Bilateral **R**esearch and **I**ndustrial **D**evelopment Enhancing and Integrating **G**RID **E**nabled Technologies

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Bridge

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Deliverable

D2.1 Description of Aerospace Scenario

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PP	Restricted to other programme participant (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Abstract

This deliverable describes the Aerospace Scenario under the BRIDGE project. It provides a detailed overview of the workflow and lists the requirements of the GRID Infrastructure (WP1) needed by the Aerospace Scenario. This deliverable also provides the details on the objectives and overall construction of the aerospace scenario, presents the process of converging to the final selected workflow along with the remaining steps required to reach a working demonstration scenario.

Revision history

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21.04.2007	1.1	Nick Tzannetakis	Added Requirements section
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1 Work package Description Summary

The aims of the Aerospace Applications work package is to set-up and demonstrate in operation a distributed workflow for optimization that includes at least two simulation modules. A total of five GRID Services will be developed and set-up during the course of the project. Each *Service* will be located and compute on different sites, three of the Services being located in the EU, while two Services being located in China:

- The *Acoustic Simulation Service* is delivered by EADS. The *Aeroelastic Simulation Service* is delivered by AVIC-II. Each service executes on computing platforms owned and operated by EADS and AVIC-II respectively.
- The *Workflow Service* and the *Design of Experiment Service* is provided by LMS. The Workflow Service allows for the encapsulation of the computational workflow and the execution of the workflow in a distributed environment.
- The *Design of Experiment Service* provides the means for generating the multiple design alternatives in providing the *Meta-Modelling Service* with data.
- The *Meta-Modelling Service* provides a high fidelity condensed representation of the analysis model as defined by the workflow. The Meta-Modelling Service is provided by FhG-SCAI. The Meta-Modelling Service contains a distributed computation schema, running on the FhG-SCAI computer clusters.
- The *Optimization Service* will be provided by AVIC II and Beihang University. The Optimization Service will operate on the Meta-Model modules provided by FhG-SCAI, and execute at FhG-SCAI computer clusters.

Each partner brings unique know-how for the corresponding service. In the complete workflow, each Simulation Service will be equipped with its own Meshing Service. The necessity for this arises from the need that each Simulation Service requires specific mesh representation. The specific mesh representation contains Intellectual Property [IP] that has to remain the property of the Simulation Service providers.

The above will be demonstrated with the use of a modified aeroplane wing, for the purposes of the project and in allowing complete disclosure of the geometry to all consortium members. The initial geometry will be supplied by AVIC-II and will be distributed to the Simulation Services as IGES, or STEP files.

The initial GRID enabling of all elements will be with the utilization of GRIA as middleware. 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 on the success or requirements for making such a schema successful will be delivered.

The following figure provides an early view of the Simulation Services along with the topology of the overall implementation and workflow execution scheme.

