TECHNICAL PAPER

The SCADE FACE Software Development Kit (SDK)

This paper presents the configuration of the SCADE toolset for the development of FACE compliant applications and the use of the resulting SCADE FACE SDK for the development of such applications. Two applications (an Air Data Computer and a Radar Altimeter) developed by Northrop Grumman Missions Systems with the SCADE FACE SDK are highlighted in the paper.

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/ 1. Configuration of the SCADE FACE SDK

1.1 The SCADE toolset

As shown in the Figure 1 below, SCADE is composed of four different tools: Lightweighting is critical and every pound counts.

- SCADE System for the description of system and embedded software architectures. SCADE System is compliant with aeronautics standards such as IMA, etc., as this will be explained in following paragraphs.
- SCADE Suite for detailed modeling, simulation and automatic code generation of embedded controls. Qualification of the tools was achieved for the DO-178C standard at Level A [DO-178C].
- SCADE Display for detailed modeling, simulation and automatic code generation of embedded HMIs. Qualification of the tools was achieved for the DO-178C standard at Level A.
- SCADE Test for testing of embedded software controls and HMIs.

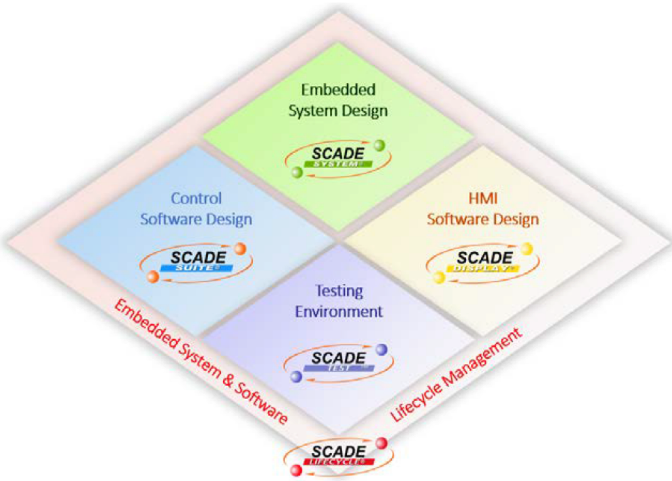

Figure 1. The SCADE Toolset.

1.1.1 The SCADE system

SCADE System is a product that provides its users with a systems design environment for use on systems with high dependability requirements, providing full support of industrial systems engineering processes, such as ARP 4754A (aeronautics), ISO 26262 (automotive), and EN 50126 (railways). This product features functional and architectural system modeling and verification in a SysML-based environment.

As shown on Figure 2, SCADE System provides a strong foundation to deploy Model-Based Systems Engineering (MBSE) processes and best practices. A key feature is the capability to generate consistent and comprehensive interface control documents (ICD) as an important outcome of the MBSE processes.

SCADE System has been specifically developed for system engineers; the underlying SysML™ technology is hidden making modeling more user friendly and intuitive than standard SysML tools or plain databases. By using SCADE System in conjunction with SCADE Suite and SCADE Display, system and software engineers can work within the same framework. Developers can quickly synchronize between the system model and the software subsystem components, ensuring consistency and efficiency.

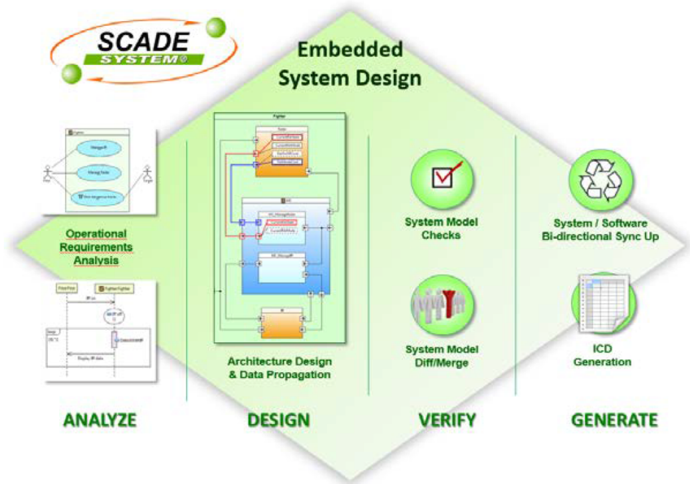

Figure 2. SCADE System.

1.1.2 Configuration of SCADE System for Domain Specific Languages (DSL)

A key feature of SCADE System is the SCADE System Configurator, a module that allows methods and tools engineers to configure SCADE System to provide its users with a specific modeler for a domain specific language (DSL).

