



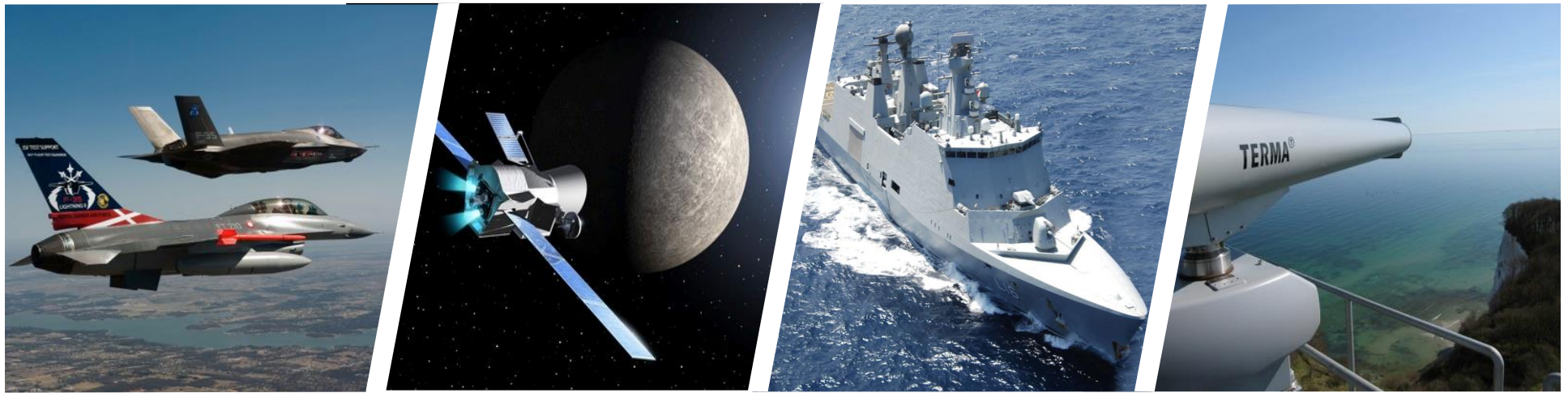
Experience with Use of Model Driven Code Generation on the ASIM Project

