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Bridge

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Deliverable

D2.2 Description of Analysis Services employed in the Aerospace Scenario

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Abstract

This deliverable describes the Aerospace Scenario Analysis Services and Workflow. It provides a detailed overview of the workflow, and demonstrates the first set of Simulation Services employed by it.

Revision history

Date	Version	Author	Modification
30 September 2007	0.5	Nick Tzannetakis	First Full Draft Version
2 October 2007	0.7	Nick Tzannetakis	Incorporated AVIC-II input
8 October 2007	0.9	Nick Tzannetakis	Consolidated document for Review process
2 November 2007	1	Nick Tzannetakis	Final, included all comments/corrections from reviewers

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1 Introduction

Analysis services, for example mesh generation tools, tools for the prediction of the structure of modules, or meta-modelling services, are the basis of virtual product development in many different industries. Such analysis services are to an increasing extent being integrated into complex problem solving environments to allow engineers to easily drive the whole development process in an integrated environment. To meet the challenges of geographically and logically distributed development processes, analysis services have to be Grid-enabled and integrated into Grid-enabled problem solving environments.

The implementation of analysis services employed in the Aerospace Scenario is based on Grid technologies. In general, Grid technologies have evolved to fulfill two major aspects. First, distributed resources are to be virtualized to provide a single, consistent view to the end-user and allow him/her to use these resources without having to worry about infrastructure or business aspect details. Second, Grid technologies are based on open standards.

Both aspects are essential requirements of the BRIDGE application areas regarding analysis services. Distributed companies and their suppliers working in multiple product development disciplines want to share analysis services based on open standards. Grid technologies are the only viable alternative to fulfill these requirements.

On a higher conceptual level, we can look at analysis services as units of work, each handling a specific functional task. These can then be combined into business-oriented transactions, which can handle business processes together in a workflow of analysis services. Therefore, once technical specialists have implemented analysis services, business process architects can aggregate them into complex problem solving environments, which deal with the solution of business level problems. This goes beyond the aim of the BRIDGE Project as such.

Today's state-of-the-art regarding analysis services is that the underlying standards like Web Services, and related technologies such as XML, SOAP, WSDL, UDDI, etc. are relatively advanced and mature. Additional standards to handle issues like interoperability, security, orchestration, etc. have also been developed, but are partially still under discussion. Well established examples for such standards from WS-I, include WS-I Basic Profile and WS-I Basic Security Profile.

2 BRIDGE Analysis Services

2.1 *Consolidated Requirements of the Analysis Services*

According to the current requirements of the Aerospace Scenario, the following functions are driving the creation of the Aerospace Analysis Services:

- Interfaces which allow to call an analysis service
    - From a command line
    - From a web browser
    - From workflow execution engines, which can be either proprietary like for the individual problem-solving environments, or generic, such as provided by OPTIMUS, or other workflow tools.

  These environments are in the following referred to as “calling context”. Note that these three calling contexts cover the invocation of analysis services from within problem-solving environments such as OPTIMUS, as it uses command line based or workflow driven calls to analysis services.
- Execute an embedded analysis code.
- Interface with existing load sharing systems such as Platform LSF and Sun Grid Engine.
- Provide status feedback to the calling context, such as
    - Pending
    - Establishing contact to service provider
    - Queued
    - Transferring data (to/from service provider)
    - Running analysis
    - Finished.
- File transfer
    - Secure

    Ability to handle large files >2GB, if possible with restart capabilities to avoid reload of data that had already been transferred when a data transfer stopped due to a problem.

2.2 *Description of Analysis Services*

2.2.1 Workflow Service

The Workflow Service allows for the definition of an initial GRIA Service enabled Workflow that captures and federates the Simulation Services to complete the overarching workflow and start the execution of all the involved tasks. It provides for the execution of the workflow in a distributed manner on the individual compute-infrastructure of EADS and AVIC-II. It further encapsulates the FhG-SCAI Meta-Modelling Service and the Optimization Service provided by AVIC II.

The workflow service is made of the following components:

1. A graphical user interface to set up the workflow (interactive)
    - Workflow definition
    - Instantiation of the workflow with actual services
    - Visualization
2. A workflow language
    - XML based description of the workflow
3. A workflow enactment engine
    - Parsing of the XML workflow language
    - Execution of tasks

2.2.2 Acoustic Service

The acoustic service is made of the following components:

1. a meshing component (optional)
    - inputs: geometry (IGES, STEP), meshing constraints
    - output: surface mesh
2. a pre-processing tool
    - inputs: surface mesh
    - output: degrees of freedom (DOF)
3. the acoustic solver
    - inputs: geometry definitions, boundary conditions
    - output: raw result on the surface
4. post-processing tool
    - inputs: far/near field geometry location, raw result
    - output: expected physical result (pressure, noise level)

Steps 2, 3 & 4 when linked together can be seen as the acoustic service.

Steps 1 & 3 provide great added value in the process. The meshing component is able to generate very large meshes (>100 M cells) while the acoustic solver is able to solve such computationally intensive problems thanks to the multi-pole method.

2.2.3 Aeroelastic Service

In similar manner an aero-elastic Simulation Service is provided by AVIC-II. This service provides the means for the qualification of the aerospace structure in terms of aero-elastic attributes. The aero-elastic program is HAJIF-II developed by China Aviation Industry and it has been used in a number of aircraft development projects. It provides the aero-elastic service in this project. HAJIF-II has the aero-elastic analysis function for metal and composite material aircraft structure. The system has the structure strength, unsteady aerodynamic and aero-elastic analysis capability.

