

**The use of an Oasys PRIMER model management database during accelerated vehicle development programs such as the 2005 Ford GT**

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**Keywords:**

CAE, CAE Process, Ford GT, Impact CAE, Impact Database, LS-DYNA,  
Model Management, Oasys PRIMER

## **INTRODUCTION**

The role of CAE (Computer Aided Engineering) in the automotive vehicle development process continues to grow in importance. CAE has been one of the key enablers in the recent reduction of vehicle development times, as it allows less reliance on time-consuming and costly prototype testing. Impact CAE has been at the forefront of this CAE revolution.

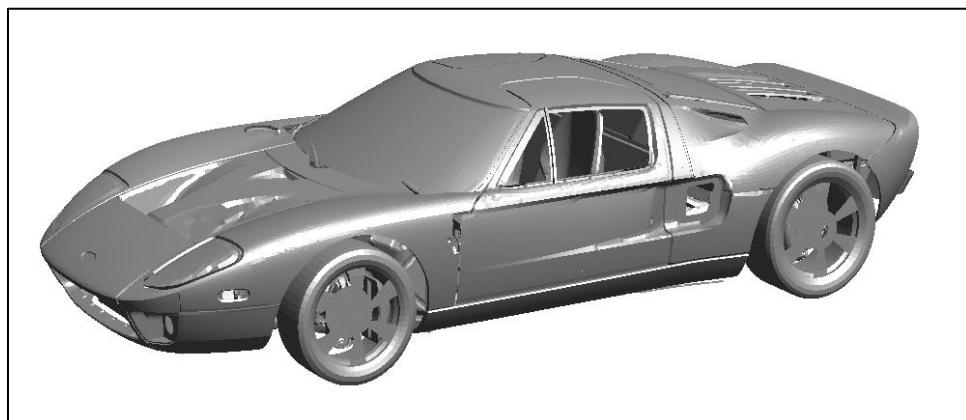
Various additional factors continue to place increased demands on the impact CAE team:

- The increased number of loadcases required to be analyzed (side impact alone can require analysis of FMVSS214, SNCAP, IIHS, ECER95 barrier, FMVSS201 pole and EuroNCAP pole impacts, as well as additional OEM-specific loadcases)
- The increased use of a single underbody for multiple vehicles (e.g. a sedan and a wagon)
- The need to analyze different vehicle options (e.g. different powertrains for front impact; an optional sunroof for side impact)
- The increased detail in today's models (in terms of the number of components modeled as well as the number of elements in the model)
- Analysis is increasingly expected to be the active driver of the vehicle design process, not just a passive predictor of performance

These factors have combined to place increased pressure on CAE engineers to achieve **rapid** creation of **multiple** loadcases for **multiple** vehicle options.

This paper describes a process for management of impact CAE models during vehicle development programs. It is based around the Oasys PRIMER model management software.

Arup used this process during the development of the 2005 Ford GT (see Figure 1). Arup performed all the structural CAE for the Ford GT, working for Mayflower Vehicle Systems and Ford Motor Company. The design and analysis of this vehicle has been described elsewhere (Reference 1) and is not repeated here. In this paper, the discussion is limited to the use of Oasys PRIMER Databases and Templates.



**Figure 1 – 2005 Ford GT CAE model**

## THE REQUIREMENTS OF A CAE PROCESS DURING VEHICLE DEVELOPMENT

The key requirements of an impact CAE process for use during vehicle development are that it should be:

Comprehensive	Must handle all LS-DYNA features required
Multi-user	Must permit a team of users to work in parallel
Efficient	Must minimize the need to repeat tasks
Easy to use	Must be intuitive and easy to learn and use

In addition, the process needs to permit the team to perform three important and distinct tasks:

- Task 1 – Assembling the model
- Task 2 – Analyzing the model
- Task 3 – Updating the model

These phases may need to be repeated multiple times during the vehicle development process.

