SIEMENS

Aerospace

# Jet Propulsion Laboratory

## NASA engineers used Femap to ensure Curiosity could endure the "Seven Minutes of Terror"

**Product**

Femap

**Business challenges**

Designing and building a new roving Mars Science Laboratory

Developing and implementing a totally new landing procedure for "the hardest mission ever..."

Missing the launch window deadline would mean more than two years of delay

**Keys to success**

Innovative, one-of-a-kind product development

Thorough project planning and execution

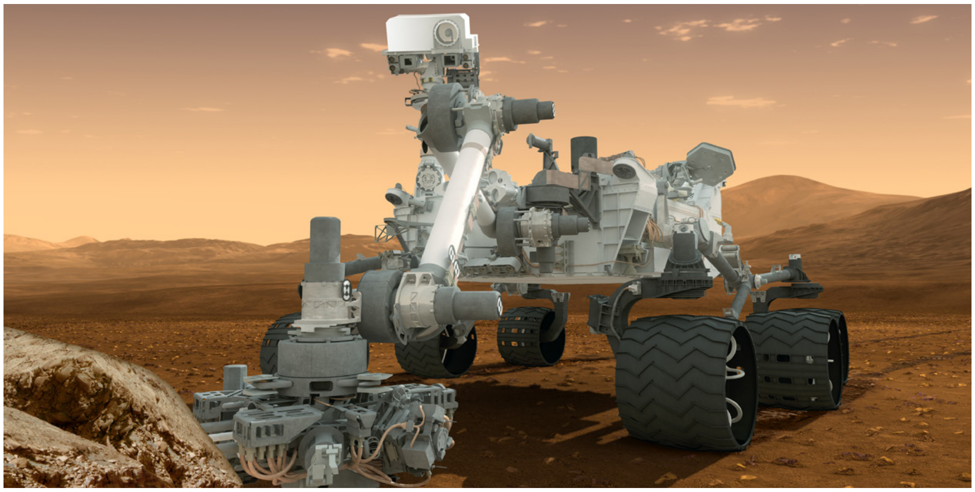
Precision engineering and fabrication

**Results**

A soft landing with no damage to components

Continuing a new era in Mars exploration

Determining whether Mars could ever have supported life



### Femap helps optimize component and parts for Curiosity's mission to Mars, the most challenging and demanding ever

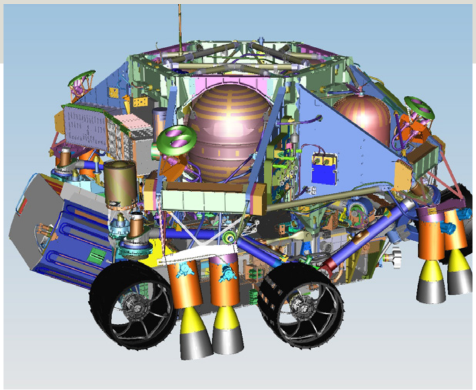
**Sending a package to Mars is a complex undertaking**

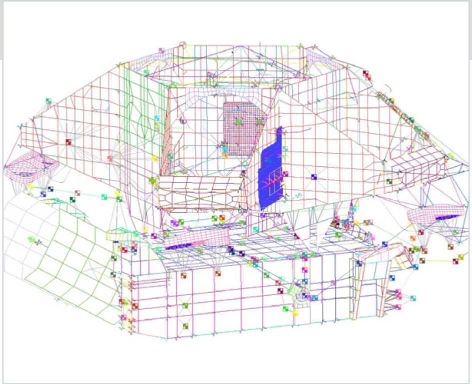
Delivering a roving science laboratory from Earth to the planet Mars requires meticulous planning and precision performance. You only have one chance to get it right; there's no margin for error. Engineers and scientists at NASA's Jet Propulsion Laboratory (JPL) at the California Institute of Technology had to make crucial decisions thousands of times over a multi-year product development schedule to successfully land the Mars Rover "Curiosity" on the floor of Gale Crater on August 6, 2012.