June 2017

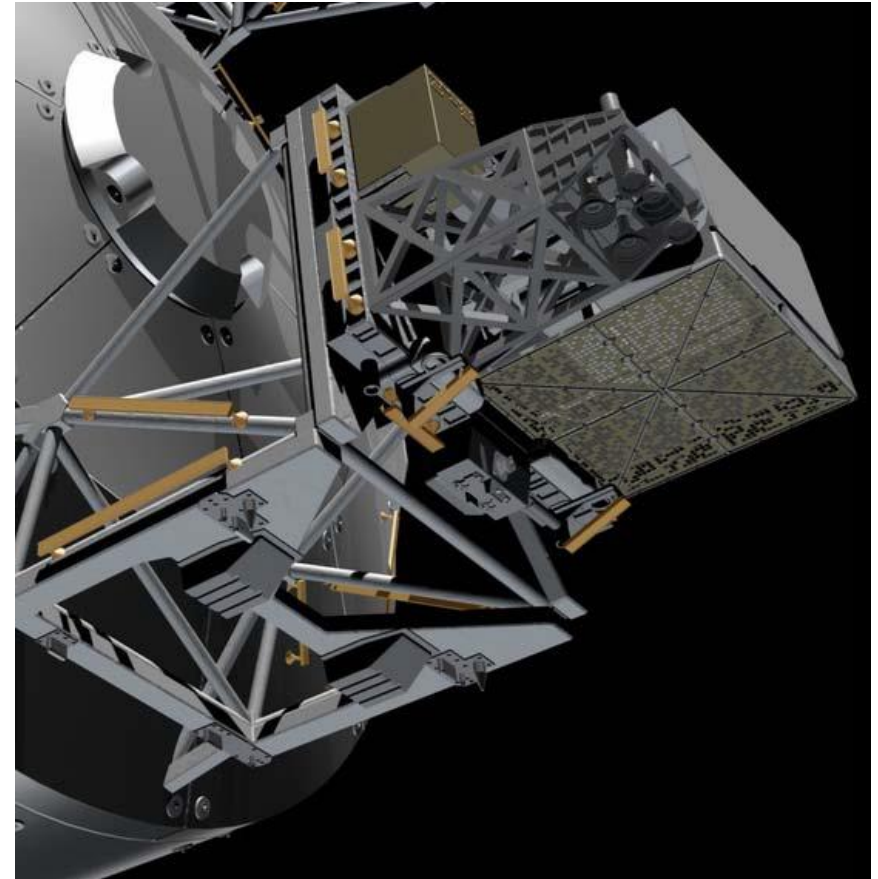
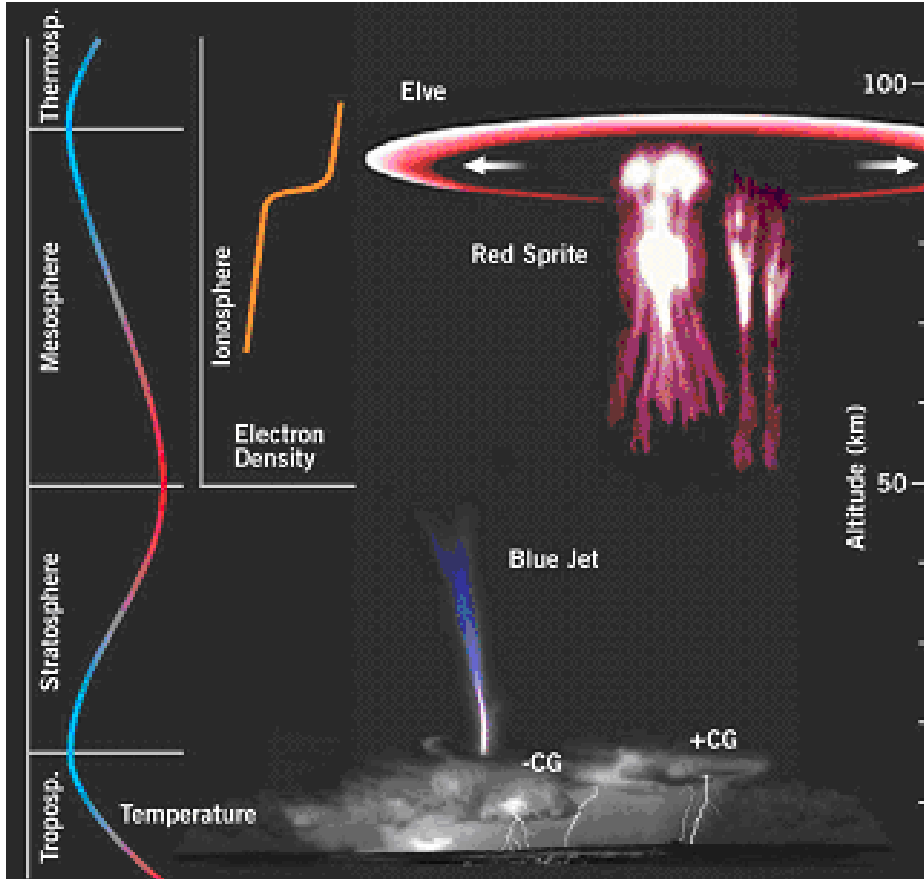
