads

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default

\\muhome2\M023206\Offline Folder\HiLite\CASE_STUDY\TMTC\MVM\src\MVM\generic\mvm-g_fu-fsm.ads

```
66
67      --*****************************************************************
68      --*                                                               *
69      --*          00000    0    00000  0  0      0    00000  00000    *
70      --*          0   0   0 0   0      0 0      0 0   0      0        *
71      --*          00000  0   0  0      00      0   0  0      0        *
72      --*          0      00000  0      0 0     00000  0  00  0000     *
73      --*          0      0   0  0      0  0    0   0  0   0  0        *
74      --*          0      0   0  0      0   0   0   0  0   0  0        *
75      --*          0      0   0  00000  0    0  0   0  00000  00000    *
76      --*                                                               *
77      --*****************************************************************
78   package Mvm.G_Fu.Fsm is
79
80      ------------------------------------------------------------------
81
82      type T_Fu is abstract new T_Gfu with private;
83
84      ------------------------------------------------------------------
85
86      package P_Commands is new P_Command.G_Commands (First_Command => First_Command,
87                                                      Last_Command  => Last_Command);
88
89      subtype T_Parameter_Id          is P_Parameter.T_Parameter_Id;
90      subtype T_Command               is P_Command.T_Command;
91
92      package P_Ap_Command            is new P_Parameter.G_Command (T_Command_Id => T_Ap_Id);
93      package P_Ap_Commands           is new P_Ap_Command.G_Commands (First_Command => T_Ap_Id'First,
94                                                                      Last_Command  => T_Ap_Id'Last);
95      package P_Ap_Command_Call       is new P_Ap_Command.G_Call (T_Reference_Id => T_Parameter_Id);
96
```

Inheritance

Insert | Writable | Unmodified | 1:1

Messages | Locations

GPS - (Mvm project) - mvm-g_fu-fsm.ads

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default

\\muhome2\M023206\Offline Folder\HiLite\CASE_STUDY\TMTC\MVM\src\MVM\generic\mvm-g_fu-fsm.ads

```
367    --*          00000  00000    0     0    0   0   0    0    0                *
368    --*          0      00       0     0    0   00000    0    0000             *
369    --*          0      0 0      0      0  0   0   0    0    0                 *
370    --*          0      0  0     0      0  0   0   0    0    0                 *
371    --*          0      0   0  00000     0      0   0    0    00000            *
372    --*                                                                        *
373    --**************************************************************************
374 private
375    -- ************************************************************************
376
377    type T_Fu_Ap_Status (Status_Id : T_Fu_Ap_Status_Id := Ap_Fu_Successful) is
378       record
379          case Status_Id is
380          when Ap_Fu_Successful | Ap_Fu_Failed => null;
381          when Ap_Fu_In_Progress =>
382             Ap_Command : T_Ap_Command;
383             Step       : T_Fu_Ap_Step_Range;
384          end case;
385       end record;
386
387    type T_Fu is abstract new T_Gfu with record
388       Command_Types           : T_Command_Types;
389       Transitions             : T_Transitions;
390       Superstates_Definition  : T_Superstates_Definition;
391       Fu_Ap_Status            : T_Fu_Ap_Status;
392       Ap_Command_Types        : T_Ap_Command_Types;
393    end record;
394
395    ---------------------------------------------------------------------------
396
397    -- Check the validity of an automaton
```

