Synthesis Report

Non-Confidential

AIT
DMU-FS

Contract N°:	**BRPR-CT97-0395**	
Project N°:	**BE-96 3817**	
Title:	**Digital Mock-up Functional Simulation for Product Conception and Downstream Processes (DMU-FS)**	
Project Coordinator:	**Volkswagen AG, Wolfsburg**	**DE**
	Renault (former Rover)	**FR**
	DaimlerChrysler	**DE**
	Alenia	**IT**
	Dassault Systèmes	**FR**
	Samtech	**BE**
	LMS	**BE**
	Fraunhofer IGD	**DE**
	Universita di Parma	**IT**
Starting Date:	**1st June, 1997**	
Duration:	**48 Months**	
Date of Issue of this Report:	**02.10.2001**	

PROJECT
FUNDED BY THE EUROPEAN COMMUNITY
UNDER THE BRITE/EURAM PROGRAMME

1 Table of Content

2 Summary

2.1 Keywords on the Content of the Project

Keywords : Simulation of functional behaviour of complex products, DMU, CAE, flexible parts, product design verification

The industrial problem

Current industrial practice, in automotive, aerospace, and other manufacturing industries, involves the creation of a number of physical product models. During the product development phase, both the product and the process are verified on these PMU's. HW checks though cause tremendous time delays. Moreover, a late HW verification very often leads to respectively late design changes, which are cost intensive.

The ***objective*** of DMU-FS has been to develop the technology, which allows the designer to simulate the functional behaviour in an integrated environment. This enables the designer to take into account process knowledge already identified during the very early conceptual stage of the design process and throughout downstream product development.

The technical goal of DMU-FS has not been the development of entirely new systems, but mainly the integration of existing tools, under the aspect of an innovative use of those tools into an integrated simulation environment. New tools would only be developed in areas where existing method were not applicable. Thus, the project's *expected achievement has been* the development of the integration technology and of demonstrators that use this technology to link existing simulation tools.

2.2 Abstract of the Results and Benefits of the Project

The solution

Based on the analysis of user requirements in four different areas of application (dynamics, flexible parts, electro-magnetic compatibility ad aerodynamics), a set of common user requirements was identified. This led to the definition of the integration tools required, the core system, which contains common functionality as:

- Data base
- Visualisation
- Application manager
- Drivers and tool boxes
- ..

The Core system and existing simulation tools were used to build demonstrators for different areas of applications. This way the integration of simulation tools could be demonstrated and tested. Most of the concepts and software of this project have been inserted into commercial products that are generally available by the time of this report. The following software products were involved:

- Dassault Systèmes
  - Catia V5
- LMS
  - Virtual.lab

- Fraunhofer Gesellschaft, Institut für graphische Datenverarbeitung
  - Visualisation system
- University of Parma
  - PARTICLE
- Samtech
  - BOSS Quattro
  - SAMCEF/MECANO

The Benefits

The benefits of that project are two-fold, depending on the view of the end users and of the IT vendors:

The application of the results within user companies, like automotive and aerospace industries, as well as other industries, will achieve dramatic changes in the processes and the benefits from the resulting changes will be:

- Dramatic reduction of the development time
- Product quality improvement
- Reduction of redesign costs

The economic benefits will accumulate within the next four to five years to:

- Reduction of physical mock-ups - 10 %
- Reduction of costs due to late design changes - 10 %
- Reduction of scrapping volume - 15 %
- Reduction of resources and service tools not necessary - 20 %

On the other hand, the IT vendors gained from the user input of new ideas to enhance their existing products or develop new ones. Some parts of the evaluated prototype software are already available in the market. That means that the positions of those companies were already strengthened and will continue to be in the future.

3 The Consortium

3.1 Partner Organisations

The following partner organisations belonged to the project :

Volkswagen AG
K-DOE-1; Brieffach 1811
Berliner Ring 2
D - 38 436 Wolfsburg
Germany

Contact person : Dr. Norbert Pfeiff
Tel +49-5361-9-25856
Fax +49-5361-9-71345
mailto:norbert.pfeiff@volkswagen.de

Renault Recherche et Innovation (GIE)
Technocentre Renault
1, avenue du Golf
F - 78288 Guyancourt Cedex
France

Contact person : Séverine Vosluisant
Tel +33 1-34-95-06-27
Fax +33 1-34-95-45-90
mailto:severine.vosluisant.altran@renault.fr

DaimlerChrysler AG
Abt.: F1M/SB
Hauspost E 222
D - 70546 Stuttgart
Germany

Contact person : Dr. Michael Wessels
Tel +49-711-17-20864 (secretary: -20878)
Fax+49-711-17-52416
mailto:michael.wessels@daimlerchrysler.com

Alenia Aerospazio
Divisione Aeronautica
Corso Marche 41
I - 10146 Torino
Italy

Contact person : Elena Valfrè
Tel +39-11-718-0890
Fax+39-11-718-1003 (alternatively: -1890)
mailto:Valfre@liat.alenia.polito.it

DASSAULT Systèmes, SA
PO Box BP 310
9, Quai Marcel Dassault
F – 92 156 Suresnes
France

Contact person : Gilles Frebault
Tel +33-1-4099-6679
Fax +33-1-4099-6680
mailto:gilles_frebault@ds-fr.com

Samtech
Bd Frère Orban
B - 4000 Liège

Contact person : Claudine Bon
Tel +32-42-5-44361
Fax+32-42-5-22009
mailto:claudine.bon@samcef.com

LMS International
Interleuvenlaan 68
Researchpark Hassrode Z1
B – 3001 Leuven / Belgien

Contact person : Stefan Dutré
Tel +32-16-384-657
Fax+32-16-384-???
mailto:stefan.dutre@lms.be

Fraunhofer Gesellschaft
Institut für graphische Datenverarbeitung
Rundeturmstraße 6
D - 64283 Darmstadt

Contact person : Stefan Müller
Tel +49-6151-155-188 (secretary: -124)
Fax+49-6151-155-196
mailto:stefanm@ igd.fhg.de

Dipartimento di Ingegneria Industriale
Università degli studi di Parma
Viale delle Scienze
I - 43100 Parma

Contact person : Prof. Caterina Rizzi
Tel +39-0521-905-845
Fax:+39-0521-905-705
Secretary: +39-0521-905-892
+39-0521-905-701
mailto:rizzi@ied.eng.unipr.it

3.2 Consortium Descriptions

The Consortium is composed of three different groups with specific roles within this project :

The user group
The IT vendors
The research institutes (universities)

The following partners belonged to the user group, representing the aircraft and automotive industry within Europe: Alenia, Volkswagen, Renault(at the beginning of the project Rover), and DaimlerChrysler. The user partners contributed know-how about end user needs, provided a broad cross-sectorial evaluation platform, are willing to introduce the software (as soon as available on the market), and the new kind of methods into their business processes. All of them have their own research activities, especially on the domains of their core business. Additional they are interested in improving their business processes by using better and more convenient software tools. Therefore they participate in the kind of projects where IT vendors learn from the user partners themselves, what they specifically need to improve their business processes. The IT vendors will provide software tools in order to support the new processes.