## PREFERRED PROCESS FOR MODEL MANAGEMENT

In the preferred process, a single Oasys PRIMER Database is assembled which contains ALL the keyword files that are needed during analysis (vehicle; vehicle options; occupants; barriers etc.) This same database is used through the three phases (Assemble, Analyze and Update). All loadcase analysis files are created instantly from this database.

Key to the preferred process is the concept that the vehicle model (and barriers, occupants and loadcases) should be divided into multiple LS-DYNA keyword files. These files are assembled automatically in various combinations using \*INCLUDE or \*INCLUDE\_TRANSFORM keywords to create all the analysis files required. This modular approach has several advantages:

- Multiple users can work in parallel (e.g. one engineer can modify the seat while another engineer works on the B-pillar trim and a third engineer modifies the door beam).
- The individual keyword files may be initialized independently to allow checking and determination of mass, mass-scaling etc.
- The use of the LS-DYNA option \*INCLUDE\_TRANSFORM allows selected components (doors in particular) to be modeled only once. The symmetric component is created automatically.
- This approach is particularly effective when different vehicle options need to be modeled (e.g. a vehicle with and without a sunroof). In this case, three keyword files might be (1) body without roof; (2) roof with integral sunroof (3) roof without sunroof. This avoids the necessity of maintaining two body models – one with and one without a sunroof.
- Sub-system models (e.g. instrument panel beam, seats, fuel tank) are often received as stand-alone LS-DYNA keyword files and can be retained as such.

The team should divide the model into at least as many keyword files as are necessary to ensure that all analyses can be created from a union of complete keyword files. For example, the door trim would not be used in a roof crush analysis, but the door sheet metal would. It therefore makes sense to place the door trim and door sheet metal into different keyword files.

The keyword files are managed using an Oasys PRIMER **Database** and Oasys PRIMER **Templates**.

### OASYS PRIMER

Oasys PRIMER (reference 2) is a graphical model management software tool for LS-DYNA. It reads and writes all LS-DYNA v970 cards and understands the inter-relationship of the various LS-DYNA keywords.

See Reference 3 for recent enhancements to Oasys PRIMER, many of which are of direct relevance to the use of Databases and Templates. Oasys PRIMER itself is not discussed at length in this paper beyond the use of Databases and Templates.

An Oasys PRIMER **Database** is, at its simplest, a structured list of all the keyword files that are required (body-in-white; seats; powertrain; barriers, dummies etc.).

An Oasys PRIMER **Template** is used to select which \*INCLUDE files from the Database should be used for a particular analysis.

### TASK 1 – ASSEMBLING THE MODEL

The first task (assembling the model) is performed with use of an Oasys PRIMER database. A hierarchy of categories and sub-categories is used to give structure to the database. Level 1 categories would generally correspond to the main vehicle subsystems, as shown in Figure 2.

