SIEMENS
Ingenuity for life

Aerospace and defense

Lockheed Martin Space Systems

Femap with NX Nastran plays a critical role in the design of NASA's new Orion spacecraft

Products

Femap, NX

Business challenges

More than 900 load cases associated with launch and abort

FE models with up to one million elements

High volume of results data to sort through to determine critical load cases

Keys to success

Integrated FEA solver, pre- and postprocessor

Easy-to-use pre- and postprocessing (utilizing Windows) with powerful visualization

Ability to import Pro/ENGINEER CAD geometry

Creation of custom functions using the Femap API

Results

Complicated trade studies completed in two to three weeks

Improved accuracy through visualization and geometry manipulation tools that help confirm the FE model was properly created

60-analyst team uses the integrated solver, pre- and postprocessor to optimize the design of the successor to the Space Shuttle

Designing the deep space exploration vehicle

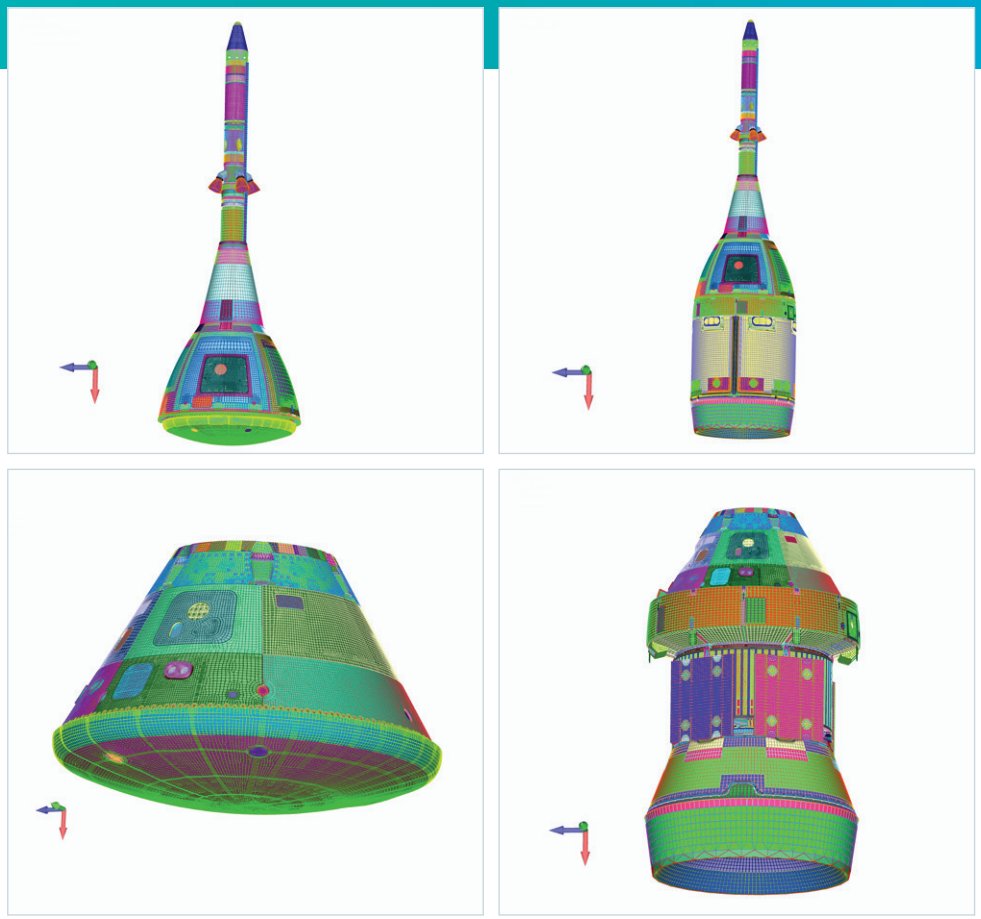
Lockheed Martin Space Systems Company, one of the four major business divisions of Lockheed Martin, is the prime contractor building the Orion Multi-Purpose Crew Vehicle, NASA's first spacecraft designed for long-duration deep space exploration. Orion will carry up to six people into space, provide emergency abort capability, sustain the crew during the space travel, and provide safe re-entry from deep space return velocities.

Orion consists of three main structures: the crew module, the service module, and the launch abort module. Finite element analysis (FEA) is playing a key role in the design of all three modules by allowing development teams to understand the loads and stresses that the modules will experience during all phases of their journey. That understanding is then used to optimize factors such as weight, stiffness, material selection, shape and strength of individual parts.

Results *continued*

Ability to sort through hundreds of load cases quickly using data ranking and free body functions

Automation of routine tasks via scripts saves time and increases accuracy



Lewis and his colleagues are currently looking at 900 load cases related to different launch and abort scenarios.