The Configurator consists in:

- A modeling editor defining the meta-model of the DSL through a simplified UML class diagram.
- An export feature that allows creating SCADE System configuration plug-in for the DSL.

The flow of using the Configurator to create an ARINC 653 [ARINC 653] integrated modular avionics (IMA) modeler is illustrated by Figure 3.

Technically speaking, a configuration is developed by describing a mapping between the DSL meta-model (an IMA meta-model in that case) and the SysML meta-model; this is what is shown on the left part of Figure 3. As a result, the end-user of the configured System tool is used a dedicated modeler for IMA; this is what is depicted on the right part of Figure 3. The Configurator allows group of users to rely on industry, company or project standards.

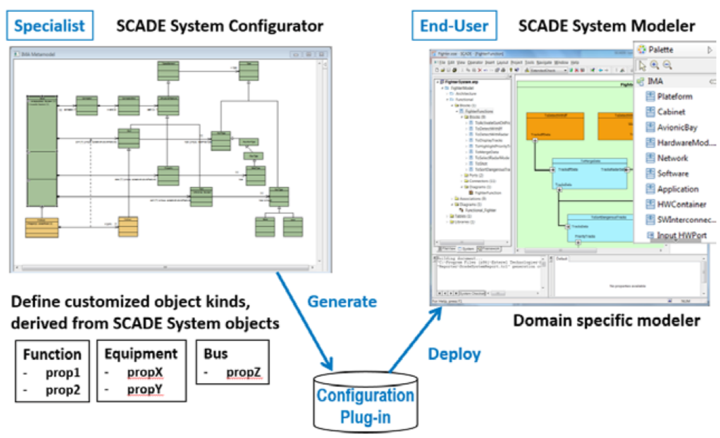

Figure 3. Configuration of SCADE System for Integrated Modular Avionics (ARINC 653).

1.2 Configuration of SCADE System for FACE

Using the above technique, SCADE System has been configured for FACE [FACE]. The configuration that we have developed corresponds to the FACE technical architecture of Figure 4.

SCADE is currently aligned with FACE 2.1. We will consider to be aligned with FACE 3.0 in the midterm. FACE 3.0 creates an "Architecture Model", which contains the DataModel, UoPModels, IntegrationModels and TraceabilityModels.

The SCADE FACE SDK configuration is built on top of the IMA configuration of the previous section as described in the architecture of Figure 5.

On this Figure we see that the FACE meta-model has been implemented on top of the IMA meta-model. The FACE meta-model that we have implemented corresponds to the FACE data model language description in [FACE], section 3.6.3.

Moreover, in this architecture, we have distinguished two different functionalities that can be addressed when using the DSL modelers:

- RTOS specific functionalities like the automatic generation of configuration tables for the operating system or the wrapping of the generated code from SCADE Suite or SCADE Display, so that it can be called in a cyclic manner from an OS task.
- Communication specific functionalities like the introduction of common protocols for mission systems, such as ARINC 429, ARINC 664 (AFDX), CAN or the DDS protocol of the FACE Transport Services Segment (TSS).

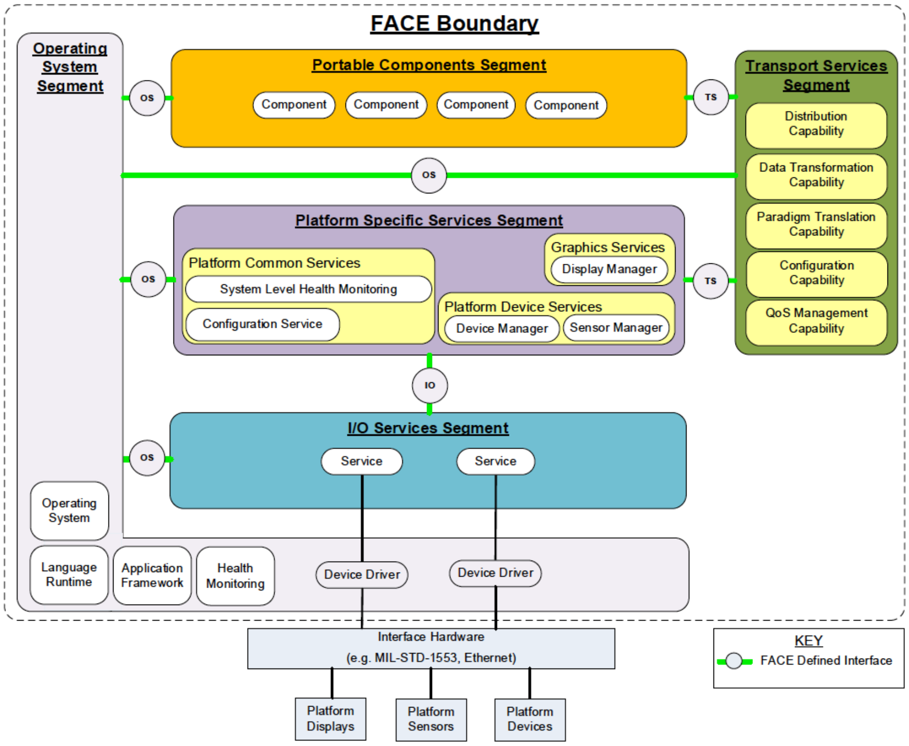

Figure 4. The SCADE FACE Software Development Kit (SDK).