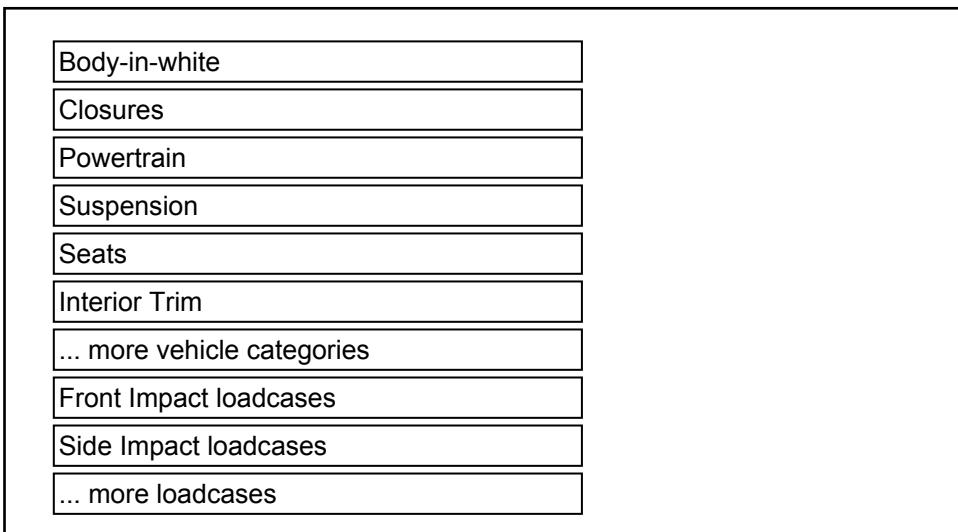
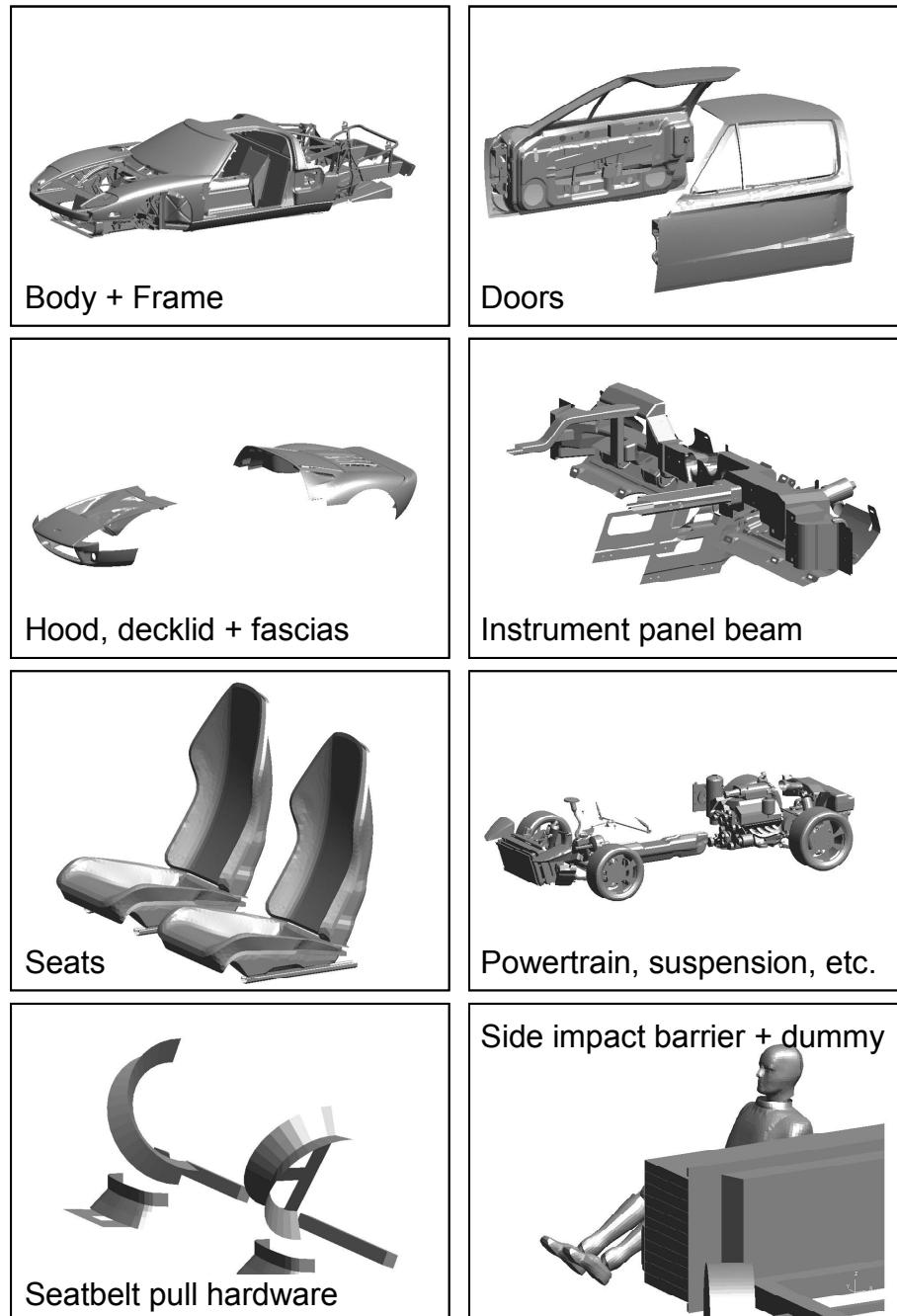