"I've used a lot of the commercial products, and Femap really supports the way that we use FEA."

Joseph Hess
Stress Analyst
Red Canyon Engineering and Software

In many ways, this is the typical iterative process between structural analysts and designers, who use FEA-based trade studies to optimize a design. Except in this case, the process takes years, and the finite element (FE) models can be huge (up to one million elements). Another important difference is the larger number of load cases that must be evaluated, which is partly a result of the complexities of launching a vehicle into space and returning it to earth, and partly due to the computing power available. (Their FEAs run on a cluster of Linux servers.)

"When I worked on an aircraft program in the early 1990s, we only had 100 load cases and maybe five of them were critical," says Eric Lewis, a stress analyst and senior staff engineer at Lockheed Martin Space Systems, who is part of the analysis team working on the Orion's service and launch abort modules. "As the computers and software have grown more powerful,

"Using Femap, you can view your model in a lot of different ways, and turn different elements and geometry on and off. This helps us doublecheck and catch mistakes."

Eric Lewis
Stress Analyst and Senior Staff Engineer
Lockheed Martin Space Systems

that's allowed most of these projects to generate a lot more load cases." Lewis and his colleagues are currently looking at approximately 900 load cases related to different Orion launch scenarios.

Integrated FEA solver, pre- and postprocessor

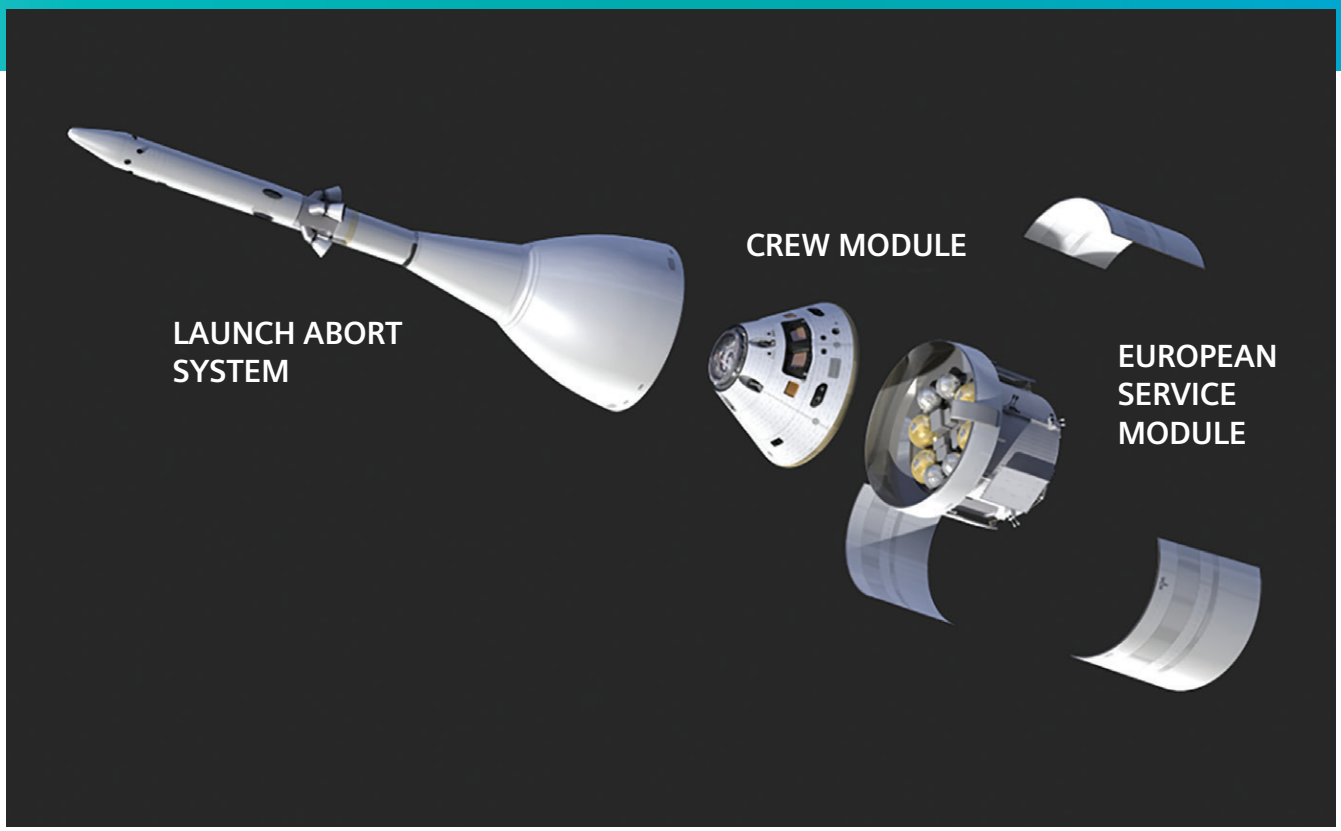
Lockheed Martin Space Systems' FEA software-of-choice for the Orion structural analysis is Femap™ with NX™ Nastran® software, an integrated FEA solver, pre- and postprocessor from product lifecycle management (PLM) specialist Siemens PLM Software. According to Lewis, Femap with NX Nastran has a lot of advantages for the Orion analysis.

