WHITE Paper

DECEMBER 2003

DWP-019701

DARATECH

Digital Simulation to Meet Today's Product Development Challenges

By Monica Schnitger

Not that long ago product design, production and marketing were fairly straightforward: a craftsman knew his customers, knew their needs and price sensitivities and was able to conceive and manufacture products meeting those needs. Once the product was in the marketplace, the craftsman repaired the product and perhaps also dealt with recycling it at the end of its life. All knowledge was closely held and easily adapted for the next product "release."

Rapid innovation is the surest way to bring a product to market when the time is right.

Today's reality is far more complex, as the village tradesman has scaled up production to meet requirements on a regional or global basis. Now companies have large groups charged with gathering consumer requirements and designing a product to deal with varying global demands. An engineering organization adds detail to this design to run analyses, deal with variations, and create manufacturing methods and tooling. Yet others do the actual manufacturing, selling and after-sales support. But the information generated at each step is very useful in designing a better product next time – the knowledge that was in

Shorter design cycles mean lower cost and risk for the product manufacturer.

Ford's keys to success include ...

... creating parallel design and engineering workflows ...

... using preliminary data where possible ...

... providing a single source of critical data ...

... evaluating more design alternatives ...

... efficient data management solutions across many disciplines.

the craftsman's head is now spread through hundreds or thousands of subject matter experts. Today's successful supply chains manage to create a complete feedback loop, so that all points within the product creation chain have the right information at the right time in order to make the best decisions.

Rapid innovation is the surest way to bring the product to market when the time is right. Coming to market quickly serves a number of purposes:

- The product is more likely to meet the customers' needs since those needs were recently defined.
- Consumers are more likely to pay a premium for a fresh, new design.
- An early market entrant can capture significant market share because it may "own" the market until competitors can come to market themselves.

These incentives serve to significantly lower the risk to the producer because the design program is shorter and the product is therefore likely to be more successful when it hits the market place.

But how does a company make IT investments to ensure that it achieves these and other business imperatives? In this white paper, you'll read how one world-class company, Ford Motor Company of Europe, redesigned many of its processes to meet its business needs. The C3P (CAD/CAM/CAE/PDM) team at Ford Europe determined that a more efficient use of PLM (Product Lifecycle Management) IT tools and infrastructure can help Ford meet customer demands, weather uncertain economic times and prepare for an eventual upswing. Ford Europe's process redesign:

- reduces time to market for new products by enabling parallel design and engineering tasks
- creates greater efficiency by using preliminary data where reasonable and waiting for final data only where required
- improves accuracy by providing a single source of critical data, enabled by efficient data management solutions, across many disciplines
- mitigates risk by ensuring more frequent analysis of critical design changes, and

- fosters evaluation of more design alternatives because of the significantly reduced times involved.

Ford needs to put more hats [the body and trim] on top of a standard platform to meet competitive pressures ...

Ford Europe discovered that a careful examination of its existing design processes, including IT tools, coupled with a clear vision of the design environment it needed to create to remain competitive, can lead to substantial savings and efficiency improvements. What can you learn from their successes?

Have you driven a Ford lately?

How can an automotive company with operations in over 145 countries, and eight vehicle brands with dozens of models compete in today's marketplace? By completely transforming the way it designs and builds cars.

The Ford Motor Company may be celebrating its 100th anniversary in 2003, but it definitely is not content to rest on its history as an innovator in vehicle design and production. In fact, the company is constantly striving to "narrow the gap between concept and production."

... This means working smarter to design the vehicle and the production tooling.

Ford Motor sold over 7.5 million cars worldwide in 2002, under the brand names Ford, Lincoln, Mercury, Mazda, Volvo, Jaguar, Land Rover and Aston Martin. According to John Sullivan, Chief Engineer for Body Product Development, Ford Europe, the way these 7.5 million cars made their way from concept to reality is about to radically change. Says Sullivan, "The market is moving from high volume [500,000 units per year of a given model] to more modest volume [five models each at 100,000 units per year]. Competitive pressures mean that Ford needs to put more hats [the body and trim] on top of a standard platform [the suspension, floor, engine and transmission]. We must reconfigure our vehicle design and production processes from doing one car design to doing five, without adding incremental resources. The only way to do this is to increase efficiency in designing the vehicle and the production tooling – and the only way to do that is to work smarter. Basically, we have to design quicker or go out of business."

"Basically, we have to design quicker or go out of business."