Inheritance

Insert | Writable | Unmodified | 1:1

Messages | Locations

```
procedure Run_Plans (Obcpe : in out T_Obcpe) is
  Execute_Next_Command : Boolean;
  ---------------------------------------------------------------------------
  procedure Step_Further (Plan_Id   : T_Plan_Id);
  procedure Step_Further (Plan_Id   : T_Plan_Id) is
  begin
    if Obcpe.Plans_Status (Plan_Id).Current_Step < Obcpe.Plans (Plan_Id).Steps_Nb then
      Obcpe.Plans_Status (Plan_Id).Current_Step := T_Step_Range'Succ (Obcpe.Plans_Status (Plan_Id).Current_Step);
    else
      Obcpe.Plans_Status (Obcpe.Active_Plan) := T_Plan_Status'(Status_Id    => Plan_Failed,
                                                               Plan_Failure => End_Of_Plan_Reached,
                                                               Failure_Step => Obcpe.Plans_Status (Obcpe.Active_Plan).Current_Step);
    end if;
    Execute_Next_Command := True;
  end Step_Further;
  ---------------------------------------------------------------------------
begin
  Mvm.Obit.Run_Time (Current_Time => Obcpe.Current_Time);
  if (case Obcpe.Obcpe_Status is
      when Obcpe_On                => True,
      when Obcpe_Off | Obcpe_Failed => False) then
    P_Events.Check_Monitoring (Events       => Obcpe.Events,
                               Current_Time => Obcpe.Current_Time);
    loop
      P_Vaps.Run_Vaps (Obcpe.Vaps, Obcpe.Current_Time);
      Execute_Next_Command := False;
      case Obcpe.Plans_Status (Obcpe.Active_Plan).Status_Id is
      when Plan_Inactive =>
        pragma Assert (False, "An Inactive Plan can not be executed");
      when Plan_Ready =>
        pragma Assert (False, "A Ready Plan can not be executed");
      when Plan_Terminated =>
        pragma Assert (False, "A Terminated Plan can not be executed");
      when Plan_Failed =>
        declare
          Alternative_Plan : T_Plan_Id;
        begin
          Alternative_Plan := Obcpe.Plans (Obcpe.Active_Plan).Alternative_Plan;
          if Obcpe.Plans_Status (Alternative_Plan).Status_Id = Plan_Ready then
            Obcpe.Active_Plan := Alternative_Plan;
            Obcpe.Plans_Status (Alternative_Plan) := T_Plan_Status'(Status_Id    => Plan_Running,
                                                                    Current_Step => T_Step_Range'First);
          else
            Obcpe.Obcpe_Status := Obcpe_Failed;
          end if;
          Execute_Next_Command := True;
        end;
      when Plan_Running =>
        declare
          Current_Step : T_Step_Range;
          Instruction  : T_Instruction;
        begin
          Current_Step := Obcpe.Plans_Status (Obcpe.Active_Plan).Current_Step;
          Instruction := Obcpe.Plans (Obcpe.Active_Plan).Steps (Current_Step);
          case Instruction.Instruction_Id is
            ---------------------------------------------------------------------
            -- Status: Wait for the end of the execution
          when Send_Cmd_To_Fu_Instruction | Protected_Send_Cmd_To_Fu_Instruction =>
            declare
              Fu_Command   : T_Fu_Command;
            begin
              -- A FU command call is created
              Fu_Command := P_Fus.P_Gfu.P_Command.Create_Command (Command_Id    => Instruction.Fu_Command_Call.Command_Id,
                                                                   Parameters_Nb => Instruction.Fu_Command_Call.Parameters_Nb);
              -- Update the referenced parameters
              if Fu_Command.Parameters_Nb > 0 then
                -- Update the referenced parameters
                for Parameter_Id in T_Parameter_Id range T_Parameter_Id'First .. T_Parameter_Id'First + Fu_Command.Parameters_Nb - 1 loop
                  case Instruction.Fu_Command_Call.Actuals (Parameter_Id).Actual_Type is
                  when Numerical =>
                    -- The numerical value shall be copied
                    Fu_Command.Parameters (Parameter_Id) := Instruction.Fu_Command_Call.Actuals (Parameter_Id).Value;
                  when Reference =>
                    -- The referenced of the referenced parameter
```

Too big subprogram

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Results

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See PDF

Overview

- Introduction
- Astrium Space Transportation Case study
  - Numerical algorithm
  - Event driven
- Conclusion

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Conclusion

- Compared to SPARK 2005
  - Great improvement
  - Larger perimeter of Ada
  - “Executable contracts” is a major progress
  - ➔ The ROI of contracts writing is positive, even without formal proof
- Operationally deployable?
  - The use of proof still requires a high level of expertise!
  - ➔ Proof may be costly
  - Proof is not 100% sound! (float versus real)
  - Final version of SPARK 2014 is promising

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