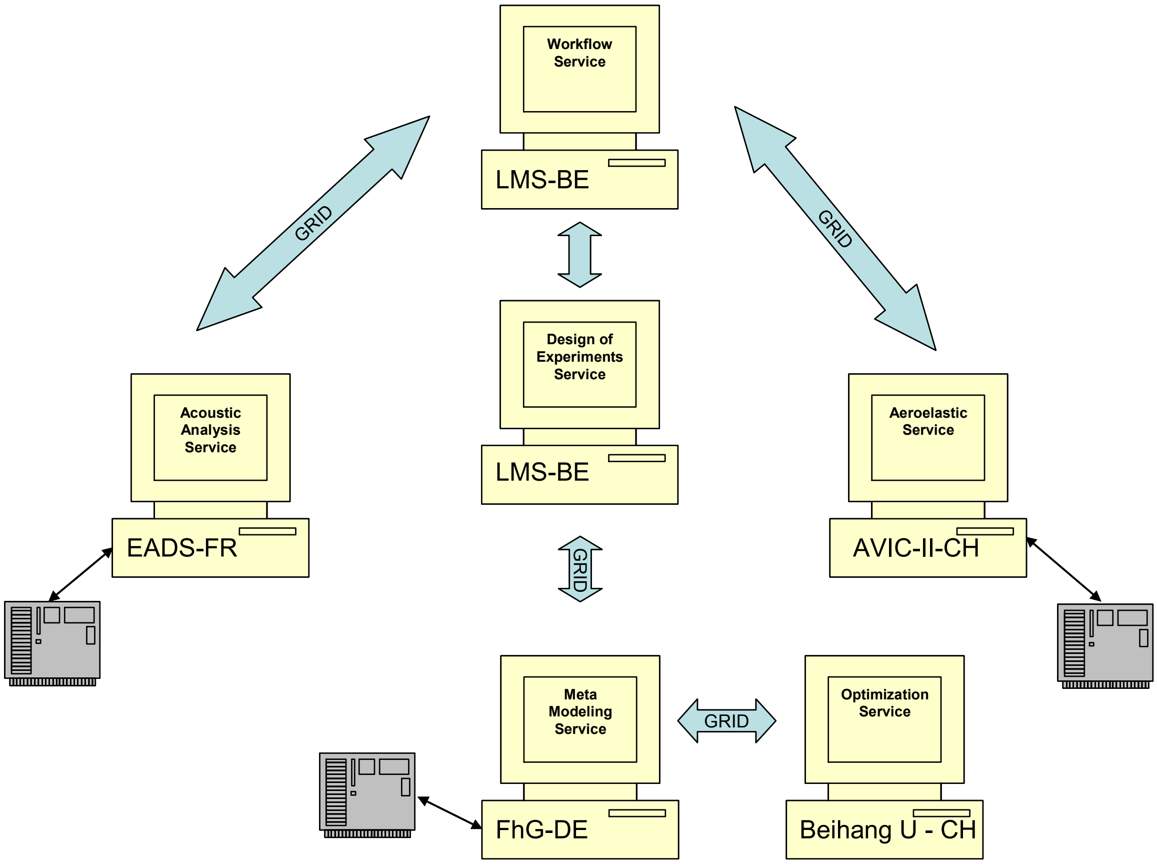

Figure 1.1. Schematic of the GRID Enabled Implementation

1.1 Description of work

The target is to set up a distributed workflow for optimization, which includes simulation modules from EADS and AVIC II on a more generic test case. The EADS modules would be executed on EADS platforms, the AVIC II modules on their platform. For the description of the workflow, OPTIMUS from LMS would be used. LMS' responsibility (together with their Chinese office) would be also to get the prototype running. FhG-SCAI would contribute the Meta modelling components and modules for the distributed computation of Meta modules. The scenarios would be the primary test case for the development on the basis infrastructures. The workflow differs from the Aerospace workflows undertaken in SIMDAT in two major ways. Firstly, the current workflow will work across two distinct GRID middleware architectures, GRIA and CNGrid GOS. Secondly, it differs in its construction as it involves meta-modelling services.

To realize the aerospace scenario and its associated workflow, the following tasks have been identified:

Definition of the overarching workflow (optimization workflow), and application scenario (inputs, outputs, overall workflow, definition of optimization scenario)

The aerospace product development business is becoming rapidly a "globalized" business with partners spanning the globe (example Boeing and the risk-sharing-partnerships). Industrial partners are more and more involved in multiple projects that involve the collaboration of multiple entities, usually not connected through the same company structure, but supplying each other with specific services. Depending on the consortia, they may be simultaneously partners and/or competitors. This dual role has to be specifically addressed by the simulation middleware and infrastructure in order to protect its IPR. In this workpackage the BRIDGE consortium members will set up and demonstrate a clear case that provides a concrete example on how the GRID is enabling this collaboration while protecting the IP of each contributing member. The common input will be the geometry definition of an aerospace structure. The Simulation scenario will be captured by an overarching Workflow tool that utilizes GRIA enabled Simulation Services. Geometry modifications will be made according to the needs of an optimization scenario that will optimize several Acoustic and Aeroelasticity functional performances of the aerospace structure. The Optimization will be performed based on Meta-Models in order to accelerate the optimization process

Definition of the Analysis Services

The Workflow Service will allow for the definition of an initial GRIA Service enabled Workflow that captures and federates the Simulation Services to complete the optimization task. It will provide for the execution of the workflow in a distributed manner on the individual compute-infrastructure of EADS and AVIC-II. It will further encapsulate the FhG-SCAI Meta-Modelling Service and the Optimization Service provided by AVIC II.

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.

In similar manner an aero-elastic Simulation Service will be provided by AVIC-II. This service will provide 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 some aircraft development. It will provide the aero-elastic service in this project.
The aero-elastic service is made of the following components:

1. a structure meshing function
    a. geometry definition
    b. meshing constraints (boundary condition)
    c. 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

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. 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.

The Optimization Service is highlighted in the schematic below. 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 and internal Meta-Modelling mechanism to accelerate the convergence and reduce the number of needed evaluations.