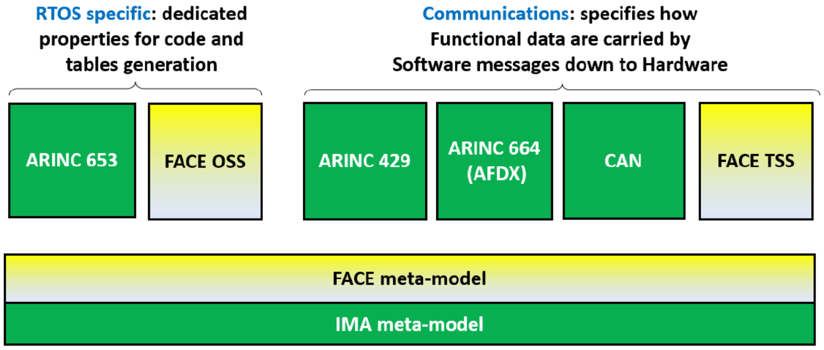

Figure 5. FACE and IMA in SCADE System.

In addition to the SCADE System configuration for FACE, the SCADE toolset brings a number of other functionalities that will be extremely useful for the development of FACE-compliant mission systems. This includes:

- Automatic and certified code generation in agreement with the Safety Profile of [FACE], section 2.8.2:

  - The SCADE Suite and SCADE Display KCG code generators have been certified at TQL-1 for DO-330 (to be used to develop Level A software).

- Generation of simple and safe C code in agreement with the Security Profile of [FACE], section 2.8.1:

  - The SCADE Suite and SCADE Display KCG certified code generators generate such simple and safe C code. This can be considered as a definite advantage when one has to develop high-assurance, deterministic, security components and services that support multiple levels of security. This is discussed in [CEEC].

- Interactive graphic HMI capabilities relying on the OpenGL standard:

  - SCADE Display is generating code that complies either to OpenGL ES (for the General Purpose Profile of FACE) or OpenGL SC (for the Safety Profile of FACE).

- Automatic code generation of TSS functions. A custom wrapper has been developed to encapsulate the generated SCADE Suite KCG code, allowing for a single-click creation of an UoP.

- Development of ARINC 661 [ARINC 661] User Application (UA) and ARINC 661 Servers. Typically, the User Applications are interactive applications (such as a Flight Management System) that communicate with display pages handled within the Cockpit Display System (CDS) ARINC Server. From the FACE architecture point of view, the UAs reside in the Portable Component Segment of Figure 4 and the ARINC 661 Server reside in the Platform Specific Services Segment of Figure 4. This is detailed in Figure 6.

  - As illustrated in the Figure 7, SCADE ARINC 661 provide a complete toolset to develop ARINC 661 UAs and ARINC 661 Server:

    - o SCADE ARINC 661 UA Page Creator allows to define display pages and to automatically generate the communication code with the Server (going through FACE TSS).

    - o SCADE ARINC 661 Definition File (DF) Generator is a qualified tool (DO-330 at TQL-1) that generates the DF file needed as the input to the Server.

    - o SCADE ARINC 661 Server Creator automatically generates the ARINC 661 Server on the basis of an ARINC 661 configuration file that describes the list of the widgets that are used by the UA.