They've been doing rocket science at JPL since the 1930s. In 1958, JPL scientists launched Explorer, the first US satellite to orbit the Earth, followed by many successful missions not only near Earth, but also to other planets and the stars.

JPL engineers use a toolkit of engineering software applications from Siemens PLM Software to help them make highly informed decisions. A key component in this toolkit is Femap™ software, an advanced engineering simulation software program that helps create finite element analysis (FEA) models of complex engineering products and systems and displays solution results. Using Femap, JPL engineers virtually modeled Curiosity's components, assemblies and systems, and simulated their performance under a variety of conditions.

JPL engineers use a toolkit of engineering software applications from Siemens PLM Software to help them make highly-informed decisions. A key component in this toolkit is Femap software, an advanced engineering simulation software program that helps create finite element analysis models of complex engineering products and systems and displays solution results.





*The powered descent vehicle containing Curiosity was analyzed during the early design stages with the help of Femap.*

**From 13,000 to 0 mph in seven minutes**

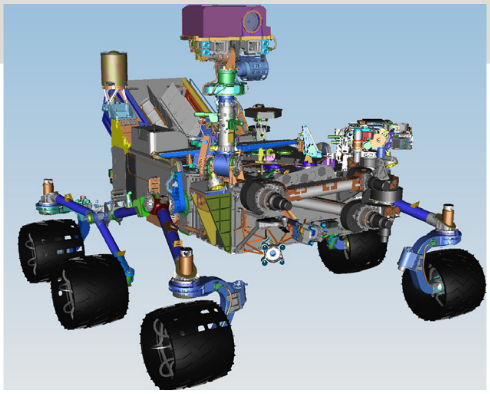
Also known as the Mars Science Laboratory (MSL), this rover is massive compared to earlier vehicles NASA has landed on the "Red Planet." In the deployed configuration with the arm extended, the rover is 2.5 meters wide, 4.5 meters long and 2.1 meters high. Weighing nearly a ton, the Curiosity rover is five times the mass and twice the length of its predecessors, which meant that an entirely new and much softer landing procedure had to be engineered.

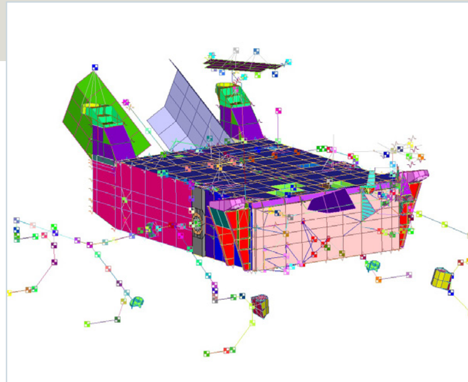
NASA needed to slow the rover spacecraft from a speed of 13,000 miles per hour (mph) to a virtual standstill to softly land the rover during what NASA calls "Seven Minutes of Terror." After completing a series of "S" maneuvers, deploying a huge parachute, and then with the unprecedented use of a specially designed "sky crane," the MSL was gently set down so as not to damage the labs' functional and scientific components.

Those components include a 2.1-meter long robotic arm, which is used to collect powdered samples from rocks, scoop soil, brush surfaces and deliver samples for analytical instruments. The science instruments on the arm's turret include the Mars Hand Lens Imager (MAHLI) and the Alpha Particle X-ray Spectrometer (APXS). Other tools on the turret are components of the rover's Sample Acquisition, Processing and Handling (SA/SPaH) subsystem: the Powder Acquisition Drill System (PADS), the Dust Removal Tool (DRT), and the Collection and Handling for Interior Martian Rock Analysis (CHIMRA) device.

Curiosity also inherited many design elements from the previous Mars rovers "Spirit" and "Opportunity," which reached Mars in 2004. Those features include six-wheel drive, a rocker-bogie suspension system and cameras mounted on a mast to help the mission's team on Earth select exploration targets and driving routes on Mars.