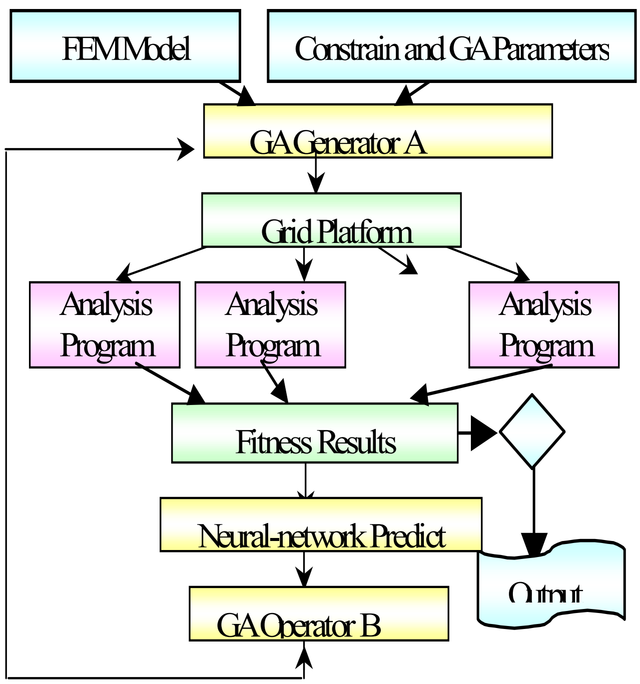

Figure 1.1.1. Optimization Service Description

Implementation of GRID Enabled Analysis Services

A GRIA enabled Workflow encapsulation and execution framework as provided by extensions to the commercially available OPTIMUS software will be made under this project.

With this we will be able to both capture and execute Simulation based workflows that contain the Acoustic and Aero-elastic Simulation Services as well as integrate the Optimization and Meta-Modelling Services. For the initial prototype, GRIA will be used as the enabling GRID Middleware. Further integration will then be made to incorporate GOS services.

The surface meshes for the acoustic and aero-elastic simulation service as well as the acoustic and aeroelastic simulation services will be grid enabled thanks to the GRIA middleware.

Beihang University has developed a LSF function GRID to support the Genetic Algorithm Optimization system to support the parallel computation. A GRIA enabled Optimization Service will also be implemented.

Implementation of GRID enabled Analysis level workflow and Overarching Optimization Workflow

An extended version of OPTIMUS from LMS will be used to encompass the task of integrating the complete workflow under a consistent framework. OPTIMUS will also be used as the main mechanisms for the execution of the workflow in an optimization loop. OPTIMUS is a generic Workflow definition, capture and federation tool, allowing the creation of “simulation” based workflows along with Workflow execution mechanisms. The extensions to be performed under the auspices of the BRIDGE project involve the complete enabling of GRID Services based workflows and the extensions necessary to integrate the AVIC-II and Beihang developed optimization methodology.

The following table analyzes the potential risks and contingencies regarding WP2:

Risk	Level	Contingencies
Difficulties in setting-up the overarching workflow involving the international cooperation and services provided by multiple partners	Med	Define multiple levels and interconnect in intermediate levels. Understand and contain any potential IT related pitfalls
Deficiencies in interconnecting multiple GRID Middleware driven/wrapped applications	Med	Close collaboration amongst partners and WP1 team.
Availability of performing GRID Infrastructure in sufficient time frame	Low	Close collaboration with WP1 for avoidance of interoperability

The following table defines the relation to SIMDAT and lists the synergies and dependencies, so as to define how redundancies are avoided.

SIMDAT Topic	Synergies	Dependencies
GRID Enablement of Workflow and DOE Service (as in OPTIMUS)	Common architecture with BRIDGE in concerning GRIA developments	Completed in SIMDAT PM24 (before the start of BRIDGE) (no risk)
Acoustic Analysis Service	Common utilization of the service	In service already within SIMDAT Aerospace Activity (no risk)

Overall sharing of know-how and standardization efforts	Common participation in SIMDAT and BRIDGE	No risk

In order to define the starting point for thee research of the WP2 project activity, the following table defines the pre-existing software.

Software	**Main characteristics**
Workflow definition and enactor service and DOE service (OPTIMUS) (Provided by LMS)	GRID (GRIA) enabled Workflow definition and enactor Web Service Enabled Design of Experiment (DOE) Engine
Acoustic Analysis Service (Provided by EADS)	GRID Enabled Acoustic Simulation Service
Aero-Elastic Service (Provided by AVIC-II)	GRID Enabled Aeroelastic Simulation Service
Meta-Modelling Service (Provided by FhG-SCAI)	Response Surface Meta-Modelling Service To be used in conjunction with the DOE service
Optimization Service (GAO) (Provided by Beihang University)	Numerical Optimization Service to be used in conjunction with the Meta-Modelling Service

2 Description of Partnership

The current members of the WP2 are as follows. During the kick-off meeting the following responsibilities have been agreed upon.