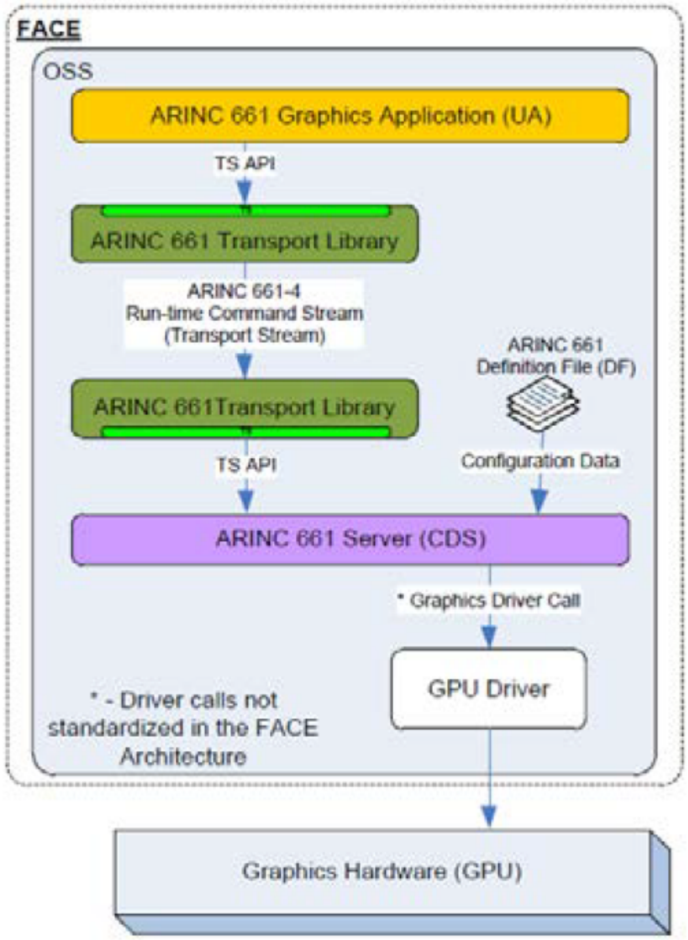

Figure 6. The ARINC 661 flow within the FACE technical architecture.

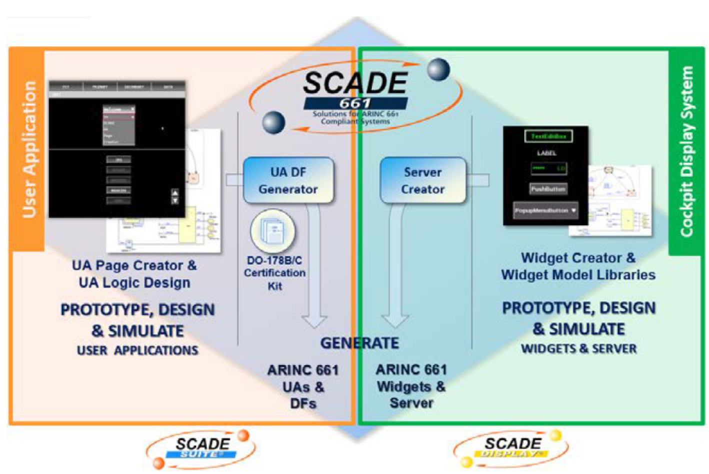

Figure 7. The SCADE ARINC 661 toolset .

1.3 Testing SCADE Generated Artifacts for Conformance

Example Data Models created and exported from SCADE System have been put through informal conformance tests using the latest available FACE Conformance Test Suite Version 2.1.3.

Using the SCADE System-SCADE Suite synchronization, the relevant components of the FACE Data Model are exported in order to begin the UoP development. The synchronization provides the top-level architectural function and all required data types for development of the internal UoP logic, leveraging the SCADE formalism for the development of safe software.

Once the logic is tested, KCG is used along with a FACE TSS Adaptor to generate the PCS code and makefiles required to generate the object code for the FACE Conformance Test of the PCS.

