IMAGE

Interoperable Management of Aeronautical Generic Executive software

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D 5.2 : Specific simulation platforms for each application case

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1 Introduction

This document describes the software specifications of IMAGE WP5 validation tests. This task includes the specific modifications that have been done to the selected applications that are used as validation cases, in order to integrate the IMAGE components.
Three applications have been selected with the purpose of validating the integration of the IMAGE components:

Application1: A real time simulation

This validation case uses IMAGE components for communication and management of ATC (Air Traffic Control) simulation processes in order to:

- enable distant communication between Student and Controller.
- enable large number of cooperative student positions.
- enable external link with other simulators.

Application2:

This validation case will demonstrate that the IMAGE results are applicable to the entire simulation domain. The generic IMAGE result is an environment for interactive simulations. The genericity of IMAGE's project applications is tested on a non-real time numerical simulation.
Numerical Simulation IMAGE Prototype is verified on the analysis of a SENER test case for standard S/C ESA (European Space Agency).

The steps to solve this Multi-physic problem are listed bellow:

- To run numerical Simulation of thermal analysis for standard S/C ESA projects.
- To create the components' thermal model, in order to run an overall thermal simulation of the whole structure.

Application3:

The task explores how to utilise IMAGE supervision, administration and security components for the set up and execution of a heterogeneous real-use simulation application based on a mixed set of numerical and real-time simulations. Real user feedback is generated and presented for future improvement of both the IMAGE components and the heterogeneous application itself.

An activity chain, corresponding to a actual real-life demand, contains the following phases:

- The experimental program SOW and geometrical data base of the product to be tested;
- Initial aerodynamic loads estimation for global simulation;
- Model design and stress analysis of the model;
- Aero-elastic analysis and system validation;
- Model manufacture and geometry validation;
- The testing program and primary experimental data reduction;
- Global dedicated analysis using experimental data;
- New inputs, involving model and/or testing program modifications.

An interactive demonstration platform for integrated application consisting of real-time and numerical applications is developed. Special emphasis is put on:

- The validation of aerodynamic analysis and experimental data post-processing tools;
- The validation of real-time planification and scheduling optimisation algorithms and tools;
- The assessment of global cost reduction;
- The efficiency as a result of using IMAGE project deliverables.

2 Real Time Simulation Application

2.1 Introduction

This chapter describes the software specifications of IMAGE WP5 validation test “real time simulation coupling”.
The goal is to make an Air Traffic simulator (SCANSIM) work together with a flight simulator (Microsoft Flight Simulator 2004).

2.2 General Architecture

2.2.1 Hardware Architecture

The hardware architecture is composed of:

- SCANSIM ATC Simulator;
- The ATC IMAGE component;
- Flight Simulator;
- The Flight Simulator IMAGE component .

2.2.2 Software Architecture

SCANSIM ATC Simulator is embedded in an *ATC IMAGE component* that provides an ATC interface with the IMAGE framework. And *Flight Simulator* is embedded in a *Flight Simulator IMAGE component.*

Both IMAGE components use the IMAGE framework for :

- Simulation data exchange by using IMAGE data subscription/publication features.
- Real time synchronization provided by the IMAGE scheduling service.
- Components deployment

2.2.2.1 SCANSIM architecture requirements

SCANSIM ‘s internal step has a period of 1 second. Therefore, it is not necessary to provide SCANSIM with high refresh rates of incoming data.

SCANSIM ‘s 3D display software has its own interpolation process.

SCANSIM ’s scheduler can be managed from outside and can receive scheduling messages from the IMAGE scheduling service.

2.2.2.2 Flight Simulator architecture requirements

Flight Simulator ‘s internal step has a non-constant period that depends on the computer’s frame rate.
Flight Simulator ‘s external aircrafts can be added by using its multiplayer interface.

Flight Simulator provides interpolation process for the external aircraft positions but not for orientation. Thus, an external application should calculate the interpolation.

Unlike SCANSIM, Flight Simulator does not support any external scheduling interface. Therefore, it is not possible to ensure time synchronization between SCANSIM and Flight Simulator, but this should not be a problem.