JPL engineers use a toolkit of engineering software applications from Siemens PLM Software to help them make highly-informed decisions.





*Femap was critical in performing all types of FEA on all aspects of the vehicle. Each component of the vehicle had a higher-level, loads-type model built, and these models were joined to create the full spacecraft model.*

Virtually all of the spacecraft itself and its payload were subjected to simulation analysis using Femap for pre- and post-processing. Simulations performed before part and system production included linear static, normal loads, buckling, nonlinear, random vibration and transient analyses. Thousands of design decisions were made using information from Femap simulations.

In addition to the complex nature of the mission itself, engineers developing Curiosity from initial design to final delivery of components to Cape Canaveral were working against the clock. The ideal time window to send a package from Earth to Mars is a 2- to 3-week period that happens roughly every 26 months. Missing that window would have set the mission back by more than two years, so JPL engineers needed to analyze parts and components quickly and efficiently so that they could be fabricated.

**The role of Femap**

Femap is JPL's primary pre- and postprocessor for FEA. For MSL, engineers started using Femap early in the design stage when they were performing trade studies on various configurations or different ways to approach the mission. As the configuration matured, they used Femap to help create the master finite element model that was used to run the various load cases.

Most of the structural analysts at JPL use Femap either for creating or viewing the results of a FEA run. The software was used for both high level-linear analysis and very detailed nonlinear analysis. These are two very different types of analysis both using the same piece of software.

**Virtually all of the spacecraft itself and its payload were subjected to simulation analysis using Femap for pre- and postprocessing. Simulations performed before part and system production included linear, static, normal loads, buckling, nonlinear, random vibration and transient analysis. Thousands of design decisions were made using information from Femap simulations.**

## Virtually all of the spacecraft itself and its payload were subjected to simulation analysis using Femap for pre- and postprocessing.

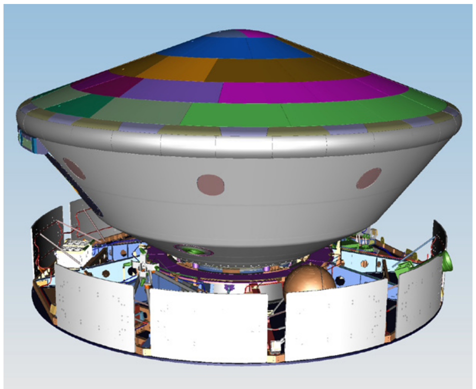
Certain jobs were simply too large for one person, and in some instances engineers had to build on the work of other people who had previously used Femap to build FEA models. Femap was designed as a very easy-to-use package, created for analysts by analysts who are acutely aware of what engineers need and how they work. They can pick it up after six months of non-use and be back to peak proficiency in a very short time.

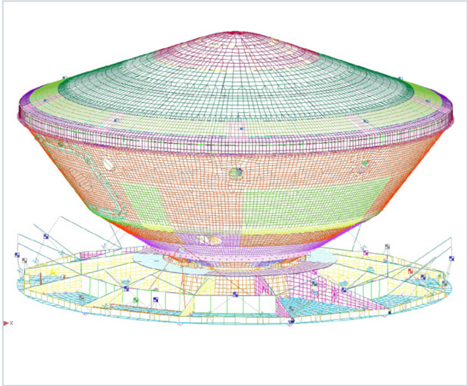
Femap was critical in performing all types of FEA on all aspects of the vehicle. Each component of the vehicle had a higher-level, loads-type model built, and these models were joined to create the full spacecraft model. JPL engineers worked through various "what if" scenarios, including as many as 37 different load cases for how the parachute would deploy during the landing process.

The Curiosity mission is not JPL's only current project. Other missions include satellites monitoring conditions on Earth, telescopes, experiments and other spacecraft.

Planned missions include the InSight mission that will place a lander on Mars in 2016 to drill beneath the surface and investigate the planet's deep interior to better understand Mars' evolution. There are even plans for a proposed Mars Sample Return mission, which would collect samples from the surface of Mars and return them to Earth.