Participant id:	**LMS**	SCAI	EADS	Beihang University	AVIC-II
Person-months per participant:	24	13	12	8	26

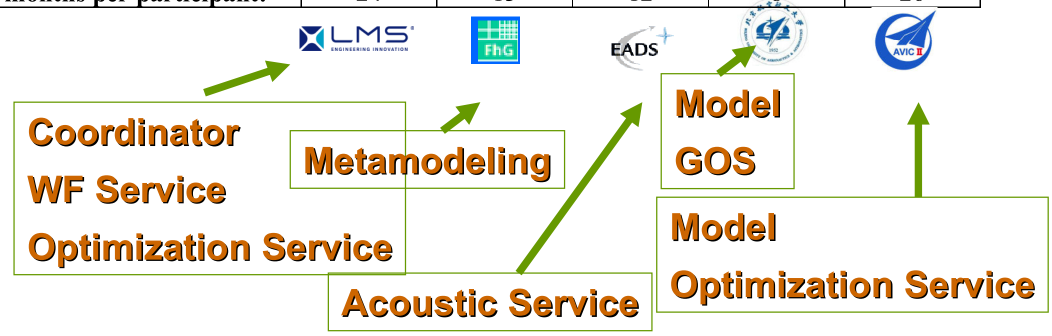

Figure 2.1.1 Consortium composition and major responsibilities

3 Description of the Aerospace Scenario

As highlighted above (and in accordance to the DoW) the Aerospace Scenario focuses on the composition of several Analysis Services and the composition of an overarching Workflow to coordinate the execution of the several analysis services.

3.1 Overall Scenario and Responsibilities

As a result of the technical meetings it has become apparent that there is a fundamental change needed in the overall composition of analysis services with the addition of an Aerodynamic Service. No aerospace scenario could be achieved in producing realistic results without the inclusion of the aerodynamic service.

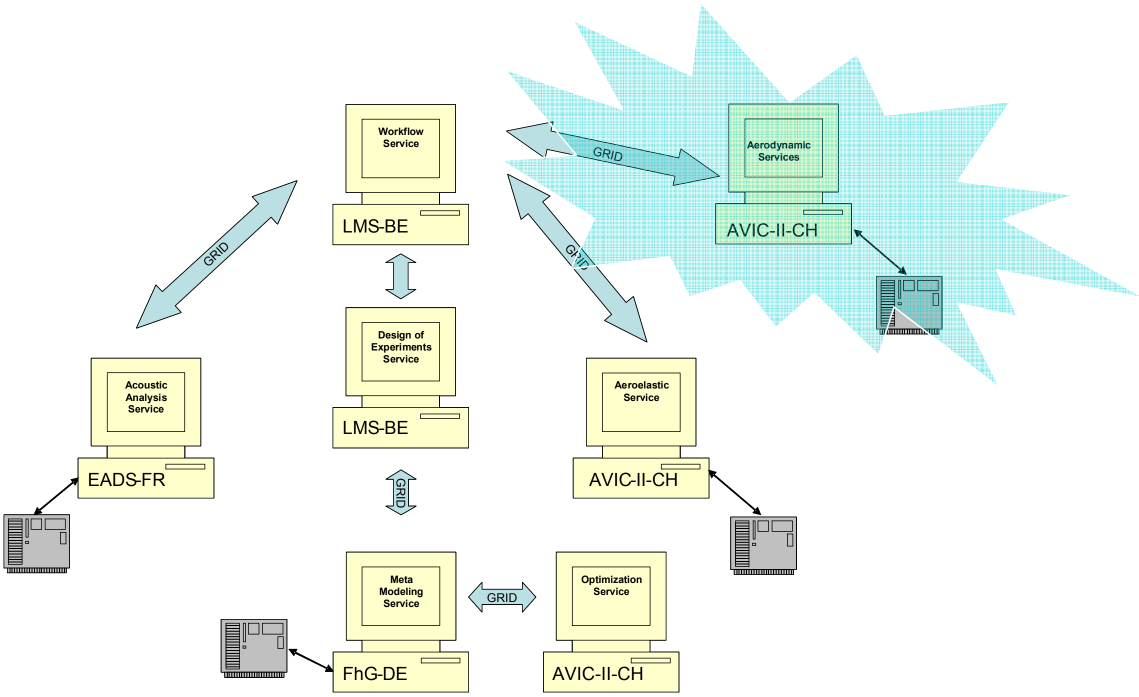

Figure 3.1.1. Revised overall workflow and analysis services

3.2 First Proposed Scenario

The team considered a number of different workflow compositions. The first proposal is shown in Figure 3.1.1 below. It consists of three computational services enhanced with a Design of Experiments and Response Surface Methodology Service. The Computational Workflow will be managed through the DOE service and Optimization would be achieved with GAO (Genetic Algorithm Optimization) interacting directly with the Meta-Model (Response Surface Method).