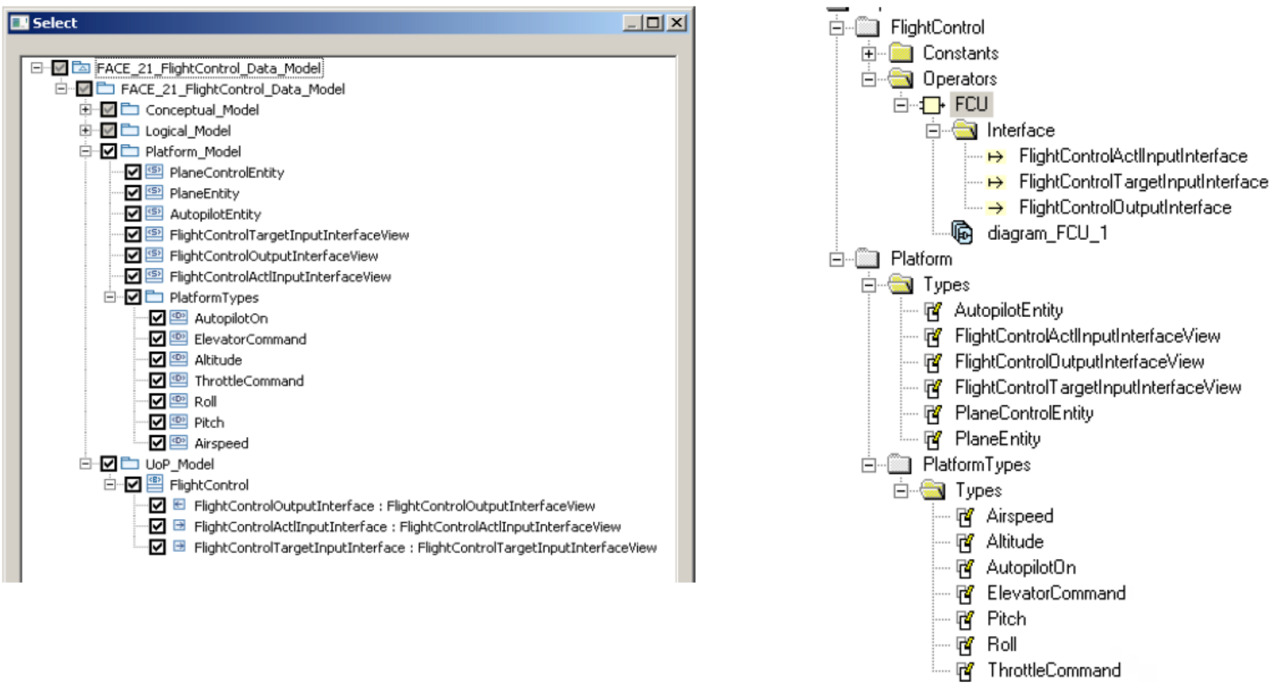

Figure 8. Flight Control Data Model synchronization from SCADE System to SCADE Suite.

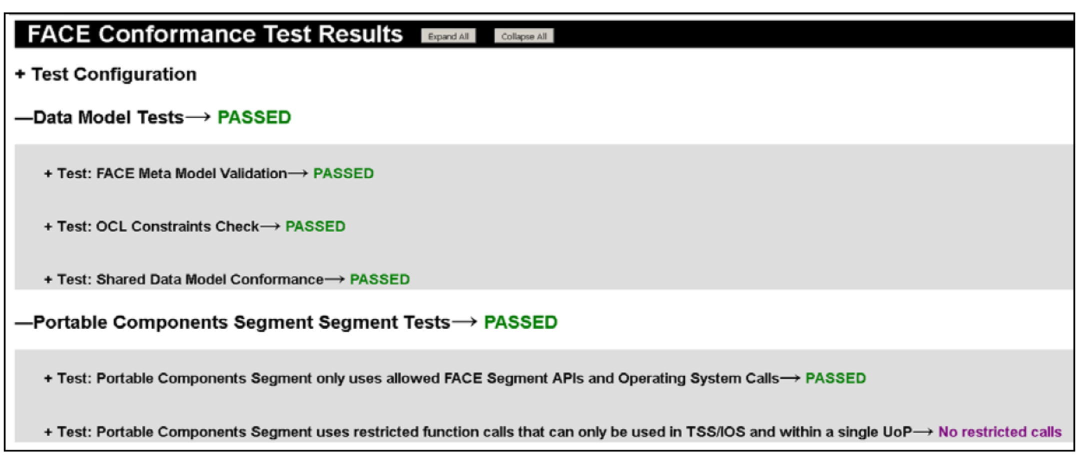

Figure 9. FACE Conformance Test Result.

/ 2. FACE USM Construction in SCADE System

Northrop Grumman Mission Systems used SCADE System to develop the FACE Data Model for their ADC and RADALT UoPs.

2.1 ADC USM

An air data computer (ADC) FACE user supplied model (USM) has been created using the FACE configuration of SCADE System. The model implements a FACE shared data model (SDM) compliant unit of portability (UoP) interface that accepts ARINC 429 data from the FACE I/O Services Segment and outputs ADC logical data to the FACE Transport Services Segment.

The process of constructing a USM using SCADE System consists of the following:

- Import FACE SDM.
- Build USM: define UoP and link model elements to the SDM.
- Export USM .face file and check for SDM conformance.

A tree view of the original SDM after being imported to a SCADE System project is shown in Figure 13.

ADC packages are created at both the Conceptual and Logical levels to include ADC entities, which are linked to SDM elements describing the observable domain concepts at the Conceptual level and measurement systems at the Logical level. An expanded tree view including the ADC entities at the Conceptual and Logical levels, as well as the SDM elements they are linked to, is shown in Figure 14.

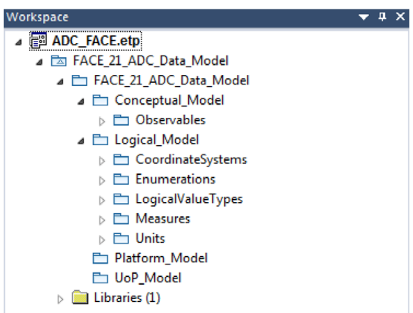

Figure 10. Shared data model in SCADE System.