The Ford Europe team decided that the only way to get to "design quicker" was to fundamentally change its design, engineering and manufacturing processes. Said Sullivan, "We can't focus on taking one or two days out of the process; we need to take out months." To

The four keys to speeding analysis ...

... preserve associativity of the design model with the analytical or digital simulation model ...

... update the CAE model at the assembly-level as well as at the component-level ...

... use a single CAE reference model across all analysis disciplines ...

... create a parallel workflow for design and analysis tasks that had previously been serial.

meet this challenge, the team identified a number of areas for improvement:

- moving data more quickly from the stylists to the engineering team
- shortening the elapsed time between freezing of the conceptual design (the "last clay model") and the release of the final design to production
- integrating the engineering of the vehicle with design of the tooling needed in production, and
- improving the group's use of its digital simulation capabilities at all points during engineering.

This last element was especially crucial for the vehicle body design team. Said John Scholfield, C3P Methods Manager European Region, "It used to take us three months to go through an analysis cycle from the time a design was clear. We had staggered the tasks as much as we could but it was clear we couldn't complete all analyses and predictions quickly enough. We really needed to shake the tree – we need analytical results in 1/2 day, and this requirement demanded a paradigm shift."

The Ford Europe team examined its current processes and bottlenecks, and decided upon four key changes that would get it closer to delivering analytical results in 1/2 day:

1. preserve associativity of the design model (using a computer aided design tool or CAD) with the analytical or digital simulation model (also known as computer aided engineering or CAE)
2. update the CAE model at the assembly-level as well as at the component-level
3. use a single CAE reference model and CAE BOM (bill of materials) across all analysis disciplines, and
4. create a parallel workflow for design and analysis tasks that had previously been serial.

Together, these changes would enable Ford Europe's vehicle body team to improve its competitiveness while enhancing its ability to deliver analytical results.

Associative Models Lead to Earlier, More Frequent Analysis – but Data Management is Crucial

Three years ago, Ulrich Fox, Supervisor, BMDG, Ford Europe started investigating new tools and procedures to speed up the design/analysis cycle. At that time, Fox says, a vehicle design would reach a milestone stage, then "data was bundled, shipped out, and the mesh team spent weeks developing the analytical model and creating results. Everybody had to wait."

Meshing components before all details have been determined allows analysis to start as early as possible ...

As the Ford Europe team examined its workflows, it saw that some elements of the body design were always finished early in the overall vehicle design process, with a high level of confidence that they will change only slightly throughout the remaining design time. The team decided that one way to shorten the overall design process would be to proceed with an analysis build based on those elements that were known at any given time. Said Scholfield, "We need to start [analysis] as soon as it makes sense for fully-defined components, with placeholders for those still in design. The model doesn't have to be 100% complete for an analysis to be meaningful. When working with a less complete model—due to an outstanding design issue in some area—we're now able to put in a placeholder."

... but the CAD and CAE tools and data must be carefully synchronized and managed...

Fox points out that this is a significant modification of how the design and analysis teams have worked in the past. Said Fox, "We must change the upstream processes and the mentality of the CAD people" to value these abstracted results. Indeed, CAE models often require significant manual adjustment to remove detailed design data for many components, so waiting for this level of detail to be completed in the CAD realm can cause delay without adding analytical accuracy. Said Fox, "It makes sense to start meshing components of the geometry before all of the details have been determined. This allows analysis to start as early as possible."

Meshing before content is frozen requires focus on how to manage the evolving data.

But for this process to be successful, the CAD and CAE tools and data must be carefully synchronized and managed. Ford Europe found that its use of more than one tool created the need for interfaces and the transfer of large numbers of files between applications. The resulting file control issues made the management of common content virtually impossible. Since the CAD and CAE models are continuously changing, they must be kept in synch in order for the analysis to be meaningful. As Fox points out, "CAE people normally think about optimizing meshes. But when we started meshing before content was frozen,

All data including CAD models and CAE meshes are stored in the data management system.

A specialized CAE BOM gathers the latest CAD models, facilitates meshing and assigns material and physical properties as needed.

Data management tools ...

... create revision history information ...

... track ownership ...

... allow regression to a prior model if needed ...

... enable data reuse.

we needed to focus on how to manage the evolving data."