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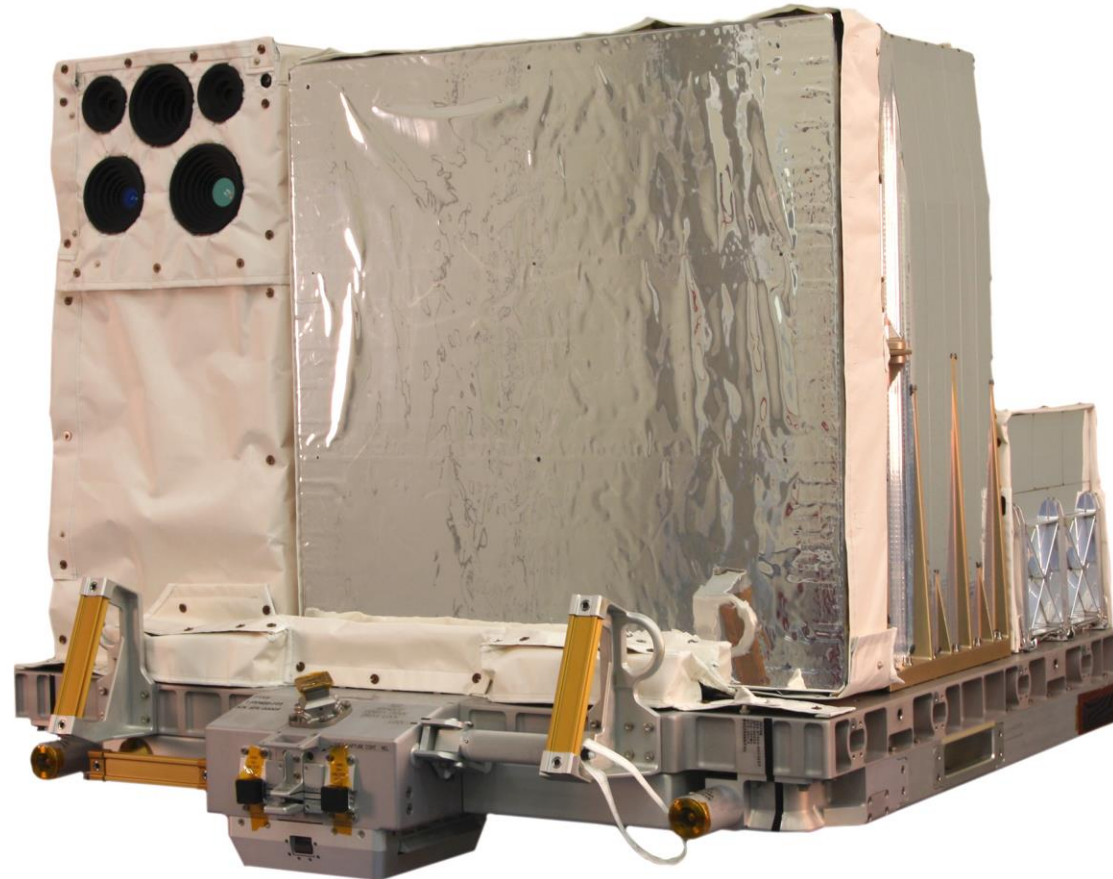
Terma at a Glance