HAJIF-II has pre and post processing function and has interface to exchange the data with NASTRAN and PATRAN FEMAP, SAP91, and QuickFEM software.

The aero-elastic service is made of the following components:

1. A structure meshing function
    - geometry definition
    - meshing constraints (boundary condition)
    - element and material properties
2. An aerodynamic surface panel mesh input
    - surface panel mesh
3. The aircraft flight parameter inputs
    - Flight condition parameters (high, temperature speed etc.)
    - the analysis goal (flutter or static aero-elastic analysis)
4. results output
    - aero-elastic results
    - the structure vibration model

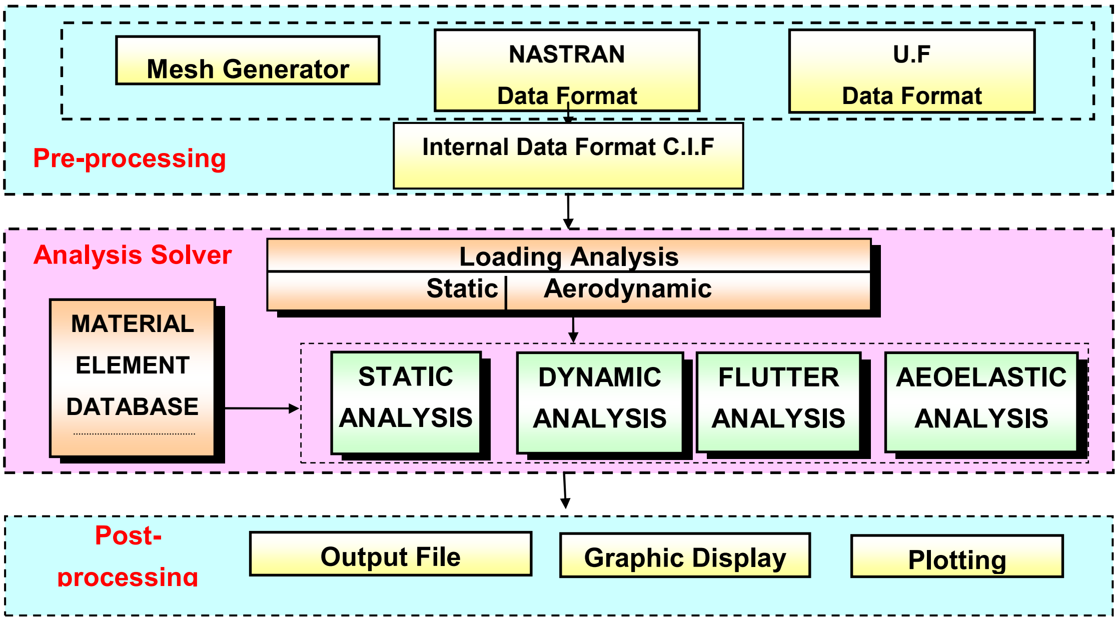

Figure 1: The aeroelastic service architecture

2.2.4 Aerodynamic Service

The aerodynamic service consists of a number of tasks that include the pre-processing steps necessary for the creation of the simulation model as well as the solving steps. Figure 3 below reveals the steps and the connections between them.

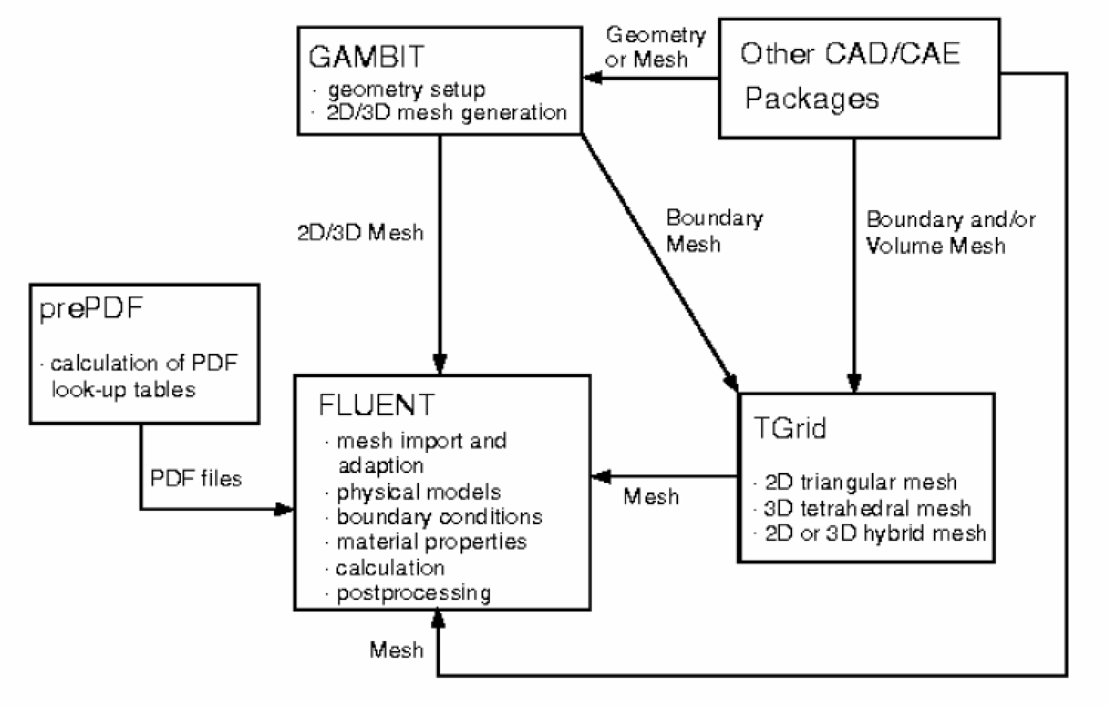

Figure 2: The aerodynamic analysis tools architecture

We can get the mesh for FLUENT computation through the following methods:

- Establish the Geometry model and Mesh model by GAMBIT
- Generate the Triangle, Quad and Mix mesh in basis of the existing boundary mesh(established by GAMBIT or other CAD/CAE software) by Tgrid
- Establish the Mesh model by other software such as ANSYS□I-DEAS, MSC/ARIES, MSC/PATRAN and MSC/NASTRAN

Here, FLUENT is the solver and PreBFC, GeoMesh are the pre-process software utilized.

The solve step consists of the following steps:

1. Create the Mesh model
2. Execute the proper solver: 2D,3D, 2DDP, 3DDP
3. Input the Mesh
4. Check the Mesh
5. Select the Solver format
6. Select the foundation equation of the solver: energy equation and turbulence model, etc
7. Confirm the necessary addendum model: fan, heat transfer, porous

medium, etc

8. Define the property for the materials
9. Define the boundary conditions
10. Set the control parameter for the solver
11. Initial the flow field
12. Solve the flow field
13. Check the results
14. Save the results
15. If necessary, thinning the mesh, modify numerical results and physical model, and then re-computation

2.2.5 Design of Experiment Service

The Design of Experiment Service allows for the automatic generation of several design alternatives based on statistical methodologies. The characteristic is the ability to intelligently scan the design space with the least possible number of design alternatives while providing the maximum of information. The DOE Service in conjunction with the Meta-Modelling Service allow for the definition of quick to evaluate mechanisms to be utilized by the Optimization Service, termed usually as surrogate models. The ability to define and iterate on the creation of the Meta-Models based on each individual Simulation Service is one of the clear innovations of the proposed approach.

2.2.6 Optimization Service

The Optimization Service is highlighted in the schematic below [Figure 3]. The evaluation of the Aero-elastic Simulation Service or Acoustic Simulation Service will be made as specified above through the utilization of the FhG-SCAI provided Meta-Modelling Service. The system will run on Grid platform, which is supported by several clusters in deferent locations. The basis of the Optimization Service is a Genetic Algorithm that utilizes an internal Meta-Modelling mechanism to accelerate the convergence and reduce the number of needed evaluations.

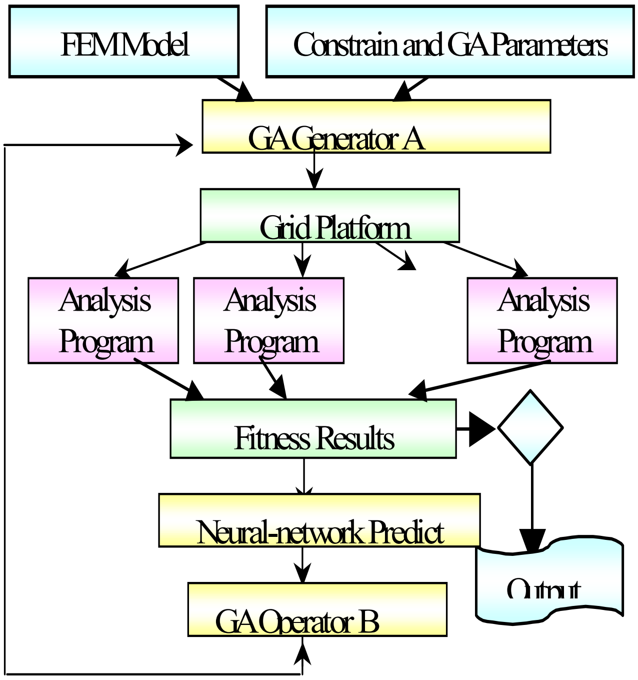

Figure 3. Optimization Service Description

2.2.7 Meta-Modelling Service

A Meta-Modeling service that allows for the definition of surrogate models for various design alternatives based on the DOE Service highlighted in Section 2.2.5 above. The Meta-Modeling service receives as input a table of design parameter settings and the corresponding design output results. It is through the Meta-Modeling service that design optimization can be achieved. Design optimization requires a great number of design alternatives to be evaluated. Depending on the actual Aeroelastic and Acoustic Analysis services to evaluate the numerous design alternatives would make optimization runs very CPU intensive and elapsed time demanding thus, making optimization not realistic.

3 Definition of Aerospace Scenario Workflow – Integration of Analysis Services

The Analysis Services participate in collaborative form in the overall Aerospace Scenario. A number of scenarios have been presented in D2.1 deliverable “Description of Aerospace Scenario”. This section highlights the integrated scenario and provides the view on the use of the developed Analysis Services.