The IT vendors were Dassault Systèmes, France, LMS, Belgium, and Samtech, Belgium. Those partners are specialists in writing software for supporting the functional simulation of product behaviour. Their role in this project consortium was to learn and understand precisely the needs of the user partners. This was the basis for the IT vendors to write new software and /or adapt and improve their own software according to match all the requirements of the user partners.

The third group was the research institutes (universities). It comprised of the Institut für graphische Datenverarbeitung, Fraunhofer Gesellschaft, Darmstadt, Germany and the Dipartimento di Ingegneria Industriale, University of Parma, Italy. They are experts in computer graphics and modelling fabrics and their role within this project was to bring in their knowledge about newest research results on the corresponding topics and to work on specific required research areas.

4 Technical Achievements

For the chosen domains of application, user requirements and typical design needs were specified in more detail as a basis for functional specification. From this a detailed functional specification for the typical application process in each domain was derived and harmonized..

Based on those specifications the design and development of the core system, which includes visualization, design of the user interface, overall system design and the development of a set of methods for data handling and exchange of data, was done. Using this core system, two application systems - one for aerodynamics and emc and one for flexible parts and dynamics - were designed and developed.

According to that approach, the technical achievements are summarised under the following four subchapters :

4.1 Requirement Collection and Functional Specification

All the user and functional requirements derived from the AIT pilot phase (ESPRIT Project 7704), DMU projects, and the evaluation of the state of the art were harmonised .
Furtheron the organisation of the user requirements by the domains considered in the project: flexible parts, dynamics, aerodynamics and EMC was an important objective and the identification and collection of the typical design needs, which were used to define a set of test cases for the prototypes were performed.
First a methodology was identified in order to adopt the process analysis and specification. The methodology was used for each domain to guarantee uniformity and a common background to all partners.

Respective for each domain of application the following work was carried out in parallel:

- a detailed analysis of the available specific methodologies and processes in the four domains of application.
- a description of methodologies and processes with the method chosen.
- an assessment of the available technologies against the processes.
- an identification of critical functionality not yet available.
- a definition of benchmarks

Starting from the User Requirements a description of the future process and methodology has been provided for each domain of application. A general future process can be summarized by the diagram described in figure 1.

Functional Simulation Process

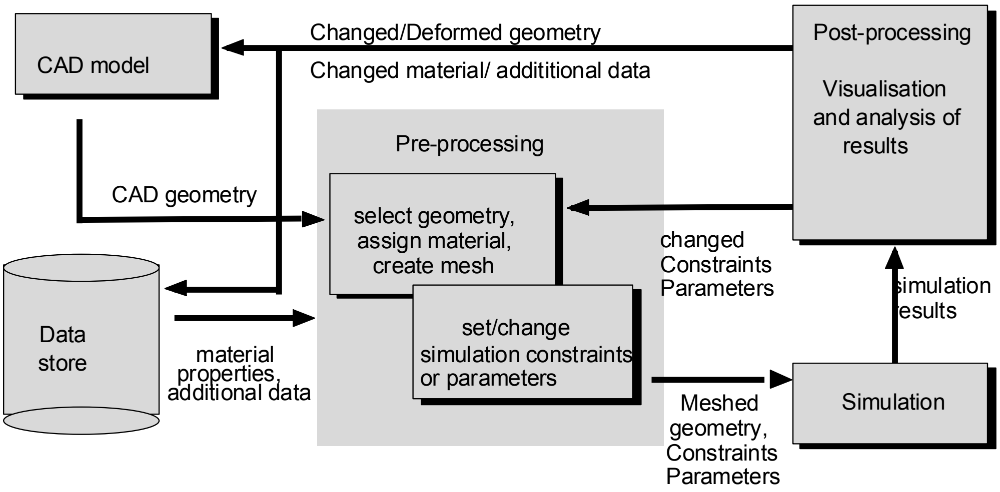


Figure 1 : Process of Functional Simulation

The results are described in detail within the deliverables :

- D-1.1 : Report “Set of user requirements”
- D-1.2 : Report “Test Cases”

- D-2.1 : Report “Specification Methodology”
- D-2.2 : Report “Functional Specification for Flexible Parts”
- D-2.3 : Report “Functional Specification for Dynamics”
- D-2.4 : Report “Functional Specification for Aerodynamics”
- D-2.5 : Report “Functional Specification for Electro-Magnetic Compatibility”

4.2 Core System Definition and Implementation

The core system was designed as an open architecture in terms of both software tools and data format.
The main objective was to integrate all the common tasks, and data, which are not specific to the four application domains. This core system contains a set of algorithms, methods, generic subsystems, visualizer etc ... , and agreed data format. One of its basic roles is to manage the computation chain including

- its interactive monitoring by the user
- the consistency of the data along it.

The concept of the core system is graphically represented in the following picture (see figure 2). Here the pre-existing CAD and simulation systems are located in the centre, linked by the software developed for the integration of different applications (the shaded components).