The ASIM Observatory



MMIA & MXGS instruments





- ❑ **Design Method: Based on ASSERT & SAVOIR FAIRE**
- ❑ **Programming Language: Ada 2012**
- ❑ **Compiler: GNAT Pro for LEON3**
- ❑ **RTOS: Ravenscar runtime library provided with GNAT Pro**
- ❑ **Computer: Xilinx Virtex-5 FPGA with a LEON3FT CPU**



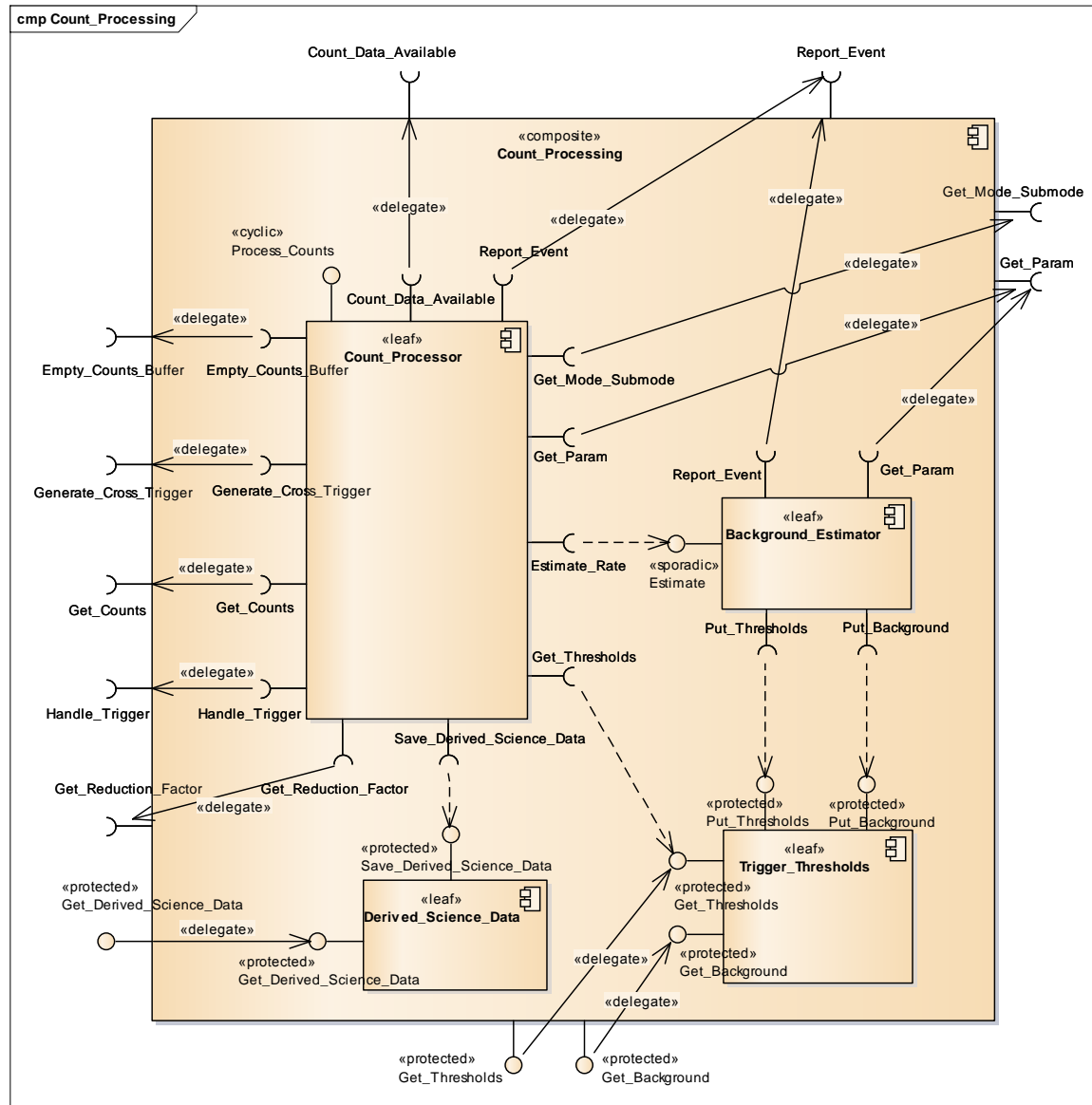
Terma has developed a modelling tool chain based on SAVOIR/ASSERT principles:

- ❑ **The Interface View:** Characterizes the provided and required services of components:
It is expressed as a component model in UML .
- ❑ **The Functional View:** Specifies the functional services provided by components:
It is defined as passive Ada packages.
- ❑ **The Concurrency View** is automatically generated from the Interface View and the Functional View.



Stereotype	Meaning	Attributes
«sporadic»	An operation performed at sporadic intervals	WCET MIAT Deadline [Queue size] [Task size]
«cyclic»	An operation performed at fixed intervals	WCET Period Deadline [Offset] [Task size]
«protected»	An operation granted exclusive access to some state	WCET
«passive»	A regular operation	-
«interrupt sporadic»	An interrupt service routine	WCET MIAT Deadline Interrupt ID

Interface View for Count_Processing Component



Functional View for Background_Estimator



```
package ASW.Science.Processing.Counts.Count_Processing.Background_Estimator is  
  procedure Estimate (...);  
end ASW.Science.Processing.Counts.Count_Processing.Background_Estimator;
```

```
package ASW.Science.Processing.Counts.Count_Processing.Background_Estimator.RI is  
  procedure Put_Thresholds (...);  
  ...  
end ASW.Science.Processing.Counts.Count_Processing.Background_Estimator.RI;
```

```
with ASW.Science.Processing.Counts.Count_Processing.Background_Estimator.RI;  
package body ASW.Science.Processing.Counts.Count_Processing.Background_Estimator is  
  procedure Estimate (...) is  
  begin  
    ...  
    RI.Put_Thresholds (...);  
    ...  
  end Estimate;  
end ASW.Science.Processing.Counts.Count_Processing.Background_Estimator;
```