Figure 2 – Main categories

For the Ford GT, some of the sub-assembly files used are show in Figure 3. The Ford GT vehicle model was actually divided into 46 individual keyword files for

the vehicle and an additional 51 keyword files were used to define the various barriers, occupants and loadcases. This number of files does not lead itself to easy graphical representation on a single sheet of paper and so many sub-assemblies have been grouped together.



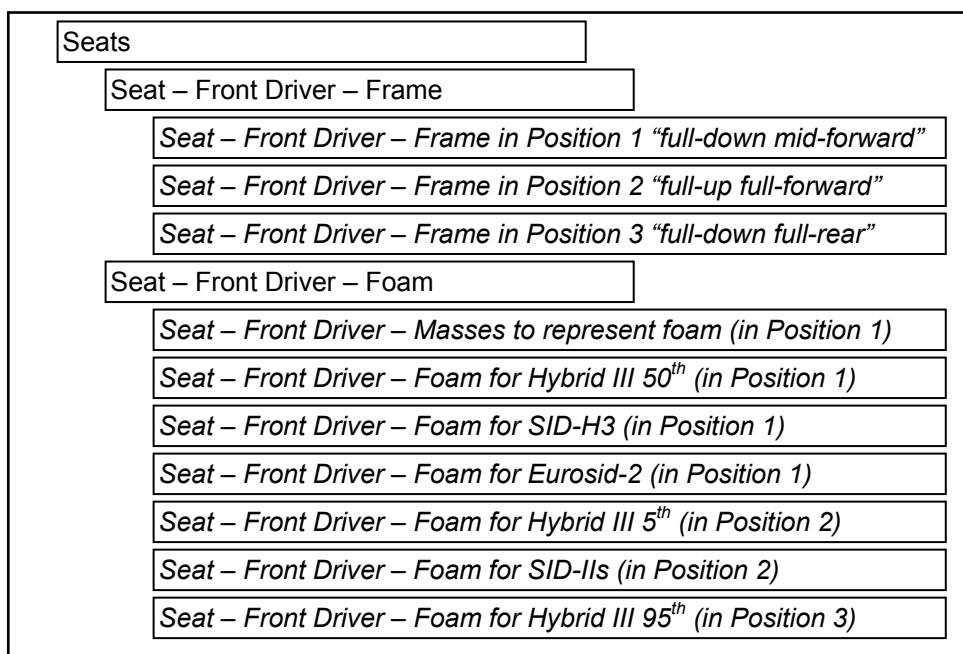
**Figure 3 – Ford GT sub-assembly keyword files (simplified)**

The Ford GT only has one body style and one powertrain. For vehicles with more options (sedan/wagon; sunroof; diesel/gasoline) the database can be much larger even than the Ford GT database.

A database can be created in one of two different ways. An existing vehicle model could be divided into \*INCLUDE files from within Oasys PRIMER and then

saved as a database. Alternatively, the database could be created within Oasys PRIMER by selecting pre-existing keyword files for each sub-assembly. A graphical user interface (GUI) is available for both these options.

As a further illustration of the database concept, consider the front driver seat of a vehicle. For a full set of impacts, the team might need to analyze the seat frame in three different positions (5<sup>th</sup>, 50<sup>th</sup> and 95<sup>th</sup> percentile dummies) and to include the foam, either as lumped masses or as solid elements deformed to "fit" the different occupant models. The database entries for the front driver seat are shown in Figure 4. Categories which would contain \*INCLUDE keyword files are in *italics*.