2.2.2.3 Simulation data

The IMAGE ATC component is working as a data bridge between SCANSIM and IMAGE.
The IMAGE Flight Simulator component is :

- A data bridge between Flight Simulator and IMAGE
- A data interpolator that provides its Flight Simulator instance with fast updates.

2.2.2.4 Scheduling and simulation state management :

Both the ATC and the Flight Simulator IMAGE components are being controlled by the IMAGE scheduling service. The IMAGE scheduling service is working as the master scheduler of the global system.

2.3 Detailed Specification

2.3.1 Module SCANSIM

2.3.1.1 SCANSIM new features :

Until now, the SCANSIM ATC simulator was not able to deal with “external” aircrafts and vehicles that would be updated by a flight simulator or another ATC simulator.
These external elements can be displayed on SCANSIM’s controller positions, 3D visuals, strip printers, and can eventually interact with SCANSIM internal elements Also, depending on its position relative to SCANSIM’s geographical position, an aircraft can be added or removed dynamically from SCANSIM’s list of aircrafts.

2.3.1.2 SCANSIM new interface :

Therefore, SCANSIM provides the IMAGE component with a new interface that offers the following methods :

- Register external aircraft/vehicle
- Update external aircrafts/vehicles
- Get internal aircrafts/vehicles
- External scheduling

2.3.1.3 Module SCANSIM : function “management of external aircrafts/vehicles”

This function describes how the SCANSIM module copes with external aircrafts.

2.3.1.4 Module SCANSIM : function “register external aircrafts/vehicles”

This function describes SCANSIM behavior as new aircrafts/vehicles are being added to SCANSIM’s simulation.

2.3.1.5 Module SCANSIM : function “update external aircrafts/vehicles”

This function describes how external aircrafts/vehicles are being updated in SCANSIM’s simulation.

2.3.1.6 Module SCANSIM : function “get internal aircrafts/vehicles”

This function describes how SCANSIM retrieves its internal aircrafts/vehicles.

2.3.1.7 Module SCANSIM : function “External scheduling”

This function describes how SCANSIM can be scheduled from outside.
SCANSIM can receive an external time pulse and a external simulation state value.

2.3.1.8 Module IMAGE ATC component

The IMAGE ATC component provides on one side an interface to the IMAGE framework and on the other side an interface to SCANSIM.

2.3.2 Module IMAGE Flight Simulator component

The IMAGE Flight Simulator component provides on one side an interface to the IMAGE framework and on the other side an interface to Flight Simulator.

2.3.2.1 Write AI

This function is responsible for writing AI (external aircrafts) into Flight Simulator‘s multiplayer interface.

3 Numerical Simulation Application

3.1 Introduction

In order to test IMAGE prototype, it has been decided to select one of the ESA (European Space Agency) projects that were 'on going' in SENER at the same time that IMAGE. For this reason, SENER selected HERSCHEL S/C (Space Craft) OBA(Optical Bench Assembly) component.

ESA HERSCHEL main objectives are:

- Study formation of galaxies in the early universe
- Investigate creation of stars
- Examine molecular chemistry of the universe

One of the components of HERSCHEL S/C is OBA which, basically, must keep 'instruments' at a very low temperature, lower than 10 K OBA is composed by:

- OBP = Optical Bench Plate, at which Instruments are bolted
- OBS = Optical Bench Shield, a dome bolted to OBP and covering Instruments
- OBHCL = Optical Bench Helium Cooling Loop. Used to Cool Instruments

So, OBA main objectives are:

- One basic function is to provide through OBP a solid and stable alignment support of the Scientific Instruments within the Herschel cryogenic environment.
- Another basic function is to protect the Instruments from starlight (OBS).
- To keep the Instruments at very low temps. through Helium Cooling Loops.

3.2 Application Description

OBA is going to work under very low cryogenic temperatures, that require the use of FEM (Finite Element Programs) and DEM (Difference Element Methods) and CAE (Computer Aided Engineering) programs.