In the following figure, the workflow is given to describe the whole process for optimization. The explanation of the modules (Analysis Services), inputs and outputs of each task/step of the workflow and variables are shown in Table 1 and Table 2. The complete optimization process includes:

1. The initial geometry model (M1)
2. During the course of pre-process, the Aerodynamic model (M2) and FEA model (M3) are established from the geometry model, besides the design variables and constrains (D1).
3. Generate the population chromosome through the Optimization (GA) module A
4. The CFD computations are carried out by the aerodynamic program and the CFD results for the given points are interpolated from the CFD results by the Meta-Model-A.
5. The Acoustic Import data and the Aeroelastic Import data are generated from the Acoustic Import Generator and Aeroelastic Import Generator separately. The feasible solution sets by Acoustic optimization server and Aeroelastic optimization server are determined.
6. After the Evaluated process from each sub-optimization is completed, the results are assembled and integrated to one overall evaluation value.
7. Through the GA module B, the step results are output and the new generation population chromosome are generated according to the evaluation values.
8. A check on the optimization criterion for convergence is carried out and if so, the output of the final results is provided and the process is terminated. If convergence has not been achieved a new design is formed by evaluating the Meta-Model-B and the execution of the GA module A.

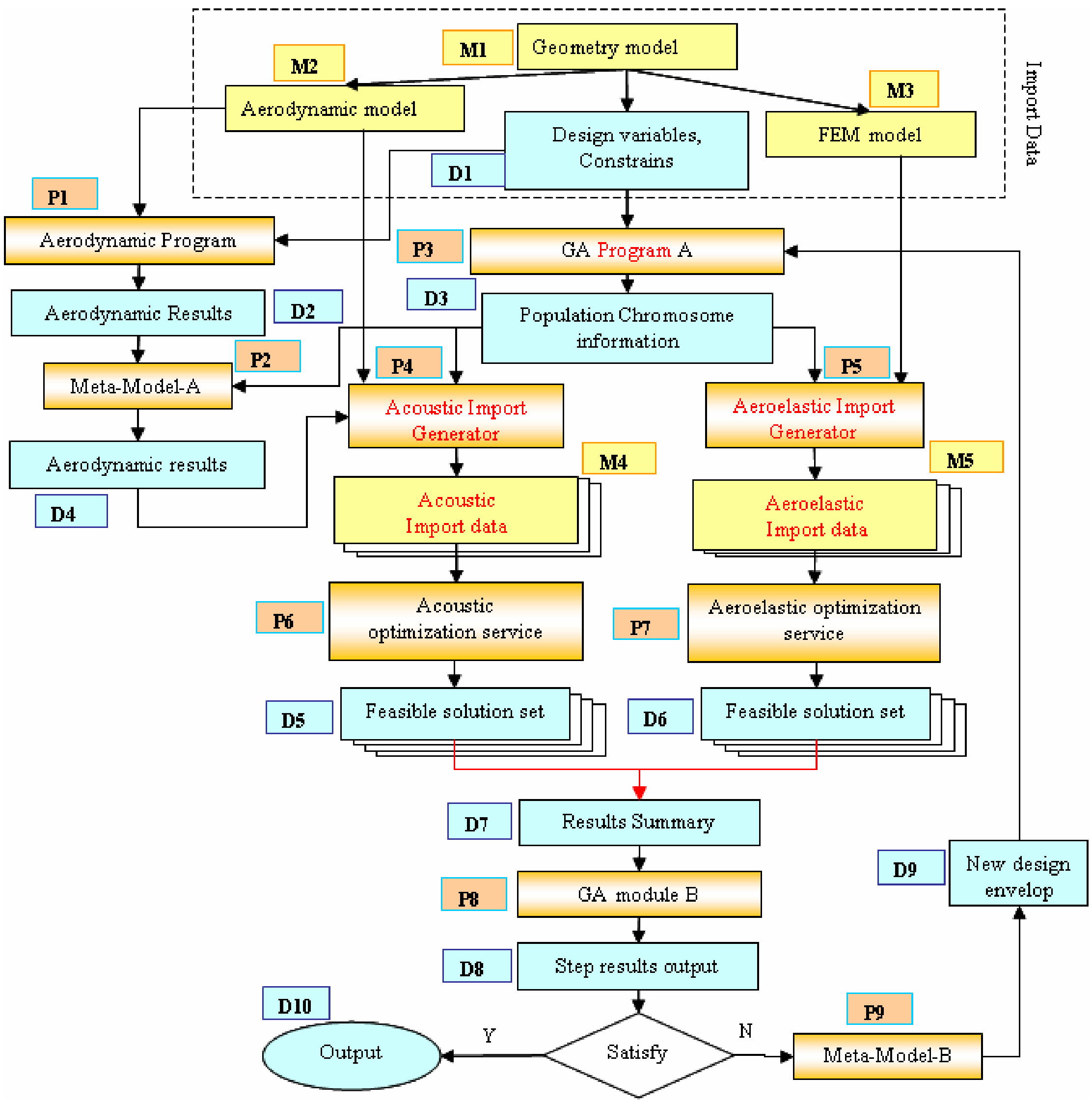

Figure 4. The workflow of optimization system

The physical system architecture for Aerospace Scenario workflow based on Grid platform is shown in the following diagram as shown in Figure 5 below. There are two clusters for the execution of the workflow, one for the Aeroelastic service and one for the Acoustic service. The overall workflow based LMS Workflow service will run in the server same server as the Aeroelastic service and be based on AVIC-II computer infrastructure. The meta-modeling service is running at FhG-SCAI.