**Figure 4 – Example of Front Seat Categories**

Additional entries could accommodate different seat frames (manual/power) or seat foams (e.g. with or without side airbag) if required.

Although it may appear at first sight that the effort required to assemble the database is considerable, the effort is generally no more than it would be to create the different seat models in stand-alone files. And once the database has been assembled, all seat files are always available at the click of a mouse.

Connections between keyword files are generally placed in separate files (each entry in the database therefore generally refers to a sub-assembly file and a sub-assembly connections file). For a seat, for example, the sub-assembly file would contain the seat parts, sections, materials, elements, nodes etc. This would be a stand-alone LS-DYNA keyword file that could be initialized and checked for errors and for mass and for timestep-dependent mass-scaling. The sub-assembly **connections** file would contain the connections between the seat and the floor. The use of \*CONSTRAINED\_RIGID\_BODIES is recommended as this is a nodeless method that allows the nodes and elements in the connected files to be renumbered freely in isolation.

A rigorous numbering scheme is an important requirement. The contents of each sub-assembly file needs to be numbered to a specific range. Oasys PRIMER has a very powerful renumbering facility.

## **TASK 2 – ANALYZING THE MODEL**

An Oasys PRIMER Template automatically creates an analysis file for a particular vehicle variant and a particular loadcase. It selects the appropriate keyword files from the Oasys PRIMER Database.

Consider the following problem:

The team has recently made some changes to a full vehicle SINCAP model and now wishes to create an IIHS side impact model.

**See**

Table 1 for two alternative approaches to creating the IIHS side impact model. The use of an Oasys PRIMER Database and Template allows the task to be performed very quickly and easily, eliminating potential user errors<sup>1</sup>.

**Table 1 - Alternative approaches to creating an IIHS Side Impact model from a SINCAP model**

<b>Traditional process</b>	<b>Process when Oasys PRIMER Database and Templates exist</b>
<ol style="list-style-type: none"><li>1. Delete the SINCAP barrier</li><li>2. Add the IIHS side impact barrier</li><li>3. Adjust vehicle-to-barrier contact</li><li>4. Delete front SID occupant</li><li>5. Delete rear SID occupant</li><li>6. Move front driver seat (with side airbag) to new position or replace seat and bag with seat and bag in correct position for SID-IIIs</li><li>7. Add front SID-IIIs occupant</li><li>8. Modify the shape of the rear seat foam or replace rear seat foam with seat foam with correct surface geometry for SID-IIIs</li><li>9. Add rear SID-IIIs occupant</li><li>10. Adjust occupant-to-vehicle contacts</li><li>11. Add occupant head-to-barrier contacts</li><li>12. Modify fire time of front side airbag</li><li>13. Modify fire time of SABIC</li><li>14. Modify termination time</li><li>15. Write out the loadcase keyword file</li><li>16. Initialize in LS-DYNA to determine if there are errors</li></ol>	<ol style="list-style-type: none"><li>1. Open Oasys PRIMER</li><li>2. Select the vehicle database</li><li>3. Select the template (a pre-defined list of *INCLUDE files) for the appropriate loadcase (e.g. "IIHS Side Impact with sunroof")</li><li>4. Check the model (Oasys PRIMER performs more than 2,500 LS-DYNA error checks)</li><li>5. Write out the loadcase keyword file</li><li>6. Exit Oasys PRIMER</li></ol>

<sup>1</sup> An alternative approach would be to maintain separate CAE models for SINCAP and IIHS Side impact and to make every body-in-white change twice (or more if other loadcases are to be analyzed). This would be an inefficient use of time and resources.

The templates are created within Oasys PRIMER by selecting the appropriate \*INCLUDE files required for the various loadcase files. See Figure 5 for an example (*not* from the Ford GT) of the Template editor within Oasys PRIMER.