Concurrency View for Background_Estimator



```
package CV.ASW.Science.Processing.Counts.Count_Processing.Background_Estimator is  
  procedure Estimate (...);  
end CV.ASW.Science.Processing.Counts.Count_Processing.Background_Estimator;
```

```
package body ASW.Science.Processing.Counts.Count_Processing.Background_Estimator.RI is  
  ...  
  procedure Put_Thresholds (...)  
    renames CV.ASW.Science.Processing.Counts.Count_Processing.Trigger_Thresholds.Put_Thresholds;  
  ...  
end ASW.Science.Processing.Counts.Count_Processing.Background_Estimator.RI;
```

```
package body CV.ASW.Science.Processing.Counts.Count_Processing.Background_Estimator is  
  package Spo_Task is new CV_Utils.Sporadic_Task  
    (... , Standard.ASW.Science.Processing.Counts.Count_Processing.Background_Estimator.Estimate);  
  procedure Estimate(...) is  
  begin  
    if not Spo_Task.Request_Sporadic_Operation(...) then  
      CV.ASW.Failure_Detector.Tasking_Event_Storage.Put_Tasking_Event(...);  
    end if;  
  end Estimate;  
end CV.ASW.Science.Processing.Counts.Count_Processing.Background_Estimator;
```



WCETs are obtained by running a timing test on the software image

- ❑ **The tool chain supports the build of three kinds of images:**
 - ❑ The **flight image** to be used for controlling the MXGS or MMIA instrument
 - ❑ A **non-flight image** instrumented to measure execution times for tasks (*Ada.Execution_Time*)
 - ❑ A **non-flight image** instrumented to measure execution times for protected operations

- ❑ **A Ground Test TC can be used to:**
 - ❑ Dump the found worst-case execution times
 - ❑ Clear the worst-case execution times

Schedulability analysis is based on Response Time Analysis and it uses:

- ❑ **The mode-dependent worst-case execution times obtained in the timing test.**
- ❑ **The static concurrency attributes defined in the Interface View**

Experience related to schedulability analysis

- ❑ **Basically, no schedulability problems in the MXGS and MMIA software**
- ❑ **Issue related to "realistic" WCET versus "worst" WCET**

Key Issues

- Natural way to define concurrency aspects
- Easy to discuss design issues related to concurrency
- The design is always consistent with the source code
- Tool support necessary to validate the design
- Some diagrams cluttered by many links

Features added to the tool chain during the software development:

- Support for measuring of WCETs during execution of the software
- New attribute for <<sporadic>>: Delay



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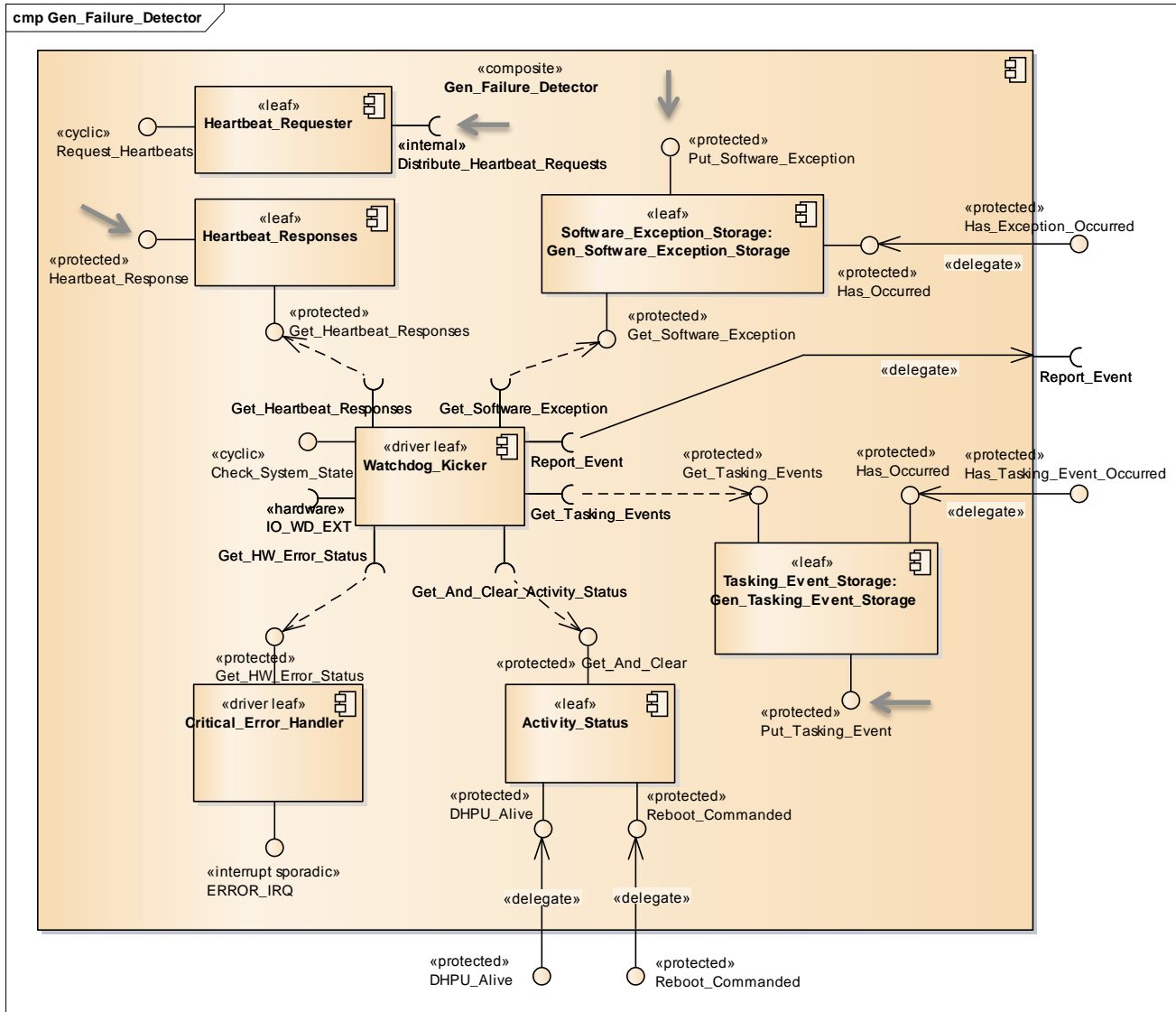
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Handling of Tasking Issues