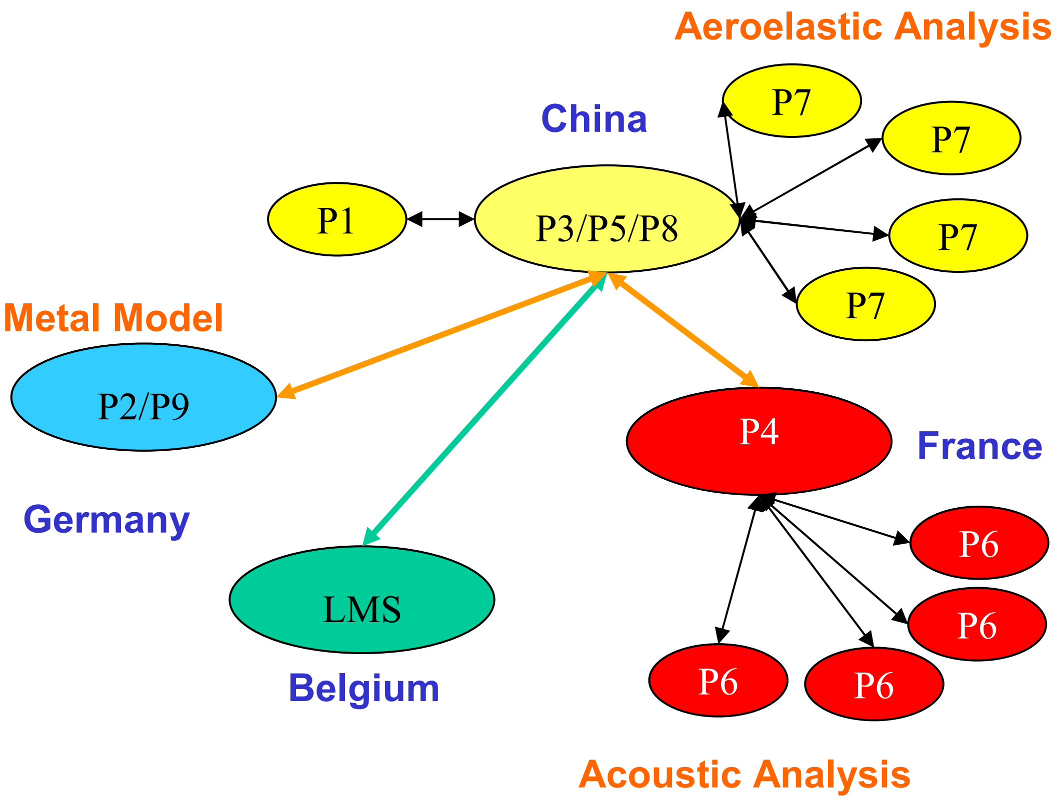

Figure 5. The physical location and workflow of optimization system

Table 1. The description for the program

No	Name	Description	Input information	Output information	Responsibility
P1	Aerodynamic program	CFD (Computational Fluid Dynamics)	M2, D1	D2	AVIC/EADS
P2	Meta-Model-A	Compute the whole design envelop results from CFD results by interpolation	D2, D3	D4	FhG./SCAI
P3	GA module A	GA (Genetic Algorithm) module A, generate the population chromosome information	D1	D3	AVIC
P4	Acoustic Import Generator	The necessary data for Acoustic optimization transferred from population chromosome information	M2, D3, D4	M4	EADS
P5	Aeroelastic Import Generator	The necessary data for aeroelastic computation according to the population chromosome	M3, D3	M5	AVIC
P6	Acoustic optimization server	Acoustic optimization server	M4	D5	EADS
P7	Aeroelastic optimization server	Aeroelastic optimization server	M5	D6	AVIC
P8	GA module B	Assemble the computation results from the two sub-server, Evaluate the results and generate the next generation population	D7	D8	AVIC
P9	Meta-Model-B	Predict the new design variables envelop	D8	D9	FhG./SCAI

Table 2. The description for the data and model

Category	No	Name	Description	Responsibility
Model	M1	Geometry model	The structure model, IGS format file	AVIC
	M2	Aerodynamic model	CFD model (wing body combination), Flight state parameter, Flap location. FLUENT software input file(*.msh)	AVIC/EADS
	M3	FEA model	FEA model of the wing	AVIC
	M4	Acoustic model	Wing acoustic model, CFD results, Flight state parameter, Flap location	EADS
	M5	Aeroelastic model	Aeroelastic model of the wing, Aeroelasitic computation parameter, Flight state parameter, Flap location	AVIC
Data	D1	Design variables	Flight State parameter, Flap location, Acoustic noise index, Aeroelastic index	AVIC/EADS
	D2	CFD results for key points	The CFD results for key points in flight envelop	AVIC/FhG./SCAI
	D3	GA population	Feasible solution set generated from GA module A (population chromosome information)	AVIC
	D4	The interpolation CFD results	Compute the CFD result for the given points by meta-model-A (interpolation)	FhG./SCAI
	D5	Computation results of Acoustic population	The evaluated value of individuals for acoustic request	EADS
	D6	Computation results of Aeroelastic population	The evaluated value of individuals for aeroelastic request	AVIC
	D7	Overall results for the two sub-population	Compute the overall index for the acoustic and aeroelastic index of individuals	AVIC
	D8	Output	The step results (result_*.txt)	AVIC
	D9	Design variable envelop	the new design variables envelop give by Meta-Model-B	FhG./SCAI
	D10	Final results	The optimization results (results_*.txt), the optimized aeroelastic model (*.bdf), the optimized acoustic model (*.*)	

An examination of the utilization of two separate Grid middleware infrastructures, one provided by GRIA and one provided by CNGRID GOS will also be carried out during the project and conclusions either. The system architecture is shown in the following figure.