The screenshot shows a template editor interface with a grid of items and loadcases. The columns represent loadcases: FFB\_35, ODB\_64, Seatbelt\_pul, Side\_Euro, and Side\_Federal. The rows represent items: Body+Frame, Doors, Hood+decklid, IP\_beam, Seat\_frames, Seat\_foam\_Eu, Seat\_foam\_SI, Powertrain, Suspension, Seatbelt\_pul, FFB\_35mph, ODB\_64kph, Side, FFB, ODB, Side\_Euro, Side\_Federal, Rear, Eurosid, SID, and SID2S. Checkmarks indicate which items are included in each loadcase. For example, Body+Frame is included in all loadcases except Side\_Euro and Side\_Federal. Side is included in FFB\_35, ODB\_64, and Side\_Euro.

	FFB_35	ODB_64	Seatbelt_pul	Side_Euro	Side_Federal
Body+Frame	✓✓✓✓✓				
Doors	✓✓✓		✓✓✓		
Hood+decklid	✓✓✓		✓✓✓		
IP_beam	✓✓✓		✓✓✓		
Seat_frames	✓✓✓✓✓				
Seat_foam_Eu			✓		
Seat_foam_SI					✓
Powertrain	✓✓✓		✓✓✓		
Suspension	✓✓✓		✓✓✓		
Seatbelt_pul			✓		
FFB_35mph	✓				
ODB_64kph		✓			
Side			✓✓		
FFB	✓				
ODB		✓			
Side_Euro			✓		
Side_Federal				✓	
Rear					
Eurosid			✓		
SID				✓	
SID2S					✓
database items					

**Figure 5 – Oasys PRIMER Templates – selection of \*INCLUDE keyword files for various loadcases**

The templates created within Oasys PRIMER can be stored and retrieved in subsequent sessions.

Figure 6 and Figure 7 show how templates can be used to assemble two loadcases for the Ford GT – a side impact loadcase and a seatbelt pull loadcase.