JPL engineers are currently using and will likely continue to use Femap to help accomplish these and other missions of engineering, discovery and science.





*Using Femap, JPL engineers virtually modeled Curiosity's components, assemblies and systems, and simulated their performance under a variety of conditions*

### Solutions/Services

Femap
www.siemens.com/plm/femap

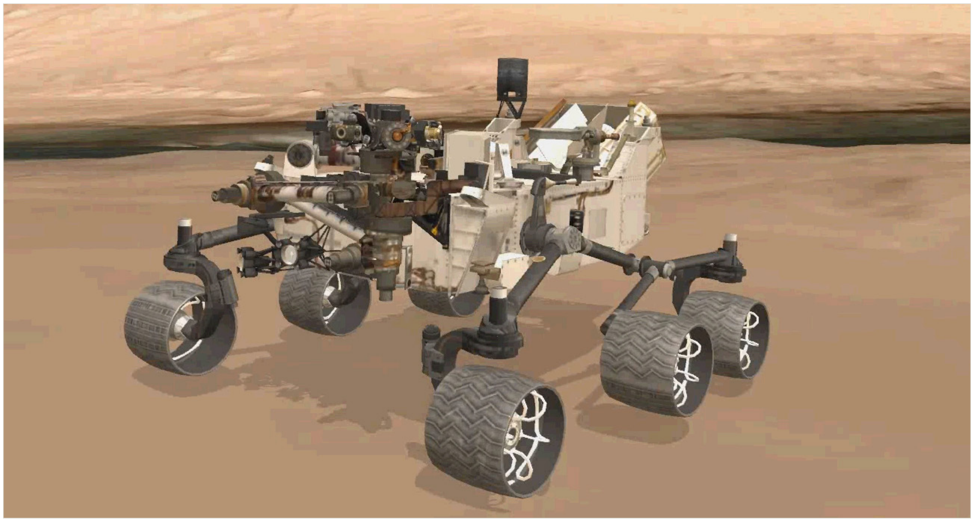
### Client's primary business

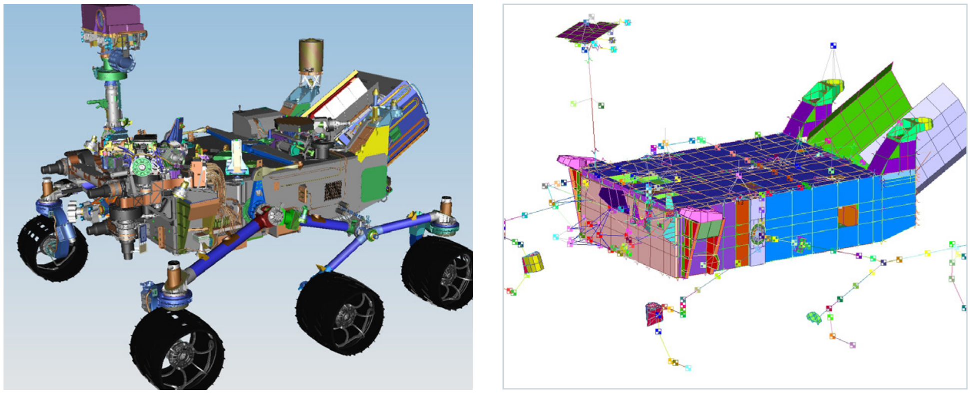
The Jet Propulsion Laboratory (JPL) is a federally funded research and development center managed by the California Institute of Technology for the National Aeronautics and Space Administration.
www.jpl.nasa.gov

### Client location

California Institute of Technology
Pasadena, California
United States

**Femap was designed as a very easy-to-use package, created for analysts by analysts who are acutely aware of what engineers need and how they work. They can pick it up after six months of non-use and be back to peak proficiency in a very short time.**





*The software was used for both high level-linear analysis and very detailed nonlinear analysis.*


**Siemens PLM Software**

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

**www.siemens.com/plm**





31591-X14 5/15 A