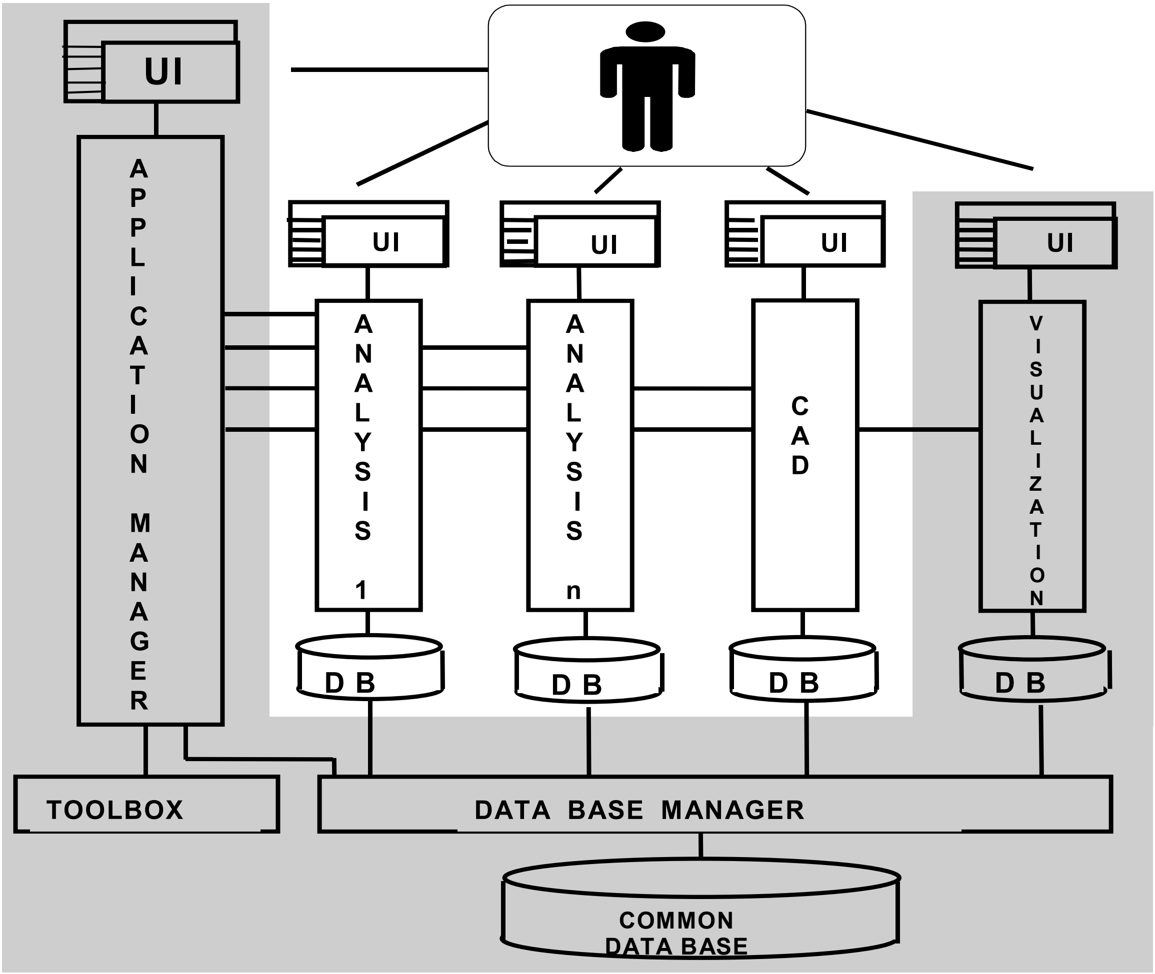


Figure 2 : Software architecture for DMU-FS

The architecture of the core system sketched graphically above was described in more detail by answering several questions :

- What is the exact role of the Application Manager ?
- Are all the data stored in a unique, common data-base ?
- What is the "data-base manager" ?
- What kind of data-flow is envisaged ?
- What are the actions available through the different User Interfaces ?
- Etc…

Furtheron the following general principles were agreed on:

- **Application Manager**

The application manager has to provide the user a way to

- Define tasks
- Organise tasks in a graph, explaining their dependencies

- Select models as input to tasks
- Select results as input for dependent tasks
- Define and use actions on models and/or results like "display", "edit", "change parameters", etc…

The application manager is not responsible of data exchange and/or conversion between applications.
The application manager is based on SAMTECH's BOSS-Quattro software.

- **Data Management**

The basic concept is to use, as far as possible, a unique, common data-base. For this project, the choice has been made to use CATIA V5 data system. With this approach, data were structured using physical considerations: different disciplines will be available (mechanics, electro-magnetism, …).
External applications (solvers) will have to access these data without any implementation knowledge (internal structure of CATIA files), by using exposed API's. This will be done by modifying directly the applications so they will be connected directly to CATIA, or by building interfaces that will transfer data between CATIA and solver's native formats.

Taking into account the specifications, we could summarise the development needs as follows:

- Increase existing software capabilities
- Develop a set of tools to access structured data in a common way.
- Provide an application manager

Some formats are published in the literature for formatted data storage. One of the solutions could have been to try to manage the data with some standard tools like STEP or IGES. The amount of data for simulation application, however, can be extremely large and requires an optimum binary format and these standards seems not allow us to integrate some complete simulation process with independent steps and strong links between the data generated by the applications. This links are useful to analyse any kind of change that can occur during the process and maintain the general consistency of the simulation data.
Therefore, instead of describing “how the data are stored inside the COMMON DATABASE” we defined a way to access and manage them. This allowed each application to have a unique way to access all common data. Data blocks will be stored within the CATIA-database that can provide them directly from the memory or directly from external files. For this version, the external files that will be supported are be restricted to the ELFINI solver and the result file for external solver. The application will not care about that. For some data, document types already exist and have to be improved.
All partners had agreed on the set of data that has to be shared and the data that has to be remained proprietary of the application.
The definition of the common database can be summarised as the capability to provide a system architecture for common data exchange that must handle all of the common data for any kind of domain (Flexible parts, Dynamics, Electro-magnetism and Aerodynamics), handle dependencies between different data blocks (e.g. dependencies between meshed geometry for simulation and CAD geometry), allow easy integration of new tools (and with them, new data types) into the system. As seen above, data can have many different types and structures, this includes CAD data with physical properties, discretised simulation input with type and structure depending on the simulation tool in use and simulation results that can be expressed as time-dependent vector or scalar data on a mesh.
To define that a data is included in the common database, some general ideas have been taken in account like:

- The need to be accessed by more than one tool.
- It will support some strong links during the process.
- It is native for the CATIA V5 tools.

- User Interfaces

It was assumed that several user-interfaces will be used. Potentially each application may use its own one, if required.

Major GUI's should be:

- CATIA V5. This will be the main GUI for model definition. Except for very specific actions, it should be the only one used to manipulate models.
- BOSS-Quattro. Through this GUI, all the applications should be started and controlled.
- IGD Post-processor. This GUI will handle IGD tools for post-processing.

Other GUI may be used to perform local actions like specific mesh, etc…

- Platforms

Some components of the future system are based on software that is not yet available on Windows NT. Therefore it was decided that the system was developed on UNIX.

- Overview of the Database organisation

The DataBase that was used is an extension of what is used for structural analysis inside CATIA V5. The Database management will be explained by using this kind of analysis as example.
It is based on different modelers:

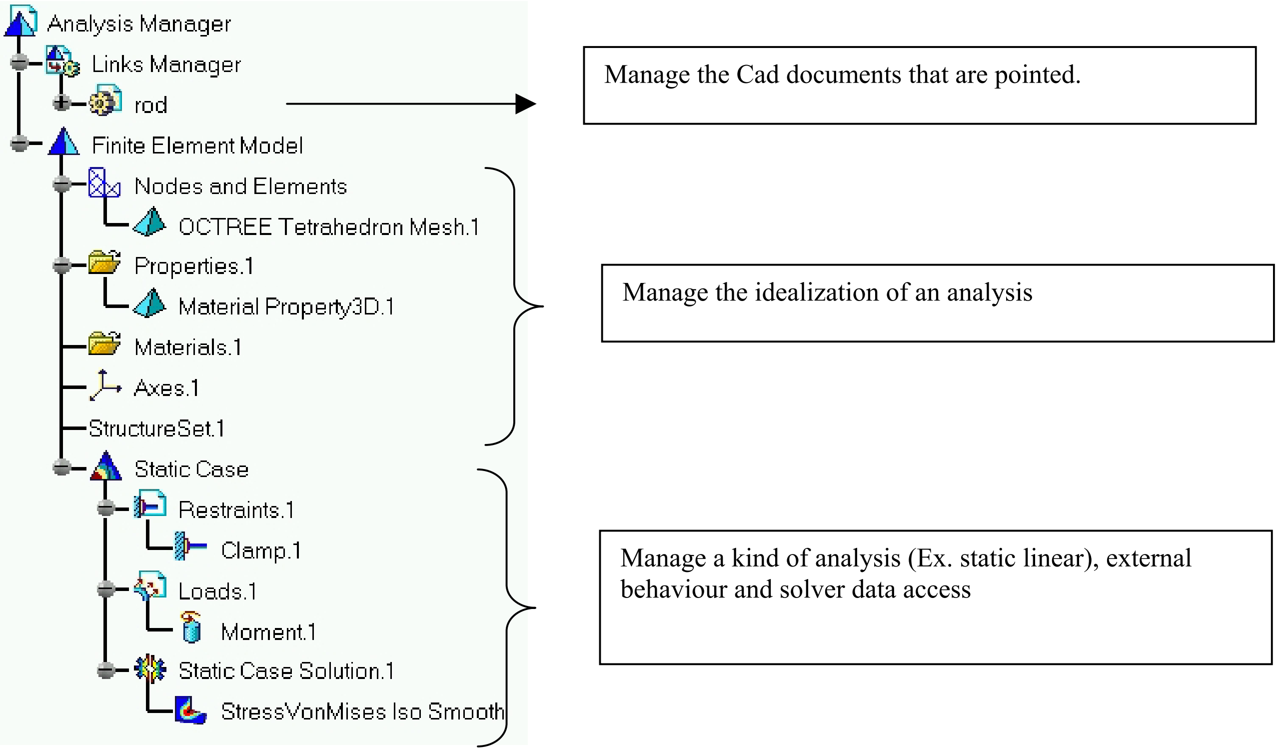
- Specification Model (feature)
- Field Model
- Meshing Model