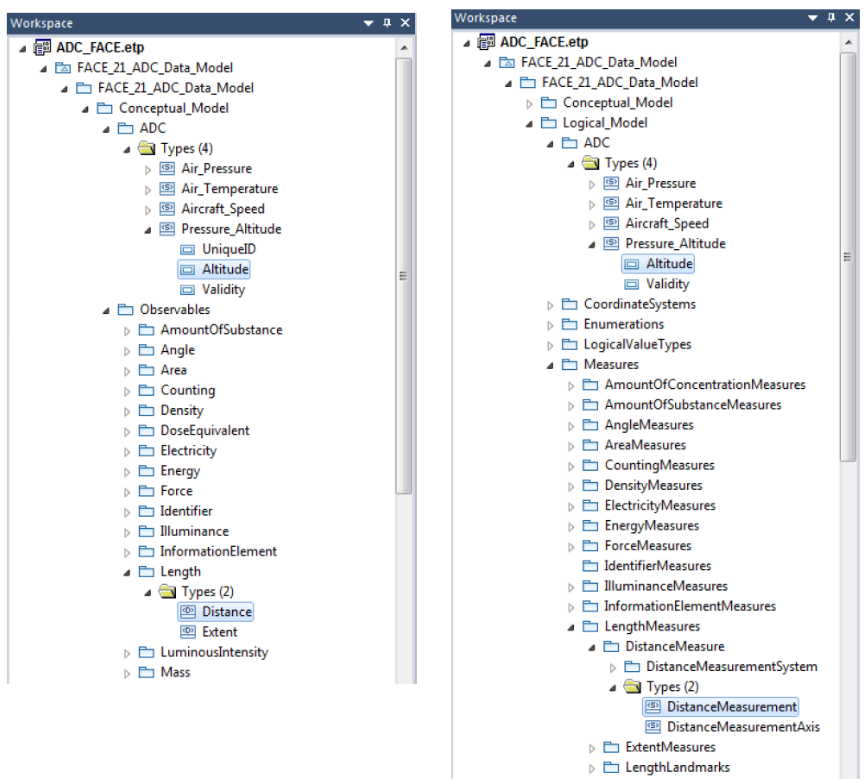

Figure 11. Conceptual level ADC USM showing link to SDM observable (left) and Logical level ADC USM showing link to SDM measurement system (right).

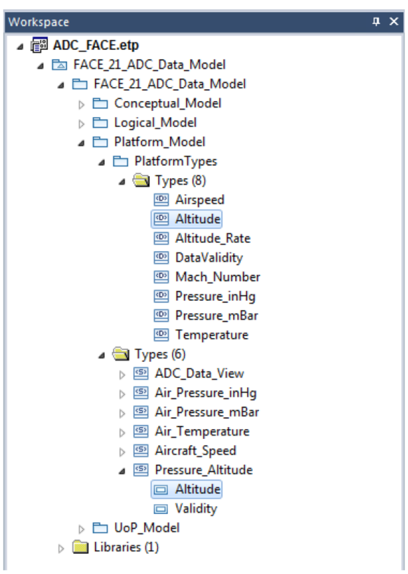

Figure 12. Platform types and Platform entities.

At the Platform level, data types are created for components of the ADC output message. These Platform types realize measurements from the Logical level, and also define the physical data types of output message components. Figure 15 shows the platform types of the ADC model. Platform entities are created that realize Logical entities and reference Platform types — these are also shown in Figure 15.

The Platform entities together are used to specify a view of the ADC output message, which is shown in Figure 16. Also shown in Figure 16 is the message port defined at the UoP level which references the view at the Platform level.

A simple block diagram illustrating the ADC UoP with the ADC logical data output and ARINC 429 interface is shown in Figure 17.

2.2. RADALT USM

The same process has been used to create a radar altimeter (RADALT) FACE USM. Various tree views of the RADALT USM are shown in Figures 18, 19, 20 and 21.