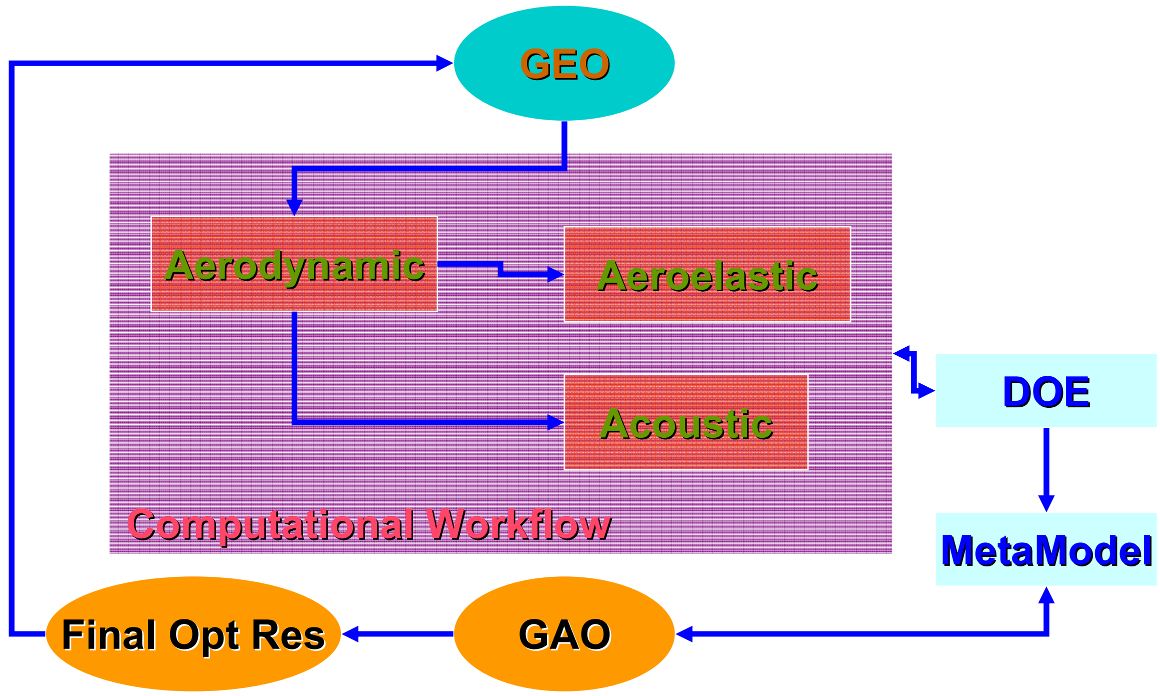

Figure 3.1.2. First Overall Aerospace Scenario Proposal

This scenario is not selected as it is considered to introduce inaccuracies during the optimization process that will lead to invalid results. A second reason for not selecting this scenario is the fact that a large number of virtual experiments (through the DOE) would be needed to make a sufficiently accurate Meta-Model.

3.3 Second Proposed Scenario

A second variant of this scenario is then examined as shown in Figure 3.1.3 below. This scenario removes the drawback of Scenario 1 by removing completely the DOE and Meta-Model service, allowing the GAO optimization to act directly upon the Analysis Services.

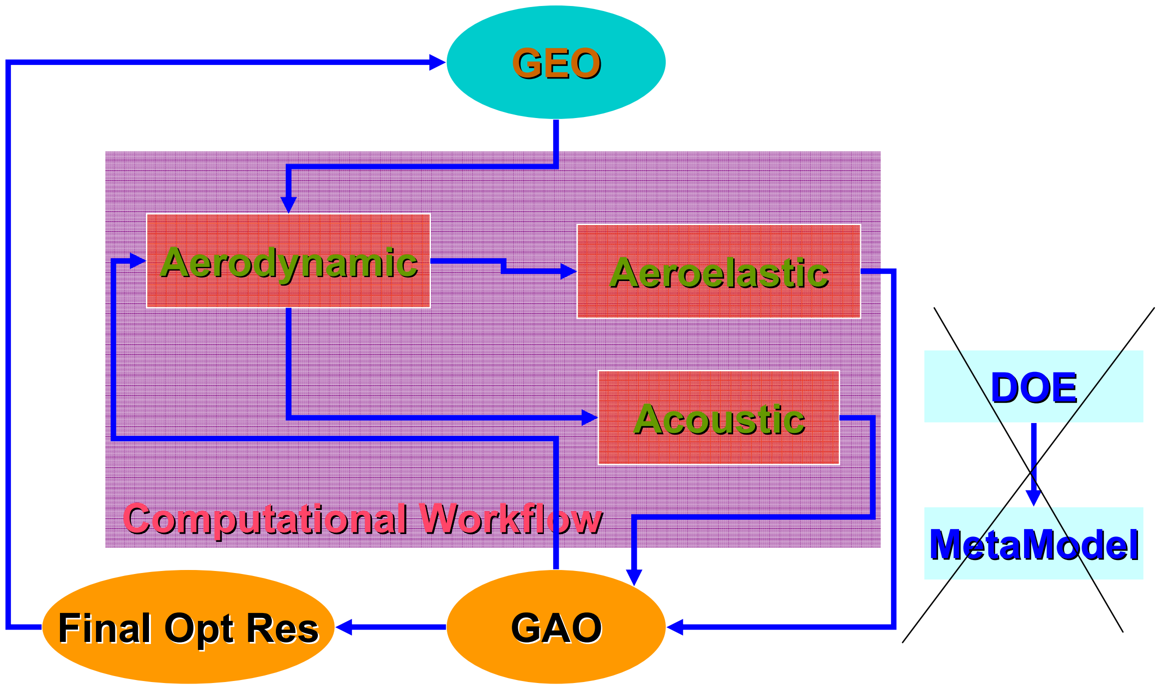

Figure 3.1.3. Second Overall Aerospace Scenario Proposal

This proposal is also rejected mostly due to the fact that Meta-Modelling is considered a necessary function for reducing computational costs and for introducing the ability to achieve results in realistic computation time.