▪ Specification Model (feature)

An example of the general tree of the specification data is shown in figure 3:

This modeller was:

- based on specification & knowledgeware CATIA V5 modeller
- supports the knowledge of Physical Quantities (solver independent),
- managed by C ++ interfaces
- can be extended to support new type of sets and new physical specifications.



Manage the Cad documents that are pointed.

Manage the idealization of an analysis

Manage a kind of analysis (Ex. static linear), external behaviour and solver data access

Figure 3: Tree of specification data

- **Field model**

The field model is a result view of the specifications. It manages data that can be understood by all solvers, is based on C++ classes and manages pre & post processing data.
The model supports the physical type definition, and the rules for its management. A dedicate "Mechanical file" lists all physical data that can be managed by the Structural Analysis Application. Four kinds of objects are defined in it.

1. The set is the image of the Feature sets.
2. The entity reflects a physical action applied on FE support.
3. The characteristic is the physical data that support the numerical values.
4. The charac-collector manages the characteristic values obtained by combining the information of basic characteristics over several entities.

- **Meshing model**

Meshing data are the support to build the Finite element view of the model. They are stored inside the database in a separate container. The Mesh Manager gives access to:

1. The Mesh set that manages nodes, elements and connectivity's. At this level the finite elements do not support any physical types, they are only defined by a connectivity (geometrical shape).
2. The associativity object that manages the links from finite element entities and the design features.
3. The meshing specifications.

The results are described in detail within the deliverables :

- D-3.1 : Report “System architecture”
- D-3.2 : Report “Data structures“
- D-3.3 : Report “Interface prototype“
- D-3.4.: Report “Visualisation“
- D-3.5 : Report “Data base”
- D-3.6 : Report “Architecture and application manager”
- D-3.7 : Report “Description of the Link software”
- D-3.8 : Report “Description of Software for flexible parts”
- D-3.9 : Report “Test report Integration”

4.3 Development of a Demonstrator System for the Domains of Aerodynamic and EMC

We give here a short description how the demonstrator for aerodynamics and EMC has been constructed. The data flow from different packages is summarised by a block diagram showing the input/output data between packages. Each block of the diagram corresponds to a specific package implementing a certain functionality (e.g. a Mesh generator) while the arrows are data flows between different applications. A special attention is focused on the decision, what data’s are declared as common and are to be stored in the CATIA Data Base.
For every application domain the whole process was modelled with the IDEF0 methodology used in the functional specification part of the project (see WP2, D2.2 ...D2.5).

4.3.1 EMC Electro-Magnetic-Compatibility

Alenia Aeronautica has developed an FDTD code, named STASME, to solve computational electrodynamics problems of aeronautic interest. Accurate numerical modelling of electromagnetic interactions among complex objects is a difficult numerical task because of the complexity of typical aeronautical structures. The FDTD approach used is a marching-in-time procedure that simulates the continuous actual waves by sampled-data numerical analogies propagating in a data space. The STASME solver code is composed of two main parts:

- the first, being the core of the code, in which the FDTD method is applied to solve Maxwell’s equation, runs on CRAY;
- the second, in which the surface currents are calculated, is scalar

The complete STASME tool is composed of the following 5 separated software packages:

- STASME Main dimension: Main dimension definition package (node A2431 in IDEF0) running on workstation (WS).
- STASME Mesher: Mesh generation package (node A2433 in IDEF0) running on CRAY.
- STASME Mesh Visualiser: Mesh visualisation package (node A2434 in DEF0) running on WS
- STASME Solver: EM Simulation package (node A244 in IDEF0) running on CRAY
- STASME Visualiser: Simulation results visualisation (node A2453 in IDEF0) running on WS

The following diagram shows the packages and the connecting data-flow (see figure 4).

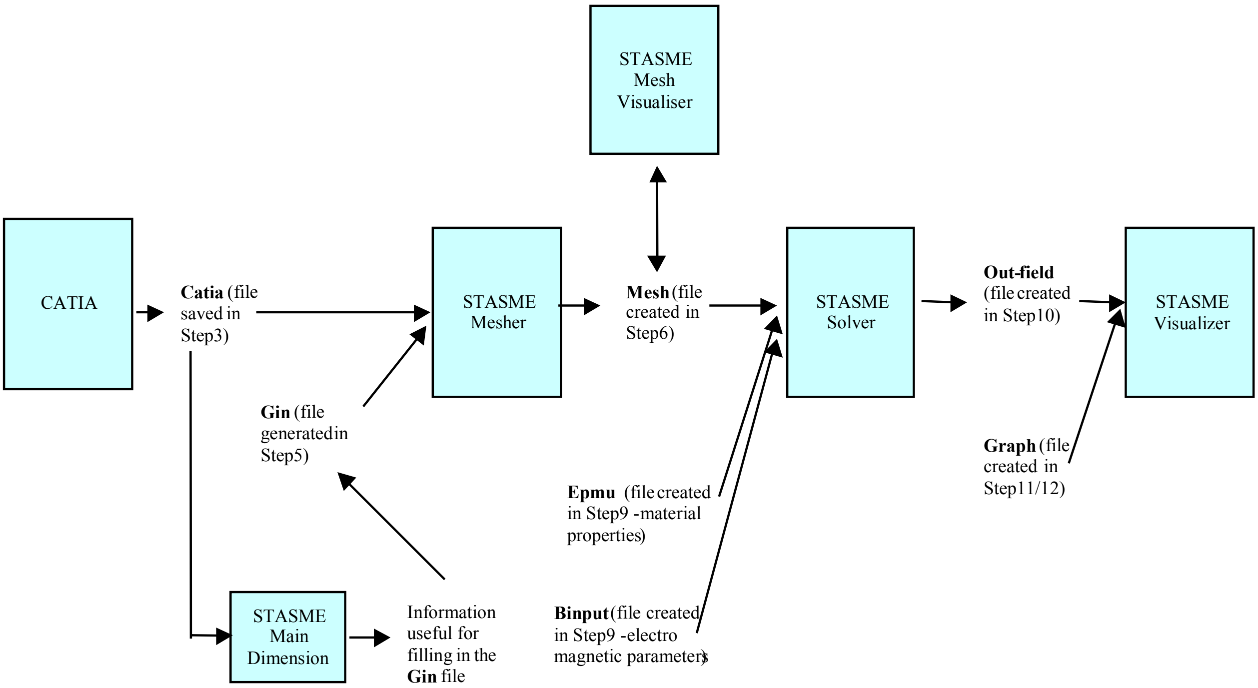


Figure 4 : STASME Diagram

As part of the demonstrator the configuration will be as in the figure below using the CATIA Database, the Boss-Quattro Application Manager and the IGD Visualisation system from the Core System.