Ford Europe currently uses UGS PLM Solutions' I-deas NX Series integrated design, analysis and workgroup data management products and will transition the data management function to Teamcenter Engineering over the next year. All data, including CAD models and CAE meshes are stored in the data management system. Ford Europe, together with UGS PLM Solutions, developed customized bill of material (BOM) software to build a mesh model out of the latest version of all CAD models. This CAE BOM is specific to the analysis realm and may differ from the manufacturing BOM for the same subassembly. For example, it is common to mesh and analyze only one of a set of symmetric components in an assembly; for manufacturing, all components must be specified. The CAE BOM gathers the latest approved CAD models for all components, facilitates meshing of the assembly and assigns material and physical properties as needed.

Use of these data management tools has many benefits. In addition to ensuring that the latest design revision of a component is analyzed, data management tools create revision history information, track ownership and allow regression to a prior model if a design change proves unsatisfactory. A side benefit, added Scholfield, is that "a structured data management approach leads to [data] reuse. We want to reuse as much as we can. To do this, we need CAE online, available for early stage design validation on a tessellated form of the data [before a detailed CAD model is available]."

Fox had one piece of advice for others considering their data management strategy: "Storing result files is a problem because they are so large. You need to compromise. We store CAE models, startup files, CAD files and analysis results summaries."

A Managed Environment Facilitates Component-Level or Assembly-Level Update

The team also examined its strategy for cascading between component-level and assembly-level analyses. As described above, the team decided to begin analysis whenever a component was ready. Since components are ready for analysis at varying times during the design cycle, analysis preparation for many components typically starts before the assembly design is frozen. Component parts, therefore, can often

be meshed independently of other components in their vicinity and without knowing their final assembly contexts. Similarly, to eliminate duplicated efforts, multiple instances of a part and symmetric parts are not meshed. The final positioning of each component and the reflection of the symmetric meshes is done just after the design freeze during the mesh assembly process.

Analysis begins when a component is ready. Parts are meshed independently of other components in their vicinity and without knowing their final assembly contexts.

The Ford Europe team also identified new tools that would be needed to further facilitate updates, whether at the component- or assembly-level. At the component level, analysts need the ability to quickly identify changes coming from the CAD model and incorporate them where appropriate. At the assembly level, analysts must be able to selectively incorporate the component-level changes. Since most pre- and post-processors do not track the specific changes within a component or assembly from one revision to another, the team had to create a way to control what to update in each situation.

To address this need, the Ford Europe team worked with UGS PLM Solutions to define a "Smart Update" process to control component updates. The Smart Update capability uses the CAE BOM defined in the data management system and the finite element modeling tools in the I-deas NX MasterFEM package. Smart Update allows the analyst to compare the CAE models to current and legacy CAD representations and quickly determine the impact of any given design change. With this knowledge, the analyst only needs to generate new mesh elements for the areas of the design that have changed while reusing the existing mesh elements in areas that have not.

The analyst generates new mesh elements for the areas of the design that have changed while reusing the existing mesh elements in areas that have not.

Once the component models have been updated with the Smart Update process, the entire CAE assembly can then be updated to reflect the latest CAE component models. With the Assembly FEM command in the NX MasterFEM package the analyst can modify, replace, or delete individual components from the CAE assembly, thereby allowing fast updates to the assembly CAE model. It is this unique combination of tools and process that enable the CAE analyst to remain synchronized with the design engineer throughout the evolution of the design.

The CAE analyst remains synchronized with the design engineer throughout the evolution of the design ...

Smart Update significantly improves the assembly modeling process by reducing the overall time required to update the assembly. What had before required a complete re-meshing of all components and connections now requires only selective meshing of changed components.

... significantly reducing the overall time required to update the assembly.

All analysis is based on a centrally built CAE model that provides a common set of content, product design and usage assumptions.

A key enabler was the prior implementation of "meshless" connections in which component meshes are modeled independently of the spot welds, seam welds and adhesive connections, significantly reducing the time to assemble the body in white or BIW model and generate the connections.

A Reference Model Saves Time, Improves Accuracy

One of the process changes Ford Europe found most effective was standardizing all analysis on a single "reference CAE model." According to Fox, each analysis group (safety, durability, CFD, NVH, etc.) originally built its own model, suited to its particular analysis toolkit – but this involved a great deal of redundant effort, since much of the underlying model was always the same. The reference model is the centrally built CAE model that provides a common set of content and current product design and usage assumptions that each analysis group modifies as needed.

This reference model is rebuilt in its entirety at regular intervals throughout the design cycle, with complete updates every 3-4 months. Between rebuilds, only changed components are updated.