3.4 Third Proposed Scenario

The third scenario introduces again the Meta-Model as a function of GAO. While this scenario addresses both the issues of accuracy that can be hampered by the introduction of the meta-modelling element and the speed of calculation that can be improved as well with the introduction of the meta-modelling element, we believe that it does not reach far enough in making the best use of the technologies and corresponding analysis services.

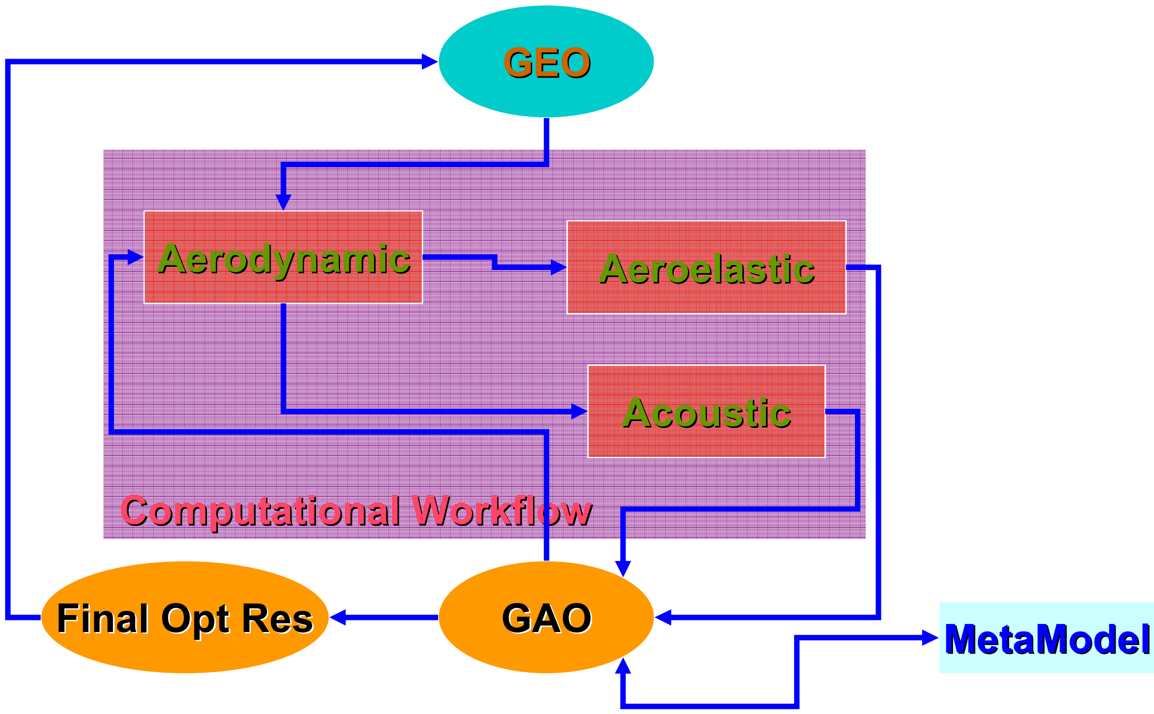

Figure 3.1.4. Third Overall Aerospace Scenario Proposal

3.5 Fourth Proposed Scenario

The fourth scenario proposed provides a resolution of the bottlenecks and challenges listed above for Scenario 1 and Scenario 2. First by concentrating the Meta-Modelling in the individual parts of the workflow that we trust, the accuracy of the Meta-Model can be achieved without risking the quality of the overall optimization results. Secondly this scenario allows the optimizer to act directly upon the Analysis Services that the introduction of a Meta-Model would significantly affect accuracy of the optimization results. By this we achieve the best utilization of both the Meta-Modelling service, accelerating the optimization process, while guaranteeing that the accuracy of the optimization result is not hindered.