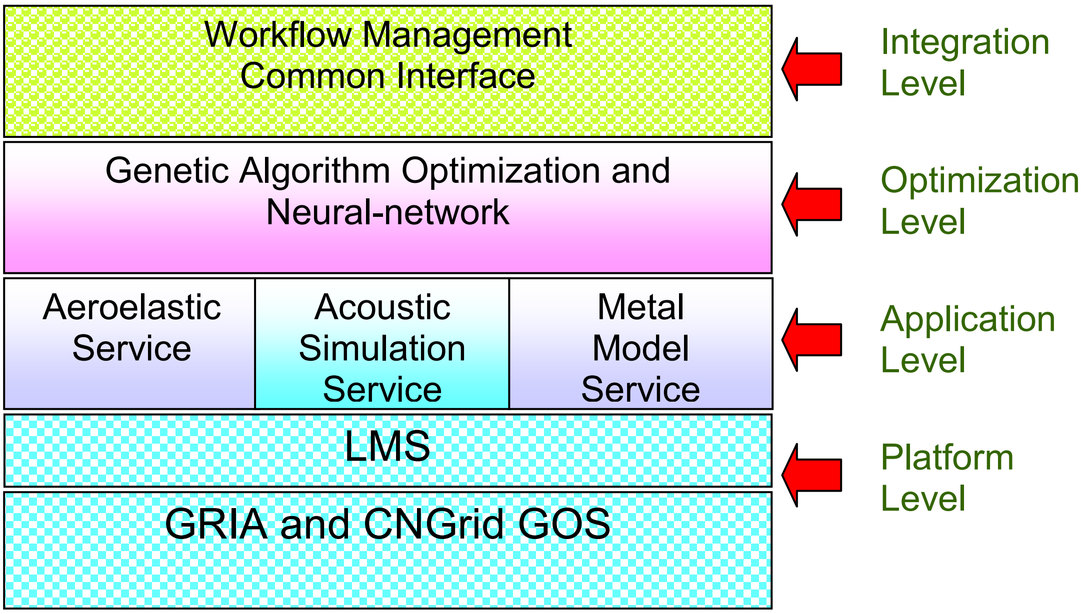

Figure 6. The architecture of aerospace application system

4 Aerospace Design Model

The design model utilized in the Aerospace Scenario is detailed in the following sections.

4.1 Geometry model

AVIC II STC has created a wing and body geometry model by CATIA-V5. The wing and body is a civil transportation aircraft which could be used to create aerodynamic, acoustic and aeroelastic models for analysis.

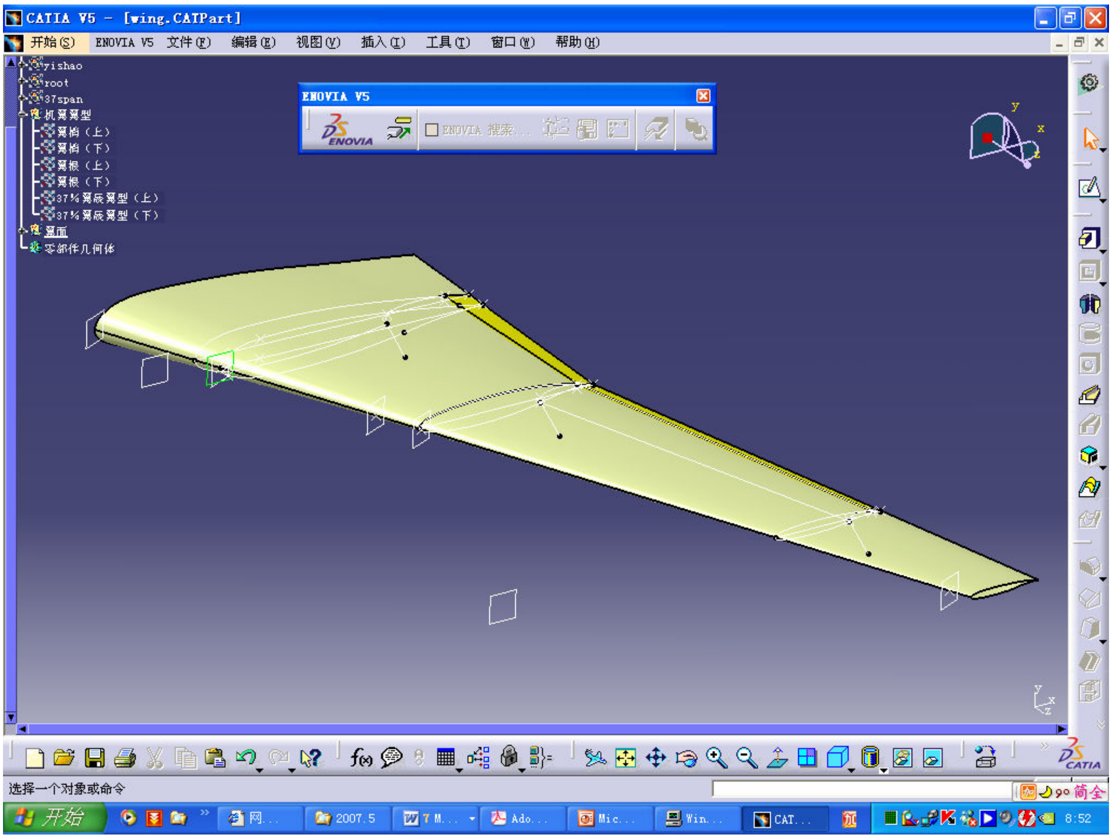

Figure 7. CATIA V5 geometry wing model

The wing geometry model is used to create aeroelastic analysis model, which could used for aeroelastic service. The wing geometry model is including wing structure (underskin) arrangement and size properties (thickness, materials, etc.).