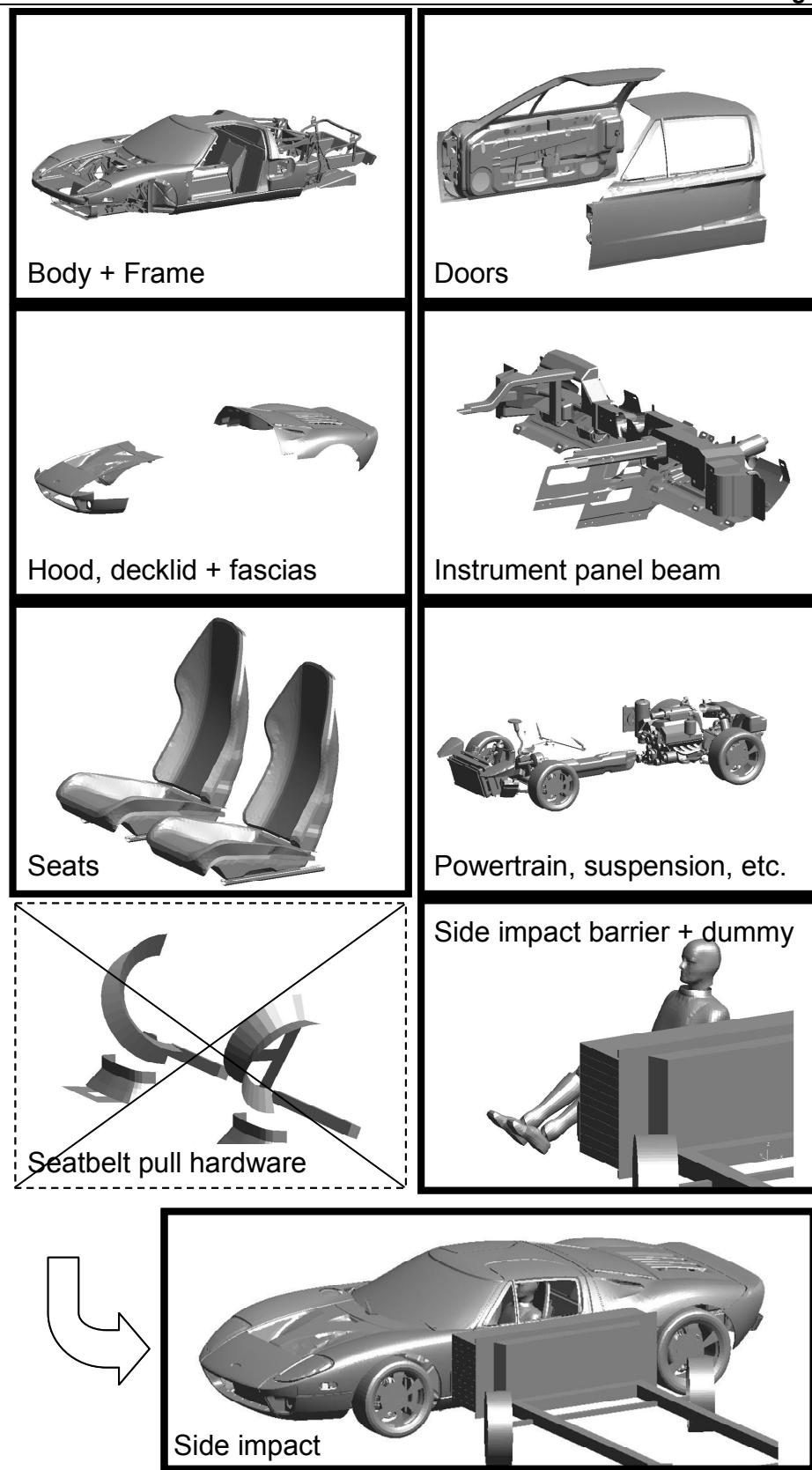


Figure 6 – Use of a template to create a side impact analysis loadcase

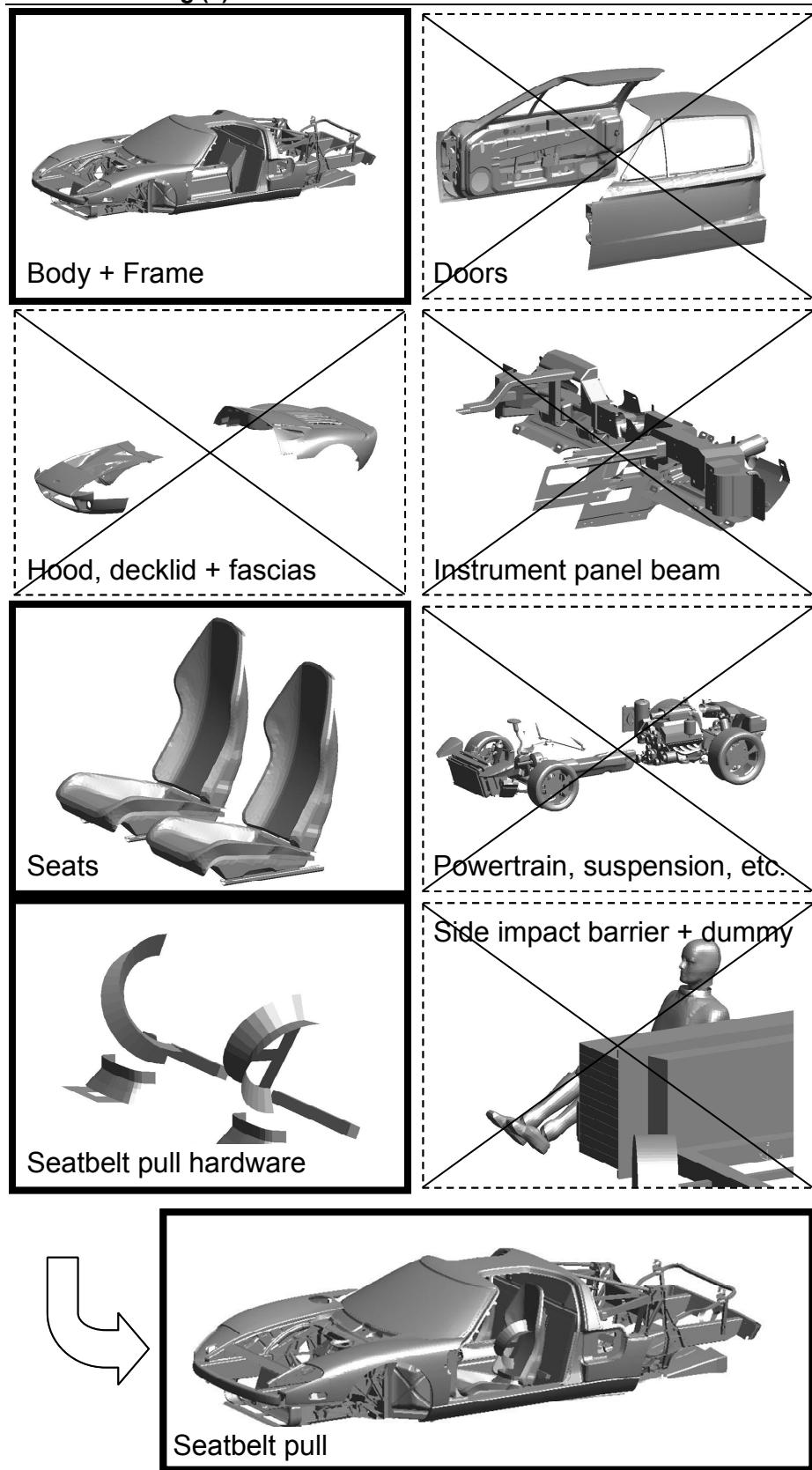


Figure 7 – Use of a template to create a seatbelt-pull analysis loadcase

### TASK 3 – UPDATING THE MODEL

Once the Oasys PRIMER Database has been assembled and an initial set of analyses has been created using Oasys PRIMER Templates, the team will need to maintain and update the database.

Entries in the Database can easily be updated within Oasys PRIMER. If the user wishes to replace the front left seat with a new seat “seat\_02.key”, then the entry in the Oasys PRIMER Database for the Category “Front Left Seat” simply needs to be changed from “seat\_01.key” to “seat\_02.key”. As long as the appropriate numbering scheme has been used, no additional changes need to be made to the seat. If the connection file for the seat uses \*CONSTRAINED\_RIGID\_BODIES cards, then no further changes to the database need to be made at all – the connections file will automatically attach the seat correctly.

When the Oasys PRIMER Database has been updated, it is not necessary to modify the Oasys PRIMER Templates. This is because the Templates refer to the Category in the Database, not to a particular keyword file. In the example from the previous paragraph, if the template refers to the Category “Front Left Seat”, then a keyword file that includes this Category will automatically include “seat\_02.key” rather than “seat\_01.key” when the Oasys PRIMER Database is modified.

### SUMMARY

This paper has presented a process for impact CAE for use during the vehicle development process. The process is based around the use of Oasys PRIMER Databases and Templates. The process has the following attributes:

Comprehensive	It can handle all LS-DYNA features
Multi-user	It permits a team of users to work in parallel
Efficient	It minimizes the need to repeat tasks
Easy to use	It is intuitive and easy to learn and use

The process does require a certain level of discipline from the CAE team. A rigorous numbering scheme must be followed. The team must communicate as changes are made to the Database. But the rewards are significant. The use of Oasys PRIMER Databases and Templates can lead to improved efficiencies and the ability to achieve **rapid** creation of **multiple** loadcases for **multiple** vehicle options.

The use of an LS-DYNA model database was one of the features that allowed the Ford GT super-car to be developed in such a short time. The process has also been used on other vehicle development programs.

### REFERENCES

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