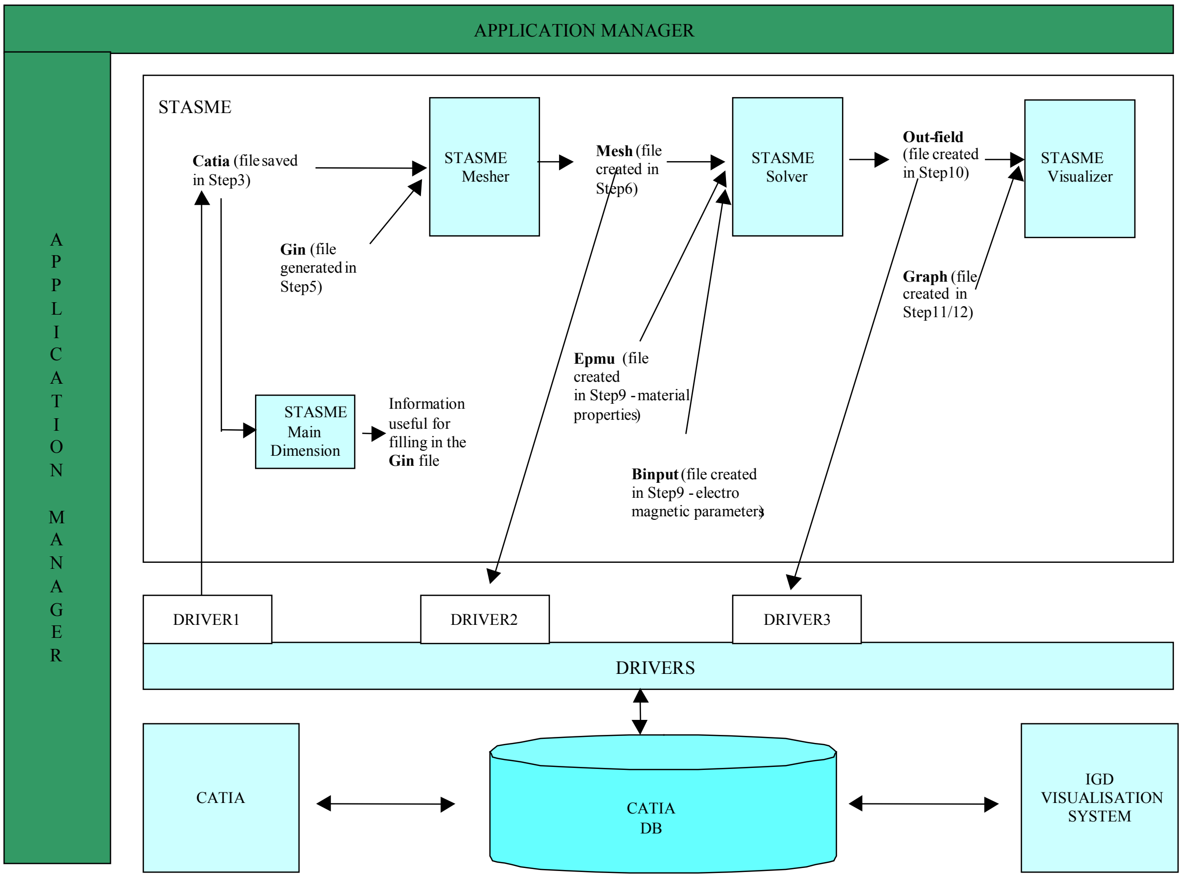


Figure 5 : EMC Simulation within DMU-FS Environment

It should be notes that this is a distributed simulation environment, where visualisation or data translation run on a workstation and the core of the simulation runs on a Cray.

4.3.2 Aerodynamics

The flow around a vehicle is of highly three-dimensional nature and has many areas of flow separation. Due to these characteristics, to this day the aerodynamic development of a car is mainly done using measurements in a model-wind-tunnel. During the concept phase a faster tool is required to make a desing verification. The Panel-Method-Tool Do_Pan and the Boundary-layer-Method-Tool Do_Boundary (both developed at Dornier) are used in this role to calculate the calculate the potential flow around a boy and analyse the boundary-layer to detect flow-separation. For a realistic discretizyation of the body both tools deliver results within minutes on a workstation.
Figure 6 describes the integration of the AERODYNAMIC software into the WP4 demonstrator. For the integration, the following drivers had to be written:

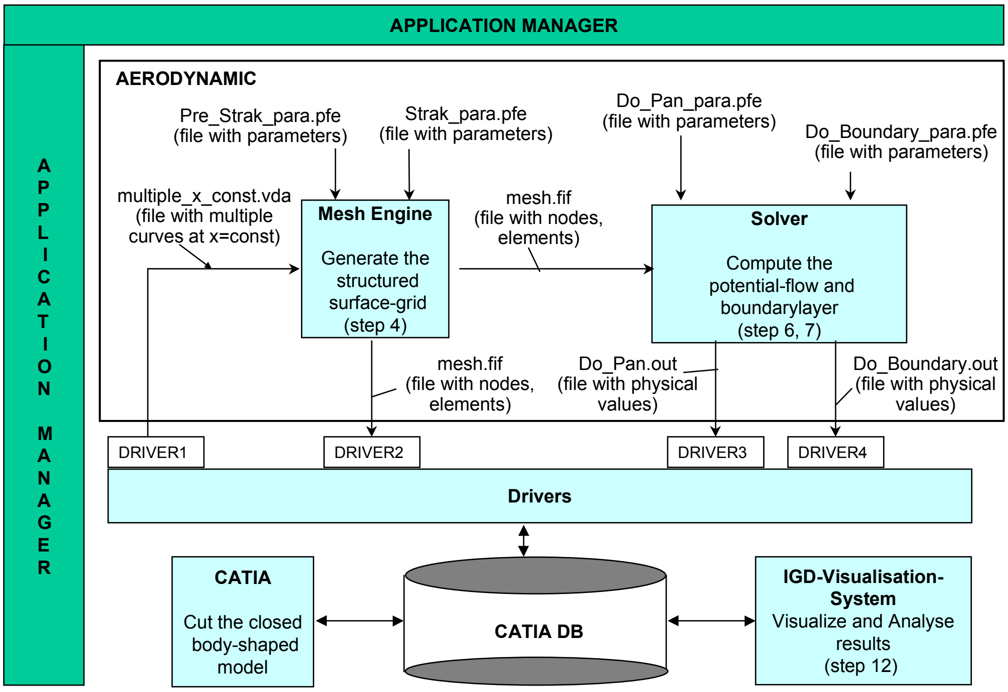


Figure 6 : The Aerodynamic Software within DMU-FS Environment

- DRIVER1: it exports curves x = const. from CATIA V5 into the file **multiple_x_const.vda** with VDA-Format, after cutting the closed body-shape in planes x = const. with functionality's of CATIA V5.
- DRIVER2: it stores the structured surface-grid in the CATIA database (DB). This driver has to write information saved in the file **mesh.fif** into the CATIA DB.
- DRIVER3: it stores the potential flow field simulation results in the CATIA DB. This driver has to write information saved in the **file Do_Pan.out** into the CATIA DB.
- DRIVER4: it stores the boundarylayer simulation results in the CATIA DB. This driver has to write information saved in the **file Do_Boundary.out** into the CATIA DB.