Operations to be provided by the Interface View:

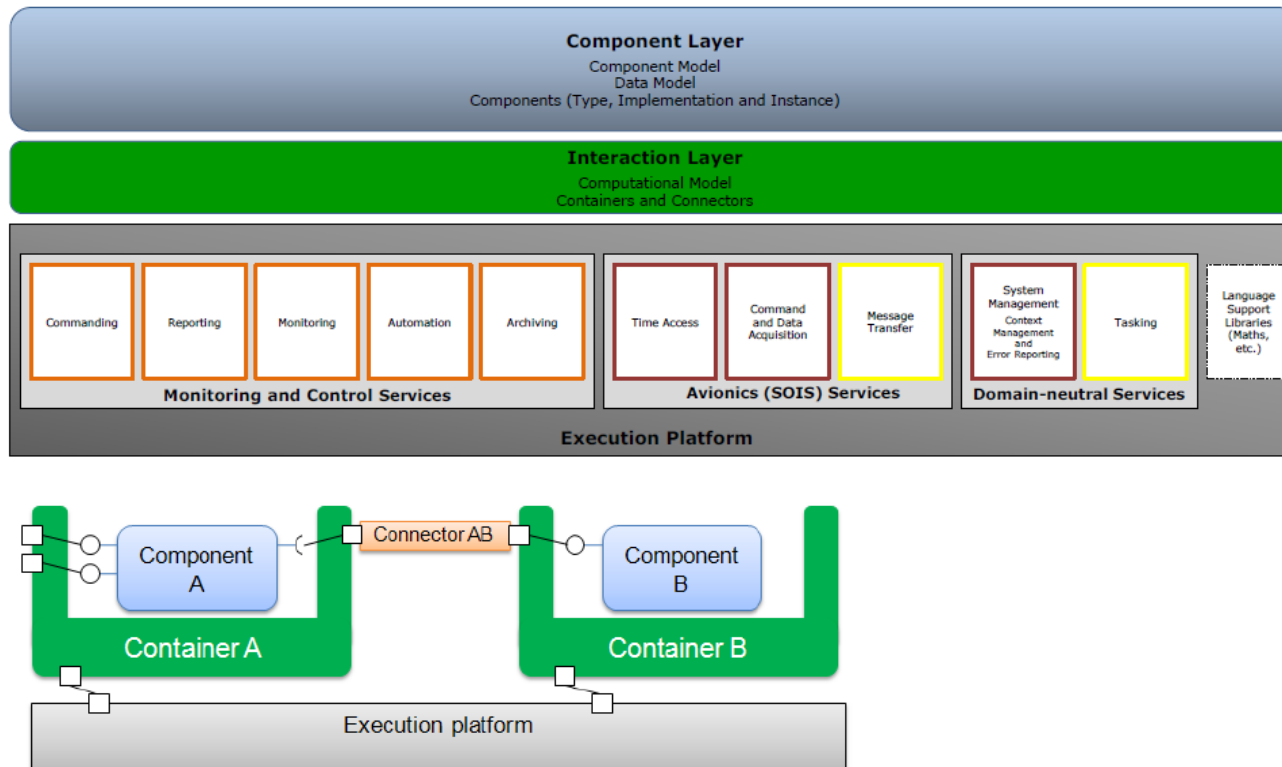
- Report_Event
- Report_Exception
- Heartbeat_Response