As standard in ESA projects OBA must be simulated at:

- Component Level
- System and or S/C level

At component Level OBA will be analysed to Structural and Thermal aspects.
The paramount structural calculations will be:

- Static (Thermo – Elastic)
- Dynamics (frequency Domain)

The static Calculations are basically thermo elastic calculations.
To perform these calculations NASTRAN FEP is the Standard 'de facto' for ESA projects.
With respect to the Thermal simulations mainly two simulations are carried out:

- Radiation Multi reflection View Factors + Environmental Impinging Energies.
- Temperatures and Heat Fluxes Evaluations.

To perform radiation view factors and environmental impinging energies ESARAD program (from ESA) should be used.
On the other hand, to evaluate temperatures and heat fluxes ESATAN program (from ESA) must be used.
At S/C level, the Prime Contractor must perform similar structural and thermal simulations.
For thermal simulations two reduced thermal models shall be provided, one for the radiation calculations, the RGMM (Reduced Geometrical Mathematical Model) and another for the temperature and heat fluxes calculations, the RTMM (Reduced Thermal Mathematical Model).

3.3 General Architecture

3.3.1 Numerical Simulation Tools

NASTRAN

NASTRAN, the NASA Structural Analysis System, is a powerful general purpose FEA program for use in computer-aided engineering.
NASTRAN is a standard in the structural analysis field.
NASTRAN permits the effects of control systems, aerodynamic transfer functions, and other non-structural features to be incorporated into the solution of the structural problem.

ESARAD

ESARAD allows a user to calculate radiative couplings and output a thermal model for the spacecraft. The thermal model takes the form of an input file to the ESATAN thermal analysis program. After performing some thermal analysis, ESARAD will also allow the user to post-process his results.

ESATAN

ESATAN is a software package for the prediction of temperature distributions in engineering components and systems using the thermal network analysis technique. It enables the user to specify his problem in the thermal network quantities of nodes, conductances and material properties, together with the sequences of solutions required to obtain the required steady-state or transient temperature distributions.

MATLAB

MATLAB is an integrated technical computing environment that combines numeric computation, advanced graphics and visualisation, and a high-level programming language.

SENsys

The most traditional and commonly used simulation is the structural behaviour. But nowadays many other physical phenomena can be simulated and are being integrated within the design process.
The problem arises when these physical phenomena are not independent, then a multi-physical simulation is needed. In these cases the simulation tools have to be linked, because the output of a simulation may be the input for other simulation.
Therefore there is a need to link the simulation packages in order to be able to perform multi-physic couples simulation analysis.
Moreover, most of the times the data has to be adapted somehow. Therefore there is a need to provide some methods and tools that allow these modifications of the data.

Specific routines ,**SENsys**, has been developed to transfer some results and to:

Read, store and handle the data from CAE analysis such as FEM and Finite Difference codes

- Write the information already stored in the input format of a CAE software
- Evaluate functions based on FEM results,
- Extrapolate of results from one mesh to another,
- Extrapolate of results for a 2D asymmetric mesh to a 3D one,
- Trim a mesh following a geometry defined in an external CAD module,
- Delete elements in a mesh according to an criterion defined by the user,
- Combine results from two or more analysis.

3.3.2 Application Components

In order to run the complete thermal analysis it has been needed to define the following components within the IMAGE framework:

Structural Component

The StructuralMM component provides on one side an interface to the IMAGE framework and on the other side an interface to NASTRAN.

Radiation Component

The RadiationMM component provides on one side an interface to the IMAGE framework and on the other side an interface to ESARAD.

Thermal Component

The ThermalMM component is the one in charge to execute ESATAN for creating the RTMM. It provides on one side an interface to the IMAGE framework and on the other side and interface to ESATAN.

SENsys Component

SENsys Component is concerned with translating from a format to another to map information of two architectures. This component will be in charge to run specific routines to transfer data from NASTRAN analysis tool and ESARAD analysis tool to ESATAN analysis tool.

MATLAB Component

The Matlab Component is connected with the SENsys Component to make the numerical calculations that are needed for obtaining the RTMM.

The above IMAGE components use the IMAGE framework for :

- Modeling
- Data exchange
- Interfacing components
- Deployment

The following figure shows the application structure defined using GME (Generic Modeling Environment) the tool selected by the IMAGE consortium to modelize the different applications.