In additon some parameters (in files) are needed:

- File Pre_Stark_para.pfe for tool Pre_Strak(A23133) as part of the **Mesh Engine** package
- File Stark_para.pfe for tool Strak(A23133) as part of the **Mesh Engine** package
- File Do_Pan_para.pfe for tool Do_Pan(A2321) as part of the **Solver** package
- File Do_Boundary_para.pfe for tool Do_Boundary(A2322) as part of the **Solver** package

For the convenience of the user a graphical ParameterFileEditor PFE, which was developed by DaimlerChrysler, was included.

Moreover, the interface and the life cycle of the AERODYNAMIC simulation, was be managed using the Application manager for the following activities:

- Launching all application using an interface
- Managing a sort of work-flow process
- Providing some interface window for changing parameter's such as number of points per cross section, mach-number etc. instead of using files with the necessary information.

This user-friendly interface (no input using files is requested) allows the use/study of the AERODYNAMIC application also by not AERODYNAMIC specialist (as it is requested today).

The results are described in detail within the deliverables :

- D-4.1 : Report "Application aerodynamics & emc"
- D-4.2 : Report "Test report aerodynamics & emc"

4.4 Development of a Demonstrator System for the Domains of Dynamics and Flexible Parts

For the domain of dynamics and flexible parts, the demonstrators were set-up in a different way: the emphasis was not on the integration of specific simulation (of the user partners) tools within the DMU-FS environment, but on the definition of test cases that were to be solved using the building blocks of the DMU-FS core system and simulation tools provided by the software partners. This was mostly due to the fact that the user partners involved (Renault and Volkswagen) perform simulations in these domains either using other systems not easily integrated into the DMU-FS environment. Hence the focus was to test the simulation tools (virtual.lab and SAMCEF/MECANO) of user partners (LMS and Samtech) integrated in the DMU-FS environment. The simulation of the opening/closing of a cabrio sun-roof is a novel type of simulation, which was not regularly performed before. It was done using the system PARTICLE of the University of Parma. The main point here was the scientific and technical achievement. In the sequel we describe the cases briefly.

4.4.1 Anti-Roll Bar in front suspension

It is a quasi-static (or "elasto-kinematic") simulation using elastic and rigid parts.

- Rigid parts belonging to the front axle with triangled-Macpherson type suspension.

Only a half front axle (left-hand side) was modelled as for the rigid parts displacements, to make the model smaller and easier to visualize.

- Flexible part (metallic): The anti-roll bar which is modelled using FEM method.

On the right-hand side end, it was attached to a fixed point of the vehicle, since the rigid parts were not modelled on this side.

The suspension system was defined inside DADS (CAD parts, joints, forces and constraints) and exported to *Virtual.Lab*. *Virtual.Lab* converts the .def files as a CATanalysis model, creates and stores CATpart, Constraints, forces, joints as Catia V5 elements. So, all the elements are stored in the CATIA V5 Database. Then, the flexible part, the Anti-Roll bar, created in NASTRAN, was exported to *Virtual.Lab* and added to the Multi-Body system. All the interface points between the Anti-Roll bar and the others parts of the systems are defined, based on nodes with specific characteristics. The whole Multi-body system is now defined and the analysis can be computed. The results are stored in the tree for each analysis case defined, and are available for visualisation (see figure 7). Both animation and plots can be displayed on the screen.
The animation shows simultaneously the displacement of the rigid parts and the deformation of the flexible part (a very important requirement). It is interesting to note that a designer can easily visualise the results of an analysis without being obliged to (re)create it immediately before, but by just retrieving the results stored in the data-base.

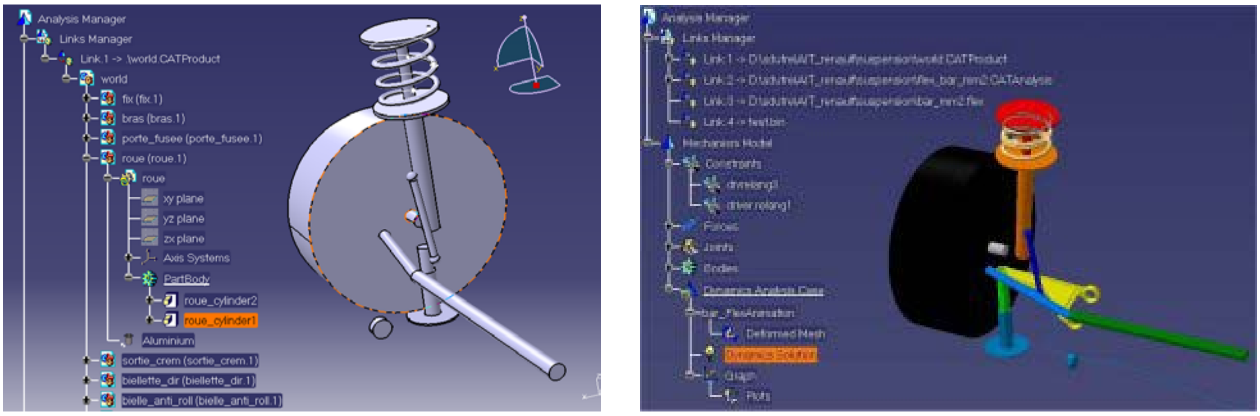


Figure 7 : Definition of the suspension model inside *Virtual.Lab* (left) and view of the simulation result

4.4.2 Case 2: Exhaust line and power plant suspension

It is an explicitly dynamic simulation which includes flexible parts (compact rubber pieces: engine mounts, exhaust line suspension pads, that can be complex (hydro-elastic mounts) and metallic tubes (exhaust line)). This system, provided by Renault was modelled inside *Virtual.Lab* as follows

- The flexibility of the tail pipe was modelled in one portion. The portion chosen as flexible links the Exhaust Silencer to the Front Silencer. The other parts of the exhaust line were modelled as rigid bodies.
- The excitation and the power train was also simplified and made by a excentric mass turning around a revolute joint. The flexible hose was modelled by a bushing.

The multi-body systems including the rigid parts, the bushings, the joints and all the specifications are made inside DADS Standalone and exported to Virtual.Lab (definition file format). Virtual.Lab imported also the flexible part as .flex files. The CAD parts are imported directly from the CATIA data base.
The Multi-body system is visualized and computed inside *Virtual.Lab*, using all the functionality of CATIA V5 data base architecture. The simultaneous animation of both displacement of rigid parts and deformation of flexible parts is possible and gives a good idea of the behaviour of the whole system that is studied. All the options of CATIA V5 visualization are available (shading, rendering, …). The user can navigate at each time step around the animated system with a good

efficiency (fluidity, swiftness, good visual definition of parts in the 3D directions). As the computation results are stored in the CATIA data base, the designer is able to visualise the results (as animation or 2D plots) without making them by himself and staying in the CATIAV5 environment (without change of desktop). Two different ways are available to visualize the results of analysis: animation that can be saved as a movie and 2D plots.