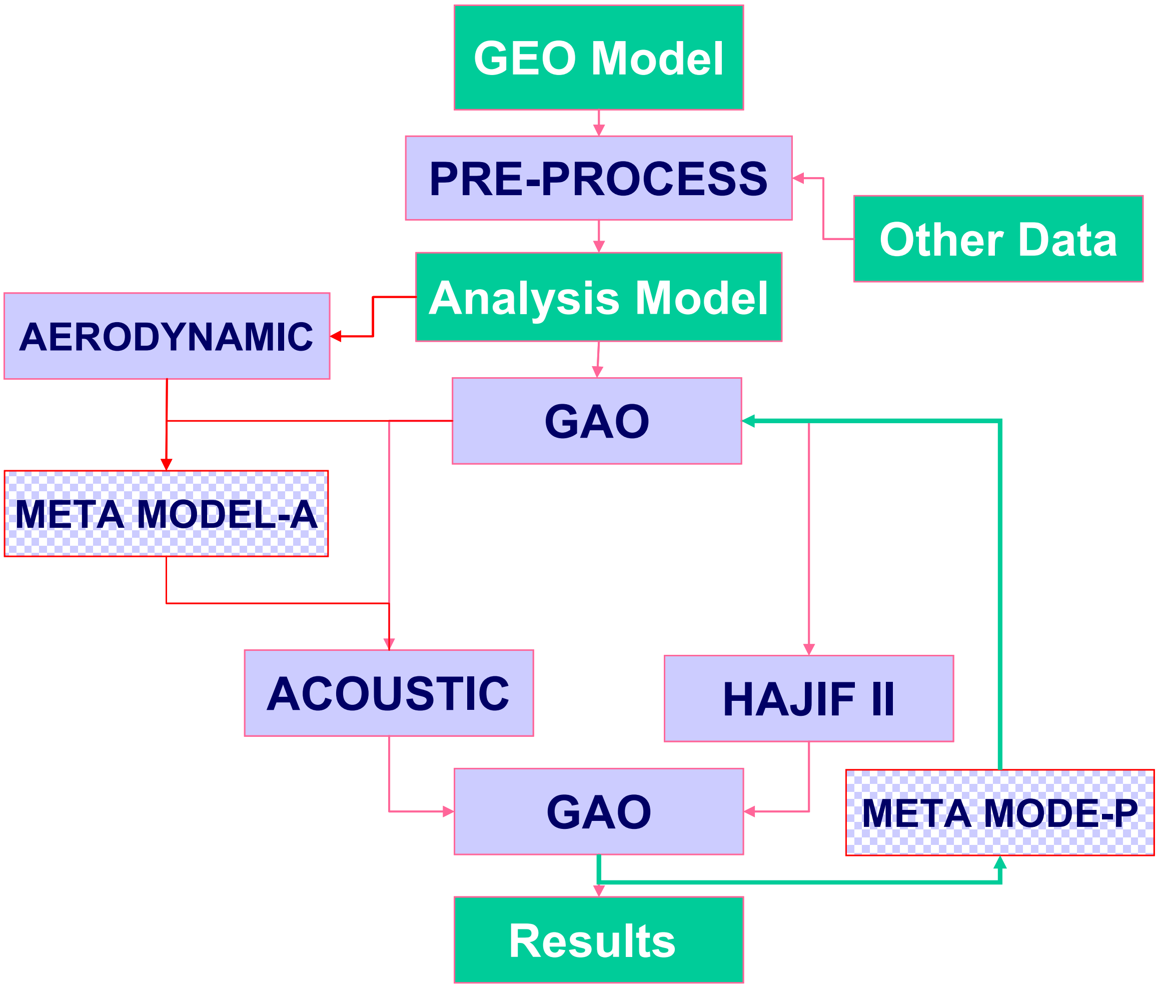

Figure 3.1.4. Fourth Overall Aerospace Scenario Proposal

It is this scenario that will be the starting point for the implementation of the Aerospace prototype. Further refinement and iterations will be performed as it becomes necessary during the implementation stage.

OPTIMUS will be used for the overall definition capture and workflow automation. Analysis Services will be developed by each party (see Figure 3.1.1 above) to allow the computational grid to operate on them.

3.6 Design Parameters

A set of initial Design Parameters have been selected as shown in Figure 3.1.5 below.