The reference model is rebuilt in its entirety at regular intervals throughout the design cycle, with complete updates every three to four months in a 24-month development cycle. In the interim, as described above, the group uses Smart Update to makes minor changes as individual components are changed.

Incremental builds are possible because of the close coupling between CAD and CAE within the data management system.

This incremental build strategy is possible because of the close coupling between CAD and CAE within the data management system. The assembly process leverages the CAE BOM – the bill of materials created specifically to manage the analysis-specific relationships between components – in the data management system. The CAE BOM tools developed by UGS PLM Solutions and Ford Europe automate the mesh assembly process, assign physical and material properties to the model, control the content in the various models within the CAE BOM (versions, quantities, etc.) and facilitate updates of existing assemblies.

Additional applications such as a "Compare CAE BOM" tool help to manage the content history within and across application areas.

Parallel Workflows Lead to Significant Time-Savings

The changes implemented at Ford Europe all revolve around transforming the engineering and analysis workflow from a sequential "freeze design, analyze, freeze design, analyze" process to a far more

parallel workflow. All elements ready for analysis can be incorporated in the reference model at any given instant and the results of analyses based on the reference model are accurate and up-to-date. Design and analysis proceed independently but are synchronized by the data management tools.

Fox points out that this approach, in addition to strong data management tools and practices, requires close coupling between the CAD and CAE groups – the CAD team must own the CAD data but make it available as quickly as possible to the CAE organization to ensure rapid turnaround and high levels of accuracy. The Ford Europe team felt that it was necessary to put the product creation and analysis groups into the same organization in order to facilitate better, more continuous communication about design concepts, required changes and the continuously evolving state of readiness of component details. Said Fox, "If design changes are significant, we can start updating the mesh [representation of that component] immediately. But only if we know about them."

When redesigning a process, start looking at details to determine what is important and what is 'noise.'

Outside consultants need to work with senior management as well as subject matter experts ...

Revamping the Design Process

As John Sullivan pointed out, a radical change was needed to decrease Ford Europe's design cycle time. But how did Ford Europe identify what to change?

The team called on outside assistance to help evaluate its body design and analysis processes. As Scholfield said, "We wanted both bottom-up and top-down approaches to reducing new car development time." Adds Fox, "Process analysis is key. Companies often don't understand their own processes and inputs and outputs. This means that they don't have clear understanding of bottlenecks and dependencies in the process. The secret is to start looking at the details, and determine what is important and what is 'noise.' Good external consultants know what's possible and bring fresh eyes to the problem. They also know what tools are available in the market. When we examined our situation three years ago, SDRC [now UGS PLM Solutions] was the natural choice of outside partner. We used their tools and they had [automobile industry] experts who could address our needs."

... to understand the job a team does ...

Fox also suggests that many different levels within the organizations must be included in a process redesign effort: "Outside consultants often talk only to senior management as they look for information. They need to talk to experts and working level, too. The consultants

... and design new processes that are acceptable to all stakeholders.

Parallel design/analysis led to ...

placed in our team were there to understand the job our team does," and this knowledge contributed to the design of a far more efficient process – that was more readily accepted by all parties concerned. Fox emphasizes the importance of working closely with outside consultants in order to successfully build solutions that address Ford Europe's specific needs. Fox said that his team worked very closely with SDRC on "solver interfaces, model assembly and key meshing functionality."

Did it Work?

... 25% reduction in staff ...

Ford Europe started to implement its new design and analysis methodology with the European replacement for the successful Ford Focus, the C307 coming to market next year. In all, the project has been a remarkable success. According to Fox, this parallel design/analysis approach has led to 25% reduction in staff, delivering significant cost savings, while enabling the CAE team to "deliver results a lot faster to same level of quality."

... delivered significant cost savings...

Scholfield is very proud of what the process redesign team has accomplished. Said Scholfield, "We've taken well over half the time out of the CAE cycle. We've gone from four to six weeks of primary analysis preparation lead-time to three days." His keys to success – and his advice to others embarking upon such a process redesign effort – are as follows:

... enabled the CAE team to "deliver results a lot faster to same level of quality."

- "Eliminate remodeling. Compare the finished model between versions and only change what's required. Is the model still close enough to use as is? If only a specific area of the design changes, only that part of the CAE model needs to change."
- "Build confidence in your tools. We remodeled [the entire model] before because we couldn't track changes. Now that we can track changes, we don't need to do that."
- "Create a managed environment with a clear record of what's changed. This affects the organization and its culture, as people will now be able to have conversations about the relevance of a design change."
- Examine new areas for improvement. "We 'drained the swamp' [during this process redesign effort] and found new areas of opportunity to pursue."