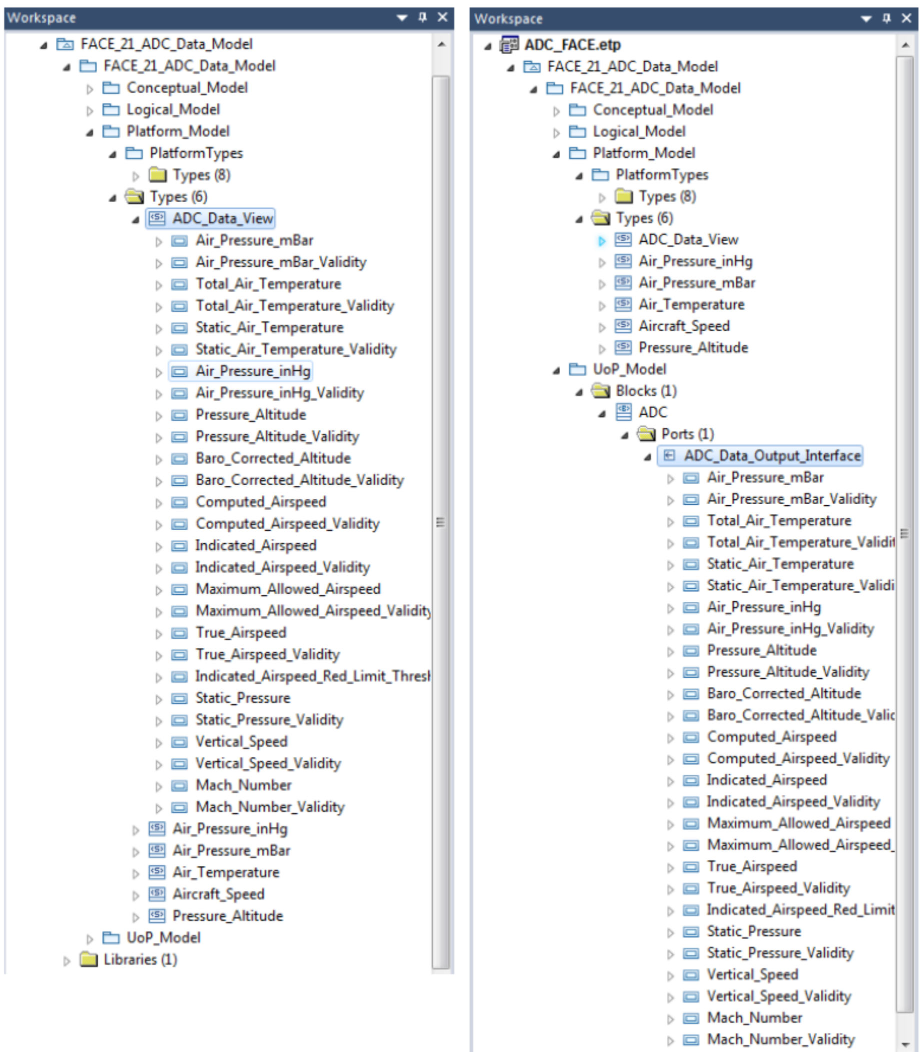

Figure 13 ADC Platform level output message view (left) and UoP message port referencing the Platform view (right).

Figure 14. Block diagram of ADC UoP.