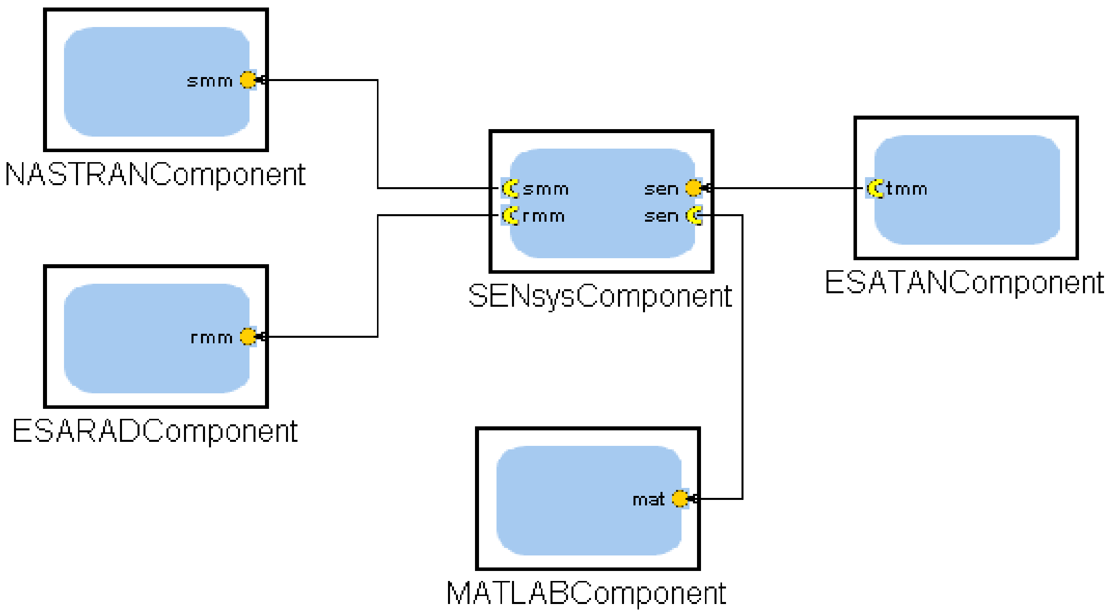

Figure 1. Application Structure

3.3.3 Application Deployment

Deployment is the process of installing or updating Software components into the Component Server infrastructure.
With component specification becoming popular, IMAGE provides deployment module that handles automatic deployment of a CORBA® component independent of the platform.

4 Hybrid Simulation Application

4.1 Introduction

This chapter describes the hardware and software architecture of the simulation application developed in order to validate the IMAGE software in the case of a mixed real-time and numerical simulation application.

4.2 Specifications

4.2.1 Overview

The validation application must be able to demonstrate that the IMAGE services are fulfilled in the case of a mixed real-time and numerical simulation application, which correspond to a real size concrete industrial production context.

This application must be various enough to demonstrate genericity, power and efficiency of the proposed method.

4.2.2 The real-time and planning aspect

The validation application must contain a real-time simulator, which is a computer program or physical process that represent a real process and respects its timescale according to an acceptable tolerance.

4.2.3 The numerical aspect

The validation application must contain a dedicated numerical simulator, which is a computer program or physical process that represent a real process but doesn't need to respect a real process timescale.

4.2.4 The communication aspect

To validate IMAGE middleware services, the validation application must make its real-time simulator and planning system communicate with its numerical simulator, which is located in a distant site.

4.2.5 The interoperability aspect

To demonstrate IMAGE's interoperability, the validation application must make heterogeneous and multi platform applications interoperate.

4.2.6 The real industrial size aspect

To demonstrate that the IMAGE software can be applied to a real size problem. The validation application must be integrated in a real size concrete industrial production context.

4.2.7 The modeling, assembly and deployment aspects

To demonstrate IMAGE 's ability to develop mixed real-time numerical simulations, the validation application must be modeled, assembled and deployed using IMAGE as a development environment.