The wing geometry and body model is used to create aerodynamic analysis model, which can show the aerodynamic interference between wing and body.

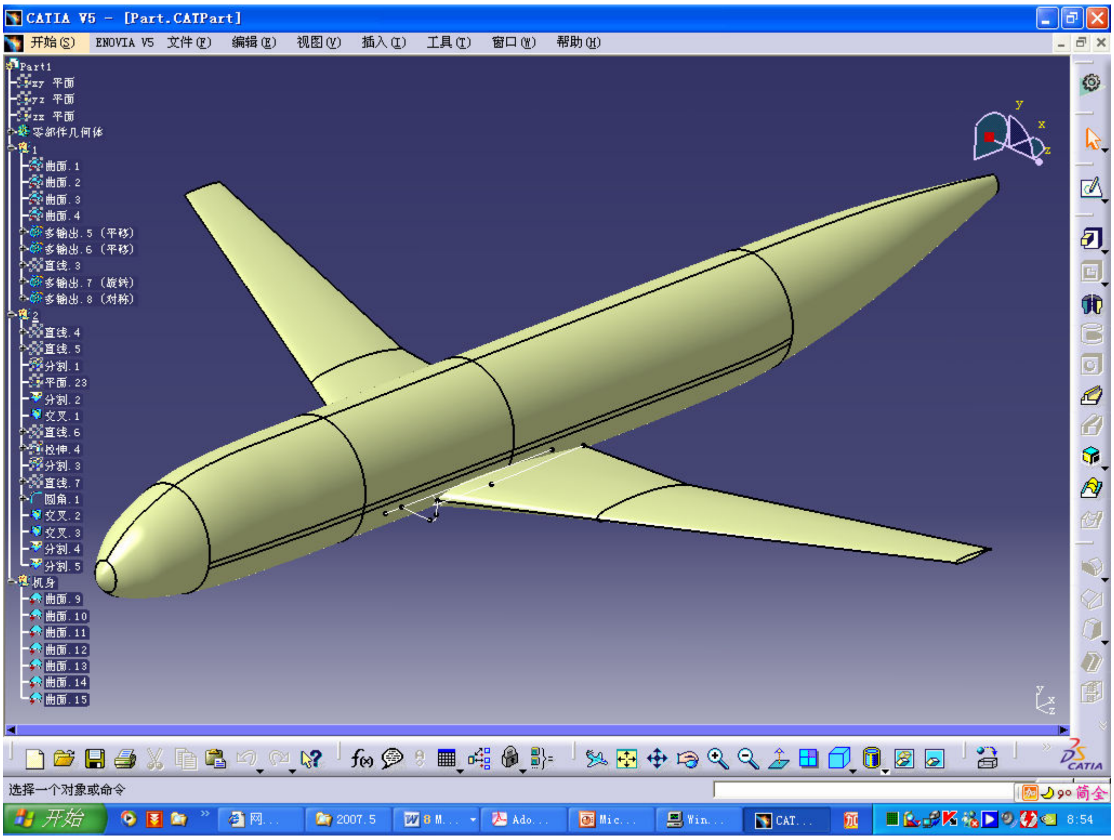

Figure 8. CATIA V5 geometry wing and body model

4.2 Aeroelastic model

AVIC II has created a wing aeroelastic model for aeroelastic service. The model includes mesh data, material characteristic, boundary condition etc. The data is meeting the requirement for HAJIF II software. The flap position has been set in a particular deployment setting as follows.

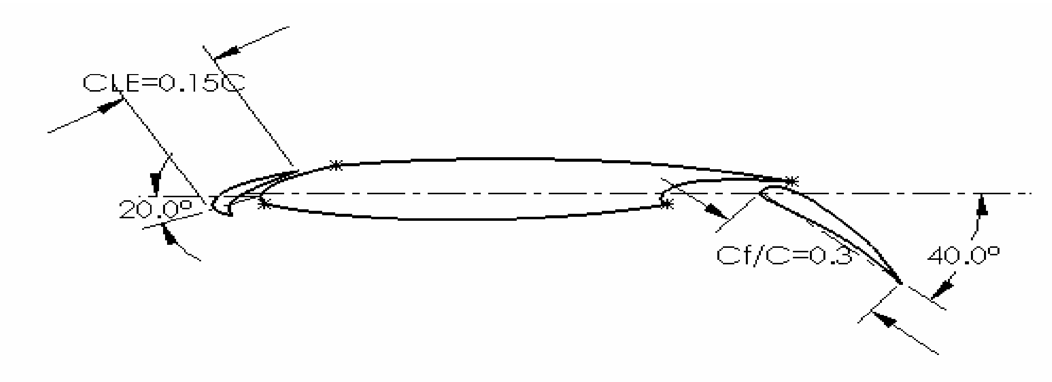

Figure 9. Flap position preliminary definition

The Acoustic model and aerodynamic model are at the time this document is written under development.

5 Concept solution for the execution of the Aerospace Scenario

There are two scenarios under development on how the services are utilized and deployed in demonstrating the complete Aerospace Scenario as shown in Figure 10. The host server is utilized to schedule another two sub servers and the two servers that include: aero-elastic computations are performed in computers located in China and acoustic computations are performed in computers located in Europe. Both scenarios will be evaluated and the relevant conclusions will be summarized.