"I've used a lot of the commercial products, and Femap really supports the way that we use FEA," says Joseph Hess, a stress analyst with Red Canyon Engineering and Software who works fulltime on the Orion project.

For example, because Femap is CAD-independent, analysts can import design geometry created using Pro/ENGINEER® software to use as the basis for FE models. Femap also offers a wealth of geometry creation and modification functions, allowing analysts to change the geometry if necessary prior to creating the FE models. The structural analysts create coarse mesh models, which are provided

"We're able to run several iterations each day, on models with approximately one million elements, and we're able to perform some fairly complicated trade studies in just two to three weeks."

Eric Lewis
Stress Analyst and Senior Staff Engineer
Lockheed Martin Space Systems



"Our engineering workstations are Windows-based, so it's easy to get information out of the Femap models into other tools such as Excel, and to pull out pictures."

Joseph Hess
Stress Analyst
Red Canyon Engineering and Software

to the loads and dynamics analysts who run coupled loads involving both the spacecraft and the launch vehicle. They also create models with finer meshes, which are more appropriate for detailed stress analyses and optimizing parts for weight and stiffness.

Hess appreciates the fact that Femap utilizes the Windows® operating system. "Our engineering workstations utilize Windows-based software, so it's easy to get information out of the Femap models into other tools such as Excel, and to pull out pictures," he says.

The structural analysts have used the Femap application programming interface (API) to create scripts that automate repetitive tasks. One script, for example, maps multiple pressure loads from one model to another. Another updates the non-structural mass/area on multiple shell properties to match the total actual mass. Others calculate optimized shell thickness based on element stresses, and resultant shear forces for cbush, cbar, and cbeam element output.

Time-saving functionality for determining critical load cases

In all, approximately 60 stress and dynamics analysts use Femap with NX Nastran on the Orion project. (This solution is used by the analysts working on the crew module, in addition to those working on the service and launch abort modules.)

One of the main benefits of Femap is that its ease-of-use helps turn around trade studies quickly. "When you're changing one or more components and looking at the effects on the whole system, Femap really helps because it's easy to modify these full-system models," says Lewis. "We're able to run several iterations each day, on models with approximately one million elements, and we're able to perform some fairly complicated trade studies in just two to three weeks."

Lewis adds, "Another thing I like about Femap is that it's very visual. It's so easy to make an error in a finite element model. Using Femap, you can view your model in a lot of different ways, and turn different

Solutions/Services

Femap with NX Nastran
www.siemens.com/plm/femap

Customer's primary business

Lockheed Martin Space Systems Company is one of the four major business divisions of Lockheed Martin.
www.lockheedmartin.com/us/ssc.html

Customer location

Denver, Colorado
United States

elements and geometry on and off. This helps us double-check and catch mistakes."

Several aspects of Femap are particularly valuable on this project because the high number of load cases requires a lot of sorting of the results data to figure out which load cases are critical. The data ranking function in the Femap data table, for example, can be used to sort the data and show the maximum and minimum very quickly. This eliminates the need to export results into an Excel software file and create minimum and maximum functions. "The data table does that for you," says Hess. "It's a huge time savings."

Another tool that can be used to narrow down the number of critical load cases is the Femap free body tool, which is an extension to the postprocessing toolbox that allows easy creation of free body diagrams and investigation of interface loads. "We like the free body tool because we can do section cuts through the vehicle at different stations and figure out the load paths to see what types of loads are in the different areas very quickly," Lewis explains.

Lewis describes himself as a "Femap champion," spreading the word about the advantages of Femap among his aerospace colleagues. "I tell them how easy it is to use, and easy-to-learn," he says. "That Femap is very powerful and intuitive software."

"We like the free body tool because we can create section cuts through the vehicle at different stations and figure out the load paths to determine what types of loads are in the different areas very quickly."

Eric Lewis
Stress Analyst and Senior Staff Engineer
Lockheed Martin Space Systems

Siemens PLM Software

Americas +1 314 264 8499
Europe +44 (0) 1276 413200
Asia-Pacific +852 2230 3308

www.siemens.com/plm

44775-A13 11/16 H