Operation provided by the Concurrency View:

- Distribute_Heartbeat_Requests



- ❑ **SAVOIR (Space AVionics Open Interface aRchitecture)** is an initiative to improve the way that the European space community builds avionics subsystems.
- ❑ **SAVOIR FAIRE (SAVOIR Fair Architecture and Interface Reference Elaboration)** is an industrial working group, who is working towards the definition of a reference architecture for software on-board spacecraft platforms.





The timing test brings the software into a number of worst-case scenarios, which together ensure that all tasks are exposed to their worst-case conditions

Test Area	Test Step
3) SRAM load and dump without stuffing	<ol style="list-style-type: none">1) Send Enable Load Memory TC to enable write access to SRAM.2) Send a sequence of 25 full sized Load Memory TCs to load in SRAM a data pattern not needing byte stuffing.3) Send Ground Test TC to dump WCET list (Cnf)4) Send Ground Test TC to clear WCET list5) Send Dump Memory TC to request a dump of the data just uploaded.6) Wait 3 sec.7) Send Abort Memory Dump TC.8) Wait until no more Memory dump TM packets are received.9) Send Ground Test TC to dump WCET list (Cnf, Tgf, Hgh, Aur)10) Send Ground Test TC to clear WCET list.
4) SRAM load and dump with stuffing	<ol style="list-style-type: none">1) Send a full sized Load Memory TCs to load in SRAM a data pattern needing byte stuffing for all bytes.2) Send Ground Test TC to dump WCET list (Cnf)3) Send Ground Test TC to clear WCET list.4) Send Dump Memory TC to request a dump of the data just uploaded.5) Wait until no more Memory dump TM packets are received.6) Send Ground Test TC to dump WCET list (Cnf, Tgf, Hgh, Aur)7) Send Ground Test TC to clear WCET list.