5.1 Scenario 1

In the first Scenario, the user submits a job locally to the host server. According to the optimization type (include aero-elastic and acoustic optimization), the job will be sent to the relevant server. The jobs are then dispatched to clusters for computation and the results will be sent back to the server after computation.

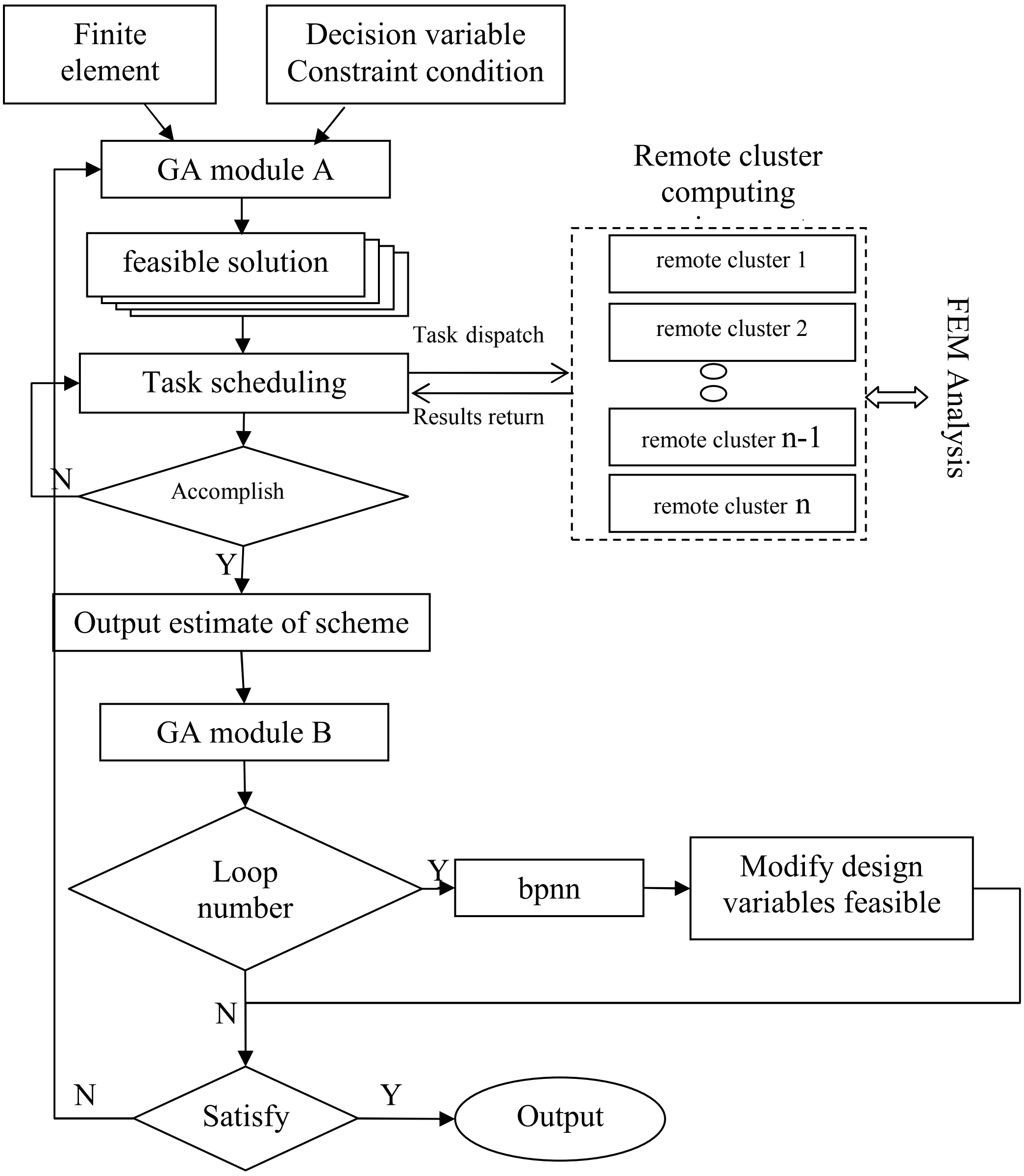

Figure 10. The multi-objective optimization Pareto solution – Scenario 1

5.2 Scenario 2

This scenario consists of employing multiple computational servers for the completion of the computations as involved in the Aerospace Scenario workflow.

The execution of the optimization according to Scenario 2 involves:

- Submit a geometry to the host server
- Establish the FEM model and confirm the design variables in host server.
- Establish the transfer relationship between design variables of models, integrate the design variables and confirm the coding method.
- Generate the population, send the population chromosome information to the two sub server(aero-elastic optimization server and acoustic optimization server)
- Generate the feasible solution sets according to the chromosome information of population independently in each sub optimization server.
- All the feasible solution sets is divided into some job units and dispatched to local/remote computation nodes through the internet by task schedule server.
- After finishing the computation, the results are sent back to the sub optimization serve.
- The results from the two sub servers are sent back to the host server and evaluated to generate the next generation population.

6 Conclusion

We have currently reached a mature state in the definition and development of the Analysis Services as required for the Aerospace Scenario. The overall workflow has also been determined along with the concepts for the computation of the optimization process. That involves multiple compute clusters across the two continents (Europe and China) along with the interoperability of the two Grid middleware infrastructures. Interoperability schemas have been discussed and are analyzed in D1.3 “GRID Infrastructure Interoperability Implementation”.