4.3 Validation Application Architecture

4.3.1 Validation Application Overview

4.3.1.1 The real-time and scheduling aspect

The real time aspect is ensured by an airplane simulator coupled with a real-time scheduler responsible for providing the airplane evolutions.

4.3.1.2 The numerical aspect

The numerical aspect is ensured by a wind tunnel simulator that populates a data mine with the results of the various experimental runs processed on the aircraft model.

A post processing application is then responsible for computing the real scale values associated to the data acquired by the captors on the aircraft model.
It also generates a set of polynomials that model the real scale data.

4.3.1.3 The communication aspect

The communication between the real-time simulator and the numerical simulator is ensured by the IMAGE system, which comprises a Gateway to allow the communication wind tunnel applications.

4.3.1.4 The interoperability aspect

The validation application's components run on various hardware and software coming from various providers as detailed in the following software and hardware architecture.

4.3.1.5 The real industrial size aspect

The validation application integrates trisonic wind tunnel associated with its post processing applications.

4.3.1.6 The modeling, assembly and deployment aspects

The validation application has been modeled, assembled and deployed using IMAGE as a development environment.

4.3.2 Software Architecture

4.3.2.1 Data acquisition and initial data processing

At trisonic wind tunnel laboratory, after each test run, the primary data acquired by the captors are reduced and the results are written. In the same time, the information about the tunnel configuration, the testing regime, the model, etc. are written in a file which contains all this "master data".

4.3.2.2 Data Mine population

New experimental results are uploaded in the mine of data of access of Microsoft.
From this stage, the wind tunnel data can thus be copied on any computer and accessed by any application compatible with Microsoft Access databases.

4.3.2.3 Post processing tools

The application also offers a set of data analysis and plotting tools that are able to offer any information the aircraft designer may need. It is also able to compute a set of polynomials that model the data generated in the data mine.

4.3.2.4 Polynomials computation

In order to make the polynomials readable by the IMAGE system, a small application has been developed that generates the polynomials coefficients in a common language for the complete data domain we consider.

4.3.2.5 The IMAGE Numerical Calculator Gateway

A Gateway has been developed to read the polynomials coefficients provided by applications and transmit them to the IMAGE Numerical Calculator component.

4.3.2.6 The IMAGE NumericalCalculator Component

A NumericalCalculator CCM component has been defined in the IMAGE middleware in order to represent the numerical calculator.

4.3.2.7 The IMAGE Airplane Component

An Airplane CCM component has been defined in the IMAGE middleware in order to represent the simulated aircraft.

4.3.2.8 The IMAGE AirplaneScheduler Component

An AirplaneScheduler CCM component has been defined in the IMAGE middleware in order to represent both the pilot and weather application actions. The AirplaneScheduler component is responsible for changing the aircraft parameters on a regular time basis.

4.3.2.9 The IMAGE Components Assembly

The IMAGE Component Assembly of the current simulation case is composed of three CCM components instances.

4.3.3 Hardware Architecture

- **The Trisonic Wind Tunnel**

The wind tunnel used to produce the data is a blow down, pressurized wind tunnel. It is able to produce test runs from mach 0.1 up to mach 3.5.

- **The Data Acquisition Computer**
- **The Initial Processing computer**
- **The Data Mine with PP3S computer**
- **The IMAGE Numerical Calculator Component Computer**
- **The IMAGE Airplane Component Computer**
- **The IMAGE AirplaneScheduler Component Computer**

5 Annex A: List of Acronyms and Abbreviation

ATC	Air Traffic Control
CAD	Computer Aided Design
CAE	Computer Aided Engineering
CAM	Computer Aided Manufacturing
CCM	Corba Component Model
ESA	European Space Agency
DEM	Difference Element Method
FEA	Finite Element Analysis
FEM	Finite Element Method
FEP	Finite Element Program
LAN	Local Area Network
OBA	Optical Bench Assembly
OBP	Optical Bench Plate
OBS	Optical Bench Shield
OBHCL	Optical Bench Helium Cooling Loop
OS	Operating System
PIV	Pentium IV
RGMM	Reduced Geometrical Mathematical Model
RTMM	Reduced Thermal Mathematical Model
S/C	Space Craft