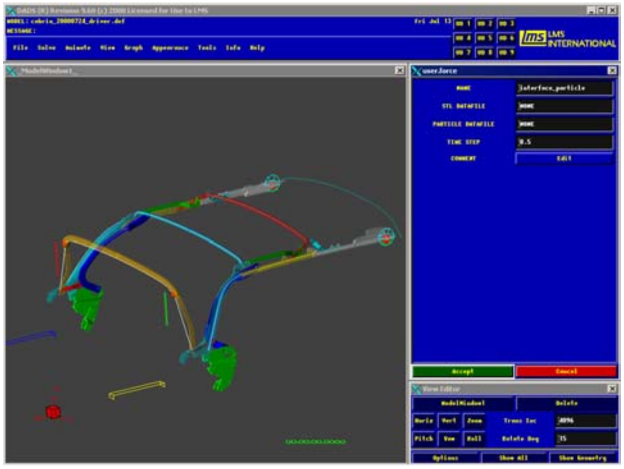
4.4.3 Case 3: Sun-roof – coupling of structure and fabrics

The main objective of this test case is to show the feasibility of this new simulation technique. It was not intended to be a ready-to-run application. Therefore some simplifications in the simulation had to be accepted and the handling of the simulation (pre- and post-processing) is not yet of industrial strength. These points are addressed in the sequel:

- **Material parameters**: The fabric of a typical sun-roof is a complicated multi-layered material. In addition to features normally found in clothes – anisotropy, e.g. – it shows a marked temperature dependence and a dependence on the strain history). Some of its components are kept secret by its manufacturer. Because of the thickness and stiffness of the material, measurement equipment normally used for clothes is ill-suited here. It must also be mentioned that material properties vary widely for different batches of the fabric.
- **Geometry and manufacture**: Today the typical manufacturing process is still based on experience and not on CAD techniques and simulation is not being used to-date. Therefore the exact 2D-geometry of the fabric is not readily available. In fact, the cut of the fabric is often changed during the manufacturing process to account for the changes in the properties of the fabric (see above). The fabric is also pre-stressed when being connected to the mechanism. The amount of the pre-stress is not precisely known. Hence instead of modelling as precisely as possible one individual sun-roof – which would have been outside the scope and the possibilities of DMU-FS – it was necessary to make reasonable simplifications.
- **Pre- and post-processing**: Pre- and post-processing has not been automated at this point of the validation of the method. As the entire process of the design and manufacture of the sun-roof is not yet fully CAD-based, there is a necessity to define the entire process, including simulation, anew and provide the necessary pre- and post-processing tools. This step can be planned, when the validation is finished.

In the simulation, two programs were combined: DADS (LMS) and Particle (Univ. di Parma). In DADS, the parts of the mechanism that are in contact with the fabric are modelled as elastic bodies (beams), whereas other parts that are not in contact and are made of steel are considered rigid. The simulation is fully dynamical. In Particle, the behaviour of the fabric is simulated at each chosen step (time step): at each step, position and velocities at the connection points of the fabric are passed from DADS to Particle, a simulation is made, and the resulting forces are returned as a result from Particle to DADS. Hence the two programs have been integrated very closely using fast techniques, as the interface is being used many times during a simulation run.

Due to space restrictions we only show the mechanism (see figure 8) in the graphical user interface for the connection of DADS to Particle and two snapshots (see figure9) of the closing sun-roof:



userForce

NAME interface_particle
STL DATAFILE NONE
PARTICLE DATAFILE NONE
TIME STEP 0.5

View Editor

Trans Inc 4096
Rotate Deg 15

Figure 8 : Sun Roof Mechanism

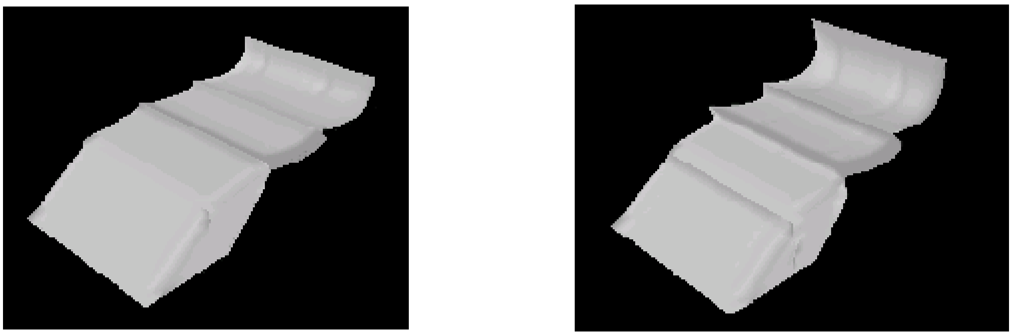


Figure 9 : Simulation Results from PARTICLE

4.4.4 Rubber Door-Seal

This test case is a section of a door seal. The flexible part is the extruded complex shape of rubber, undergoing large deformation and including a contact calculation in an explicitly dynamic simulation. The simulation is performed using the CATIA V5 Modeler and SAMCEF/MECANO Solver. The CATIA database is used for data pre- and post-processing. The test case and the simulation environment is visualized in the following pictures:

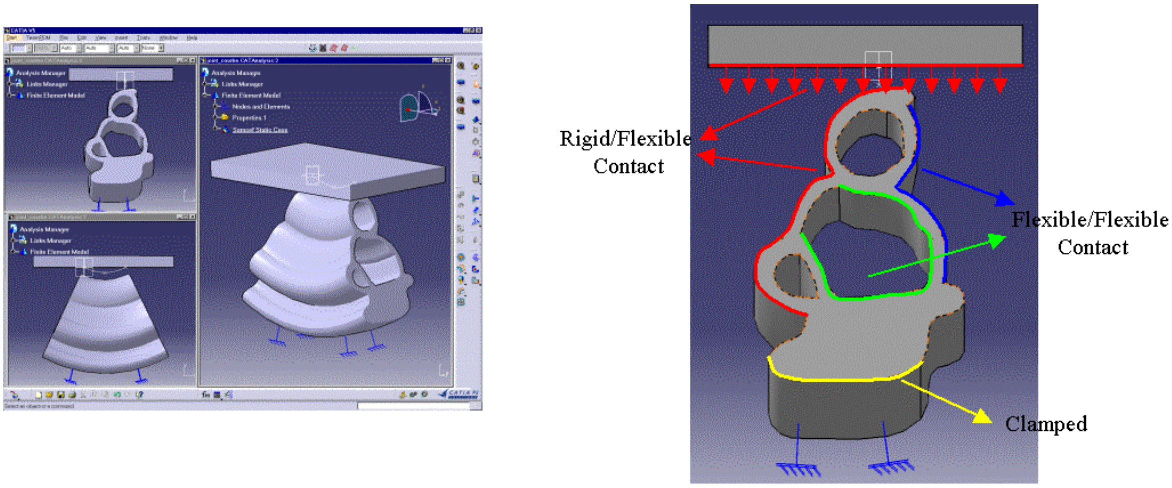


Figure 10 : Two Different Set-up's of Rubber Door Seal

The simulation procedure can be described as follows :

- Creation of the Model with CATIA V5 ;
- Launching the CATIA V5 Analysis Workbench ;
    - Creating a Samcef specific Case ;
    - Creating FEM Data using CATIA FEM Entities and Specific Mecano Entities ;Build the Solution ;
    - First step : a Bank File is created ;
    - Second step : Modification can be made before Mecano is launched ;
    - Final step : Mecano is launched using the Export file through a Script ;Visualization of the Solution for each Time Step ;
    - Deformed Mesh at different time steps can be generated ;
    - Von-Mises Stresses can also be viewed.