Schedulability Analysis Result



Analysis of the mode <i>Tgf-Hgh</i>										
Name	Period	WCET	WCBT	Deadline	WCRT	Margin	Margin (%)	Utilization (%)		
ASW.TCP_Handler.TCP_IRQ	999.60	0.09	0.08	1.00	0.17	0.83	922.2	0.01		
ASW.Science.Processing.Counts.Cross_Trigger_Handler.TRIGGER_IRQ	1000.00	0.00	0.08	1.00	0.17	0.83	N/A	0.00		
ASW.Platform.DHPU_Handler.EDLF_UART_Handler.UART_Handler.DHPU_UART_IRQ	30.00	0.38	0.18	2.00	0.65	1.35	355.2	1.27		
ASW.Failure_Detector.Critical_Error_Handler.ERROR_IRQ	1000.00	0.00	0.18	1000.00	0.65	3.43	N/A	0.00		
ASW.Science.Processing.Sensors.Controller.Progress_Control_Cycle	10.00	0.26	0.29	10.00	1.02	1.64	630.7	2.60		
ASW.Science.Processing.TCP_Receiver.TCP_Received	999.60	0.08	0.29	10.00	1.10	3.43	4287.2	0.01		
ASW.Platform.TCP_Distributor.TCP_Received	999.60	0.06	0.29	10.00	1.16	3.43	5716.3	0.01		
ASW.Platform.Supervisor.Memory_Manager.Memory_Writer.Write_Page	30.00	0.00	0.29	10.00	1.16	3.43	N/A	0.00		
ASW.Science.Processing.Counts.Count_Processing.Count_Processor.Process_Counts	10.00	5.86	0.29	15.00	7.02	1.64	28.0	58.60		
ASW.Platform.Supervisor.Memory_Manager.Dump_Cycle_Handler.Start_Dump_Cycle	500.00	1.43	0.29	18.00	8.45	3.43	239.9	0.29		
ASW.Platform.DHPU_Handler.Protocol_TC_Handler.Handle_Event	20.00	1.88	2.80	30.00	18.96	3.26	173.4	9.40		
ASW.Platform.Supervisor.Memory_Manager.NVM_Power_Handler.Handle_Command	100.00	0.02	2.80	50.00	18.98	8.52	42600.0	0.02		
ASW.Science.Processing.Counts.Collection.Primary_Science.Controller.Handle_Trigger	100.00	0.19	2.80	100.00	19.17	19.62	10326.2	0.19		
ASW.Science.Processing.Counts.TM_Formatter.Transfer_TM	100.00	2.19	2.80	100.00	29.36	19.62	895.9	2.19		
ASW.Platform.Event_Reporter.Report_Generator.Report_Event	50.00	0.70	2.80	100.00	36.56	10.21	1458.1	1.40		
ASW.Platform.Supervisor.Memory_Manager.Memory_Handler.Handle_Memory_Requests	250.00	3.06	2.80	250.00	39.62	50.80	1660.1	1.22		
ASW.Platform.Supervisor.Sensor_Power_Interface.SPI_Controller.Perform_Control_Cycle	250.00	0.12	2.80	250.00	39.74	50.80	42332.1	0.05		
ASW.Failure_Detector.Watchdog_Kicker.Check_System_State	500.00	0.20	2.80	500.00	39.94	102.07	51033.8	0.04		
ASW.Science.Processing.Counts.Collection.Secondary_Science.Collect_Science_Data	950.00	2.59	2.80	500.00	57.35	107.93	4167.2	0.27		
ASW.Science.Processing.Counts.Count_Processing.Background_Estimator.Estimate	700.00	0.38	2.80	700.00	57.73	141.73	37296.6	0.05		
ASW.Science.Supervision.Submode.Manager.Mode_Changed	999.60	0.00	2.80	999.60	57.73	201.66	N/A	0.00		
ASW.Science.Supervision.TC_Handler.Handle_TC	999.60	0.00	2.80	999.60	57.73	201.66	N/A	0.00		
ASW.Platform.Configuration_Manager.Validator.Validate_Config_Table	999.60	0.00	2.80	999.60	57.73	201.66	N/A	0.00		
ASW.Platform.Supervisor.HK_Reporter.Parameter_Collector.Collect_Parameters	999.60	0.66	2.80	999.60	58.39	201.66	30555.0	0.07		
ASW.Platform.Supervisor.HK_Reporter.Report_Generator.Start_Reporting_Cycle	999.60	2.63	2.80	999.60	69.40	201.66	7667.8	0.26		
ASW.Platform.Supervisor.MXGS_TC_Handler.MXGS_TC_Executor.Handle_TC	999.60	0.16	2.80	999.60	69.56	201.66	126039.4	0.02		
ASW.Failure_Detector.Task_Heartbeats.Heartbeat_Requester.Request_Heartbeats	1000.00	0.59	2.80	1000.00	76.27	201.66	34180.2	0.06		
ASW.Science.Processing.Counts.Grey_Mode_Handling.Handler.Determine_Grey_Mode	1000.00	0.23	2.80	1000.00	76.50	201.66	87679.6	0.02		
ASW.Platform.Supervisor.MXGS_TC_Handler.LHP_Heater_Handler.Control_LHP_Heaters	1000.00	0.02	2.80	1000.00	76.52	201.66	1008315.4	0.00		
ASW.Platform.Supervisor.Sensor_Power_Interface.PSU_Controller.Perform_Control_Cycle	1000.00	2.80	2.80	1000.00	79.32	201.66	7202.3	0.28		
ASW.Platform.Supervisor.TC_Handler.TC_Executor.Handle_TC	1000.00	0.75	2.80	1000.00	88.07	201.66	26888.4	0.08		
ASW.Science.Processing.Counts.Collection.Primary_Science.Handler.Handle_New_Trigger	1000.00	10.94	0.08	1900.00	128.39	204.14	1866.0	1.09		
ASW.Memory_Scrubber.Scrub_Memory_Locations	1000.00	0.27	0.00	5000.00	128.58	204.78	75845.4	0.03		

Total CPU load: 79.5%
 Overall margin: 22.0%
 The system is *schedulable*