Scholfield also points out that any shift of this magnitude "needs a very

clear vision. It must be audacious. One needs to pick something that forces a paradigm shift, to pick an outrageous target and really stretch [to reach it.]" Scholfield continues, "We were pleasantly surprised. We set goals that were more aggressive than we thought we could meet. The tech team delivered far more than we could have expected."

Finally, John Sullivan believes that companies are too often caught up in a shortsighted view of return on investment (ROI) and lose sight of the 'big picture.' Said Sullivan, "We have reduced our cycle time partly because we fixed disjointed processes – activities outside of known processes, open loops – and partly because of the process changes driven by new IT tools. But this was about much more than the tools. One can't get caught up in ROI. ROI tends to be viewed from 100,000-foot level. A tool or box is a small part of the picture. The real question is, 'How do you get more hats out of the design factory?' This involves changing purchasing, engaging the supply base – and lots of other peripheral issues. We are not constrained by a six- or nine-month ROI target. We are looking at this from a holistic perspective – how do you design a car 50% more quickly? We know that companies that cannot do this will fade away. Private enterprises have to evolve at a fantastic rate to stay competitive."

So, how do you redesign your design processes to cut your design cycle time?

As we've seen, rethinking the entire product creation process can lead to remarkable gains in efficiency, lowered cost, greater quality and improved productivity.

How can you apply the lessons learned by Ford Europe and other manufacturers?

- Audit your current processes to determine if they meet your organization's current needs. Often, processes grow over time but do not represent the best an organization can do today.
    - Examine processes from all angles (perhaps with outside help) to find all open loops and bottlenecks.
    - Identify what IT tools are in use in your design, engineering and analysis groups. Is there a way to reduce the number of interfaces and translations needed?

Ford Europe's keys to successful deployment of CAE:

... eliminate remodeling except for components that have changed ...

... build confidence in data management tools and processes...

... create a managed environment with a clear record of what's changed ...

... look for new areas for improvement.

Rethink your CAE work process ...

... inspect processes to see if they meet current needs ...

... discover where and how data is created and used ...

... examine your data management tools and strategy ...

... anticipate future product development plans and strategies ...

... consider applying tools for knowledge reuse ...

... and connect these processes to business goals. Use competitive pressure as a means for changing the organization's patterns.

  - Ford Europe found it essential to have product creation and analysis done within the same organization for the sake of better communication. How does your organizational structure foster collaboration between the design and analysis teams?

- Discover your current data flows – you may be surprised at how data is being used (and misused) in your "design web."
  - Is there a way to create a "reference model" in your process?
  - Can you compress time by relying on data in preliminary form when appropriate?
- Examine your current data management strategy. Are you able to track CAD and CAE representations of your designs throughout all of their revisions?
  - How can the appropriate data management solutions help?
  - What are you losing by not controlling the data as tightly as needed?
- Determine what an optimum process might be in two or five years – keeping in mind:
  - Anticipated product plans and their timeframes (changing process in mid-design is very challenging).
  - Some tasks can be done in parallel. Ford Europe has had great success in create parallel workflows for CAD and CAE, eliminating significant elapsed time from its former methodology.
- Craft a strategy for knowledge and design re-use. Key components of such a strategy include
  - Data management – if you can't find it, you can't re-use it.
  - Process changes that encourage re-use among the designers and engineers.
- Set audacious goals. As John Scholfield noted, "One needs to pick something that forces a paradigm shift, to pick an outrageous target and really stretch [to reach it.]" Set aggressive goals and challenge your team to deliver.
- Tie all process redesign to meeting business goals. Ford Europe

believes it can not remain competitive without redesigning its design and analysis processes – and, indeed, that companies that do not will no longer be in business in a couple of years. You must create processes that match your business priorities.

A world-class approach to product design and analysis can:

- create greater efficiency in the design/analysis organization
- improve design data accuracy and, therefore, product quality
- mitigate risk by enabling more frequent analysis
- foster evaluation of more design alternatives

and, ultimately, reduce time to market.

Innovating more quickly will enable you to bring a product to market that is more likely to meet the customers' needs – commanding premium prices and capturing significant market share.

The right product design and analysis process can enable a manufacturer to bring the right product to market at the right time - lowering cost, reducing risk and increasing competitive effectiveness.