At the end of the Build Solution step, Mecano dumps output files that are automatically imported in the Catia database to provide results. Currently, the results attached to the Samcef/Mecano entity are: displacements, von Mises constraints and reaction forces. They are available for the different time steps described in the Samcef/Mecano Case options.

4.4.5 Final remarks

In the two multi-body test cases and in the simulation of the door seal, different types of simulations and the necessary pre- and post-processing have been succesfully combined with CATIA V5 according to the specifications of DMU-FS. Because of the good ergonomic quality of the software, the goal of the project – to simplify the use of simulation in the design process – has been achieved.

As said above the sun-roof simulation is of novel type, still a topic for research and not ready for daily use. In this sense a considerable break-through has been achieved: it has been shown that the opening and closing of a sun-roof can be simulated and give visually realistic results. This can be a starting point to refine the simulation using better material values and more accurate geometry and boundary conditions for the fabrics. When that is done, the work that has been performed on the integration of DADS and Particle can be used to build an application based on *Virtual.Lab* and to provide improved pre- and post-processing in the DMU-FS environment.

The results are described in detail within the deliverables :

- D-5.1 : Report “Application flexible parts & dynamics”
- D-5.2 : Report “Test report flexible parts & dynamics”

5 Exploitation Plans and Follow-up Actions.

User partners (Alenia, Renault, DaimlerChrysler, and VW)
The use of the project results (intermediate and final results) was the starting point for intensive internal discussions in order to use the DMU-Technology in the areas of

- design
- packaging
- manufacturing planning (digital factory).

The efforts were concentrated to establish their own DMU projects within their companies in order to use the DMU - methodology and the available tools. For that purpose the knowledge about the results of the benchmark of the different software tools from the IT vendors was helpful.
At the same time a more or less complete reengineering of the whole business process for product development has started in all the user partner companies.
Those efforts will cover all the aspects of the DMU technologies , especially also the functional simulation of complex products. So all user partner will continue with the internal exploitation of the results of DMU-FS.

On the other hand, the suppliers of those companies get acquainted with these technologies as potential users. The experience shows that many of them will start their own DMU projects in order to be compatible with their customers.
So a wide spectrum of different industries will apply the DMU technologies and use these ideas. This process has started already and has strategic importance to the companies.

IT vendors
The IT vendors are planning (or have partially already done) to continue developing the prototype software to marketable software, which fits into their own product structure. This will be done by enhancing existing software and/or writing complete new software modules.
In detail the different IT vendors have done and/or will continue with :

Dassault Systemès:
Internal validation of the DataBase. The different prototypes allow Dassault Systemès to validate the openness of the database mainly for the CAE domain.

Samtech S.A:
Dissemination

- During the last Samtech users' conference (Paris, January 2001), a presentation of the project results was made.
- - At the last MICAD show (Paris, March 2001), a demo of the results (Mecano driven by CATIA V5 and enhanced BOSS/Quattro) was running on the Samtech's booth.

Exploitation

- All the developments made in BOSS/Quattro not related to Catia V5 have been industrialized and will be available in the next official version of Boss/Q : V4.1, to be released by the end of June 2001.
- Three "pilot" customers have already the prototype (V4.0) running for test on their site and are satisfied.

LMS International:

- LMS Virtual.lab™, the new LMS software product line which integrates multidisciplinary virtual prototyping software (CAE) and physical testing (CAT) completely uses the architecture as was developed by the AIT DMUFS project. It allows the engineer to integrate and visualize data from various sources, including multi body dynamic simulation, acoustic radiation prediction), fatigue-life prediction, test data and structural analysis data. The implementations within DMU-FS on the integration of multi body simulation inside Virtual.Lab (i.e. Virtual.Lab Motion) will be part of the next official release of Virtual.Lab motion, which is foreseen to be released end 2001.
- At last MICAD show (Paris, March 2001), a demonstration of Virtual.Lab Motion was running on the LMS booth.
- Pilot customers have evaluated prototype 2 of Virtual.Lab motion, based on a demonstrator. Their input was used for further development purposes.
- The integration between LMS DADS and PARTICLE was used to simulate the interaction between a multi body cabrio mechanism and the sunroof tissue behaviour. This integration has been demonstrated to Karmann who were very enthusiastic about the obtained result so that a European project proposal will be written to study this interaction more technically and more into detail.

Fraunhofer IGD:

The main achievement of Fraunhofer-IGD was the development of the visualisation toolkit. The base of the toolkit is the FEK (finite element kernel), which embraces the different visualisation techniques and methods (the “visualisation knowledge”). Since FEK is independent of the rendering system and UI, it could be used in conjunction with different visualisation system, e.g. the one developed within DMU-VI.
Today FEK is the base of the Scientific Visualisation Package of Virtual Design 2, a software marketed by vrcom GmbH, a spin-off of Fraunhofer-IGD. vrcom’s core business are VR solutions and its foundation was mainly inspired by the success of DMU-VI.. Without FEK, vrcom would not have been able to offer a solution for scientific visualisation problems using VR interfaces.

On that way the practical results of this project will become available to other organisations except the project partners by making new products or enhancing existing products.

University of Parma:

At academic level projects results, mainly methodologies, have been used to train students on new modelling and simulation techniques.
At research level, the Particle system, available at University of Parma, has been improved customizing it in order to meet the project requirements and to simulate the car soft-top mechanism with fabric behaviour.

Moreover, in order to disseminate furtheron DMU-FS results, a preliminary version of the Project web site (http://kaemart.unipr.it/DMU-FS) has been realized.

This service will be maintained for the next two years.

6 References

- G. Colombo, M. Prati, and C. Rizzi, Design and Simulation of a car soft top, in Proceeding 12th International Conference on Design Tools and Methods in Industrial Engineering (CD-ROM) – ADM 2001, Rimini, 5-7 September 2001, pp. A7-1-A7-8.

- G. Colombo, M. Benassi, U. Cugini, and C. Rizzi, Simulation of non-rigid product: an industrial application related to car soft top design, in Proceeding ESS2001 Conference, Marseille, 18-20 October 2001.

- Alain Remouchamps, *2001 A –design- Space Odyssey, BOSS-Quattro V4*, SAMTECH Users' Conference June 2001, Paris.

7 Collaboration Sought

All partners are interested in further co-operation in joint research and implementation projects not only in the specific areas they have been working in within the DMU-FS project, but also in their other fields of competence.

No specific collaboration sought is to be published here.