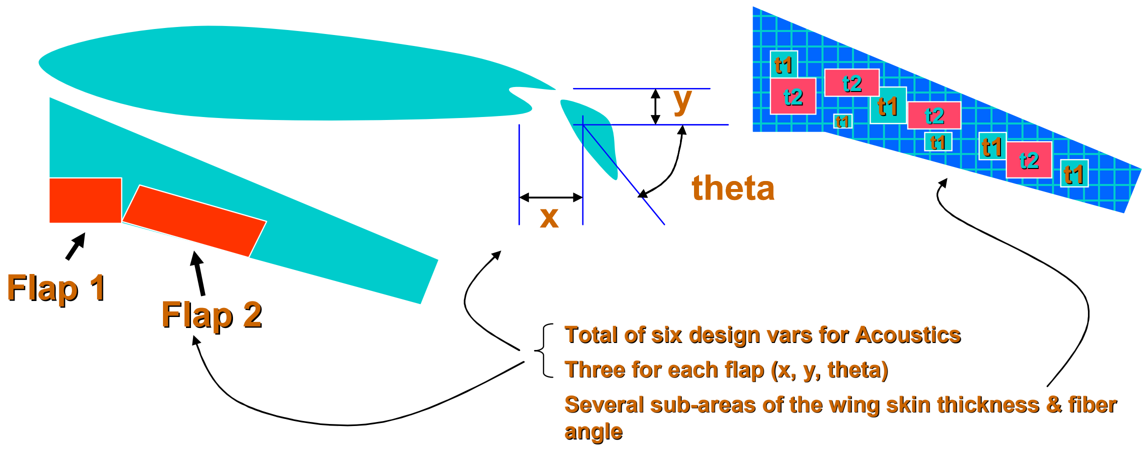

Figure 3.1.5. Design Parameters.

Six variables are influencing aerodynamic, and acoustics simulations. The scenario is based on FEM mesh modification only, with no need to re-mesh the aeroplane wing. Software to modify the FEM model with modification of the position of the flaps is required.

The second set of variables will represent the thickness of the wing skin and affect the aero-elastic behaviour. This is an iterative process that AVIC-II has expertise in order to put in place the necessary descriptions and process to define and operate on the variables.

4 Steps for the completion of the Aerospace Scenario

In completing the definition of the overall Aerospace Scenario the following steps have been agreed upon. These steps are in completing the prototype and do not influence the requirements as listed on Section 5 or the overall construction of the overarching Aerospace scenario as selected in Section 3 above (Aerospace Scenario 4). The following steps affect only the computational workflow to be implemented with the utility of OPTIMUS.

- **Step 1: Definition of Model [wing], Loadcases, Simulation Attributes namely the Aero-elasticity and Acoustics Services**

  This step is a preliminary step required in order to complete the modelling of the aeroplane wing. This step takes place only once and does not influence further the definition of the computational workflow.

- **Step 2: Definition and implementation of the Design Variables, Design Objectives and Design Criteria**

  With this the definition of the design problem will be fulfilled. The selection of the Design Variables influences the workflow definition.

- **Step 3: Consolidate scenarios for optimization**

  The selection of the design objectives and design constraints will play a determinant factor in the run time costs for the design optimization to converge. As such the aim of this step is to identify the most prominent workflows.

- **Step 4: determine possibility/cost for each optimization scenario**

  Further analysis of the each optimization scenario will result in the selection of the optimization scenario that provides the best combination of computational cost, while preserving the validity and fulfilment of the workpackage objectives. The result of this is the determination of the optimization scenario.

- **Step 6: complete the workflow and demonstrate a complete execution of the workflow**

  The final step in completing the Aerospace prototype is to implement the workflow as specified in section 1 and section 3 of this document.

5 Requirements

5.1 Functional requirements

BRIDGE Functional requirements
- To provide distributed data access and distributed analysis services
- To provide workflow facilities
- To provide a workflow definition and execution environment
- To provide a system that can be extended by adding new partners

5.2 Interoperability requirements

BRIDGE Interoperability requirements
- To provide interoperability between the two GRID middleware (GRIA and GOS)
- To be able to run workflows that go across both Middleware
- To provide a way for all components of the system (data services, analysis services) to be implemented on both GRID middleware (GRIA and GOS)
- To be able to use both GRIA and GOS's API in the same virtual machine

5.3 Security requirements

BRIDGE Security requirements
- To build an infrastructure which is compatible with the existing standard security infrastructure at each site (firewalls, DMZ, etc.)

5.4 Quality of Service (QoS) requirements

BRIDGE QoS requirements
- To provide a robust system: ▪ The system must automatically recover from errors when possible ▪ The system should always report meaningful errors

5.5 Performance requirements

BRIDGE Performance requirements
- To handle large data transfers (in the order of several Gigabytes) with performances comparables to FTP
- To be able to handle/sustain long lifecycle events (long simulation times typical to aerospace scenario)

5.6 Monitoring requirements

BRIDGE Monitoring requirements
- To provide distributed monitoring
- To provide management and queuing of the requests together with some prioritisation strategies
- To provide the facility to track the execution of a user request throughout the GRID
- To provide sufficient logging facilities for debugging and troubleshooting

5.7 Miscellaneous requirements

BRIDGE Miscellaneous requirements
- To provide mechanisms for “batch”/command utilization of the GRID Services

6 Conclusion

We have currently reached a mature state in the definition of the overarching workflow in regards to the Aerospace Scenario, through the exploration of a number of workflows that examine the advantages and disadvantages of each approach. We have also determined the remaining steps to reach a state that we can start the implementation of the workflow utilizing OPTIMUS as the workflow tool integrating and federating the Analysis Services developed by each workpackage consortium member. Requirements for the GRID infrastructure have also been identified.