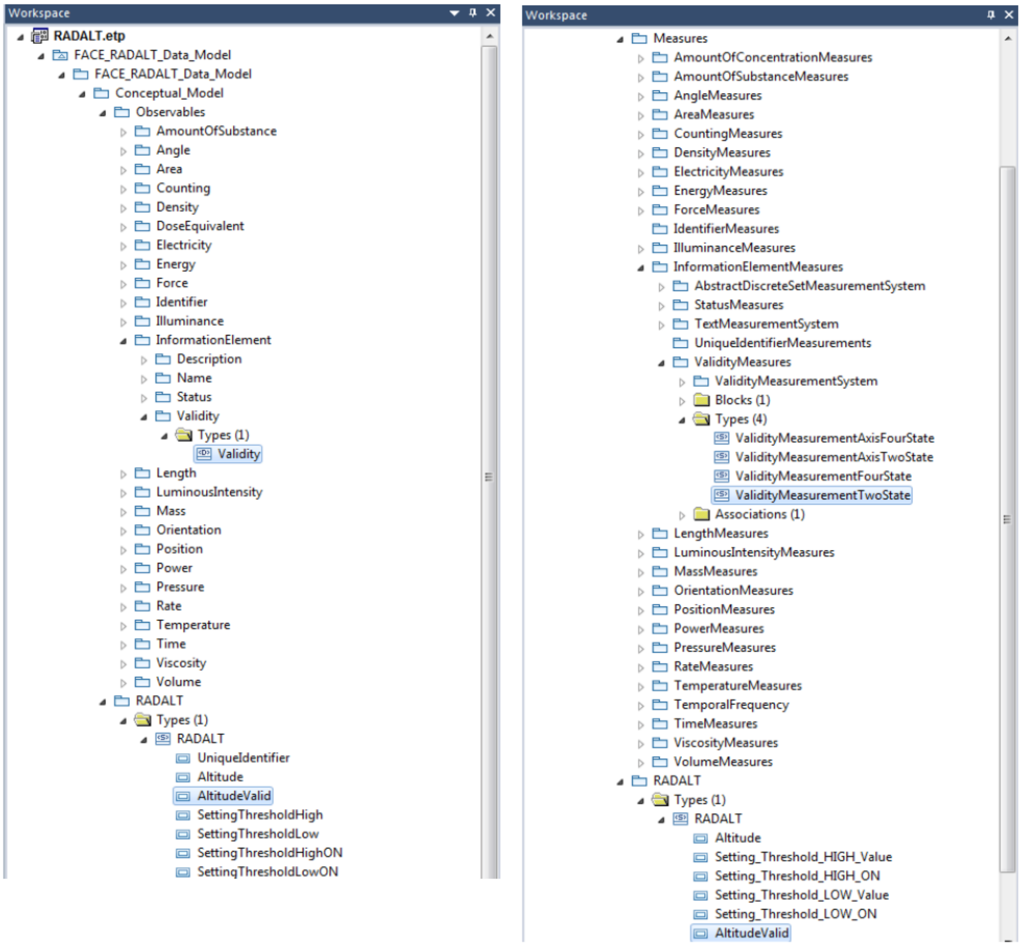

Figure 15. RADALT Conceptual level link to SDM observable (left) and Logical level link to measurement system (right).

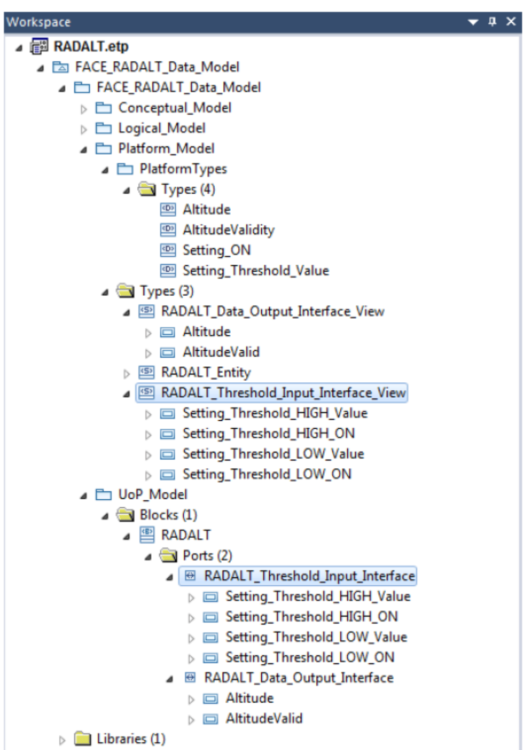

Figure 17. RADALT Platform level message port views and UoP message ports referencing the Platform views.

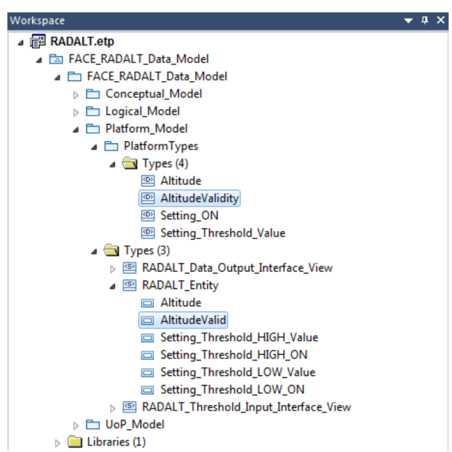

Figure 16. RADALT types and Platform entities.

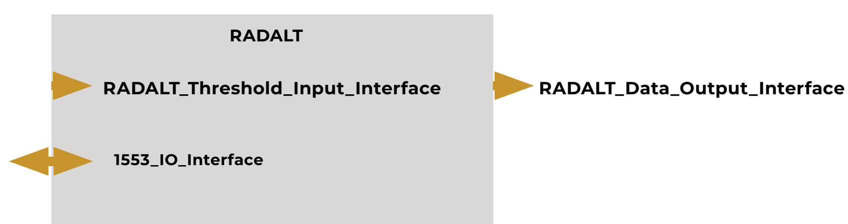

Figure 18:.Block diagram of RADALT UoP.

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/ Authors

Bernard Dion, Guilherme Goretkin (Ansys)

Benjamin Campo, Mike Vertuno (Northrop Grumman Mission Systems)

bernard.dion@ansys.com guilherme.goretkin@ansys.com benjamin.campo@ngc.com mike.vertuno@ngc.com

ANSYS, Inc.
Southpointe
2600 Ansys Drive
Canonsburg, PA 15317
U.S.A.
724.746.3304
ansysinfo@ansys.com

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