

# simulating **REALITY**

MSC Software Magazine

Volume I | Summer 2011

## THERE IS A **BETTER WAY**

INTRODUCING A CFD SOLUTION  
FOR MSC USERS

## Optimizing Aircraft Performance

RESULTS CORRELATE  
"SO WELL IT WAS  
HARD TO BELIEVE"

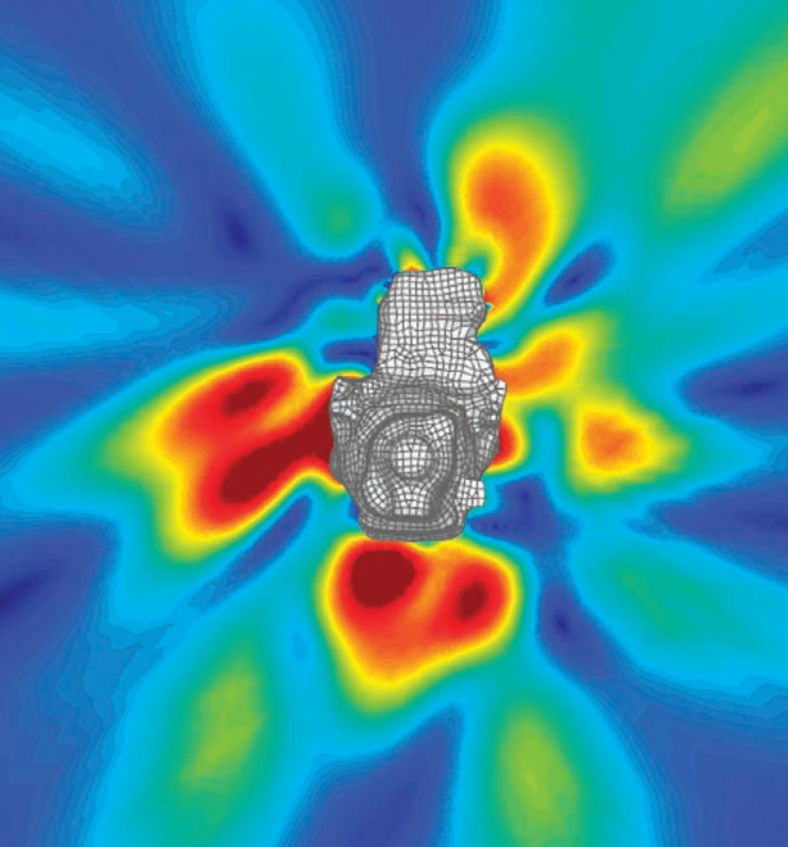
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MSC ADAMS HELPS REDUCE  
EXPENSIVE TRIALS

## Simulating Manufacturing Processes

SETFORGE SIMULATES  
THE FORGING PROCESS  
AND REDUCES  
MAINTENANCE  
COSTS





# ACTRAN

Acoustic simulation software

Your solution for:

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- Coupled acoustics and structural vibration analysis
- Trimmed body modeling
- Broadband aero-acoustics
- Turbo machinery noise
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& temperature**  
problems in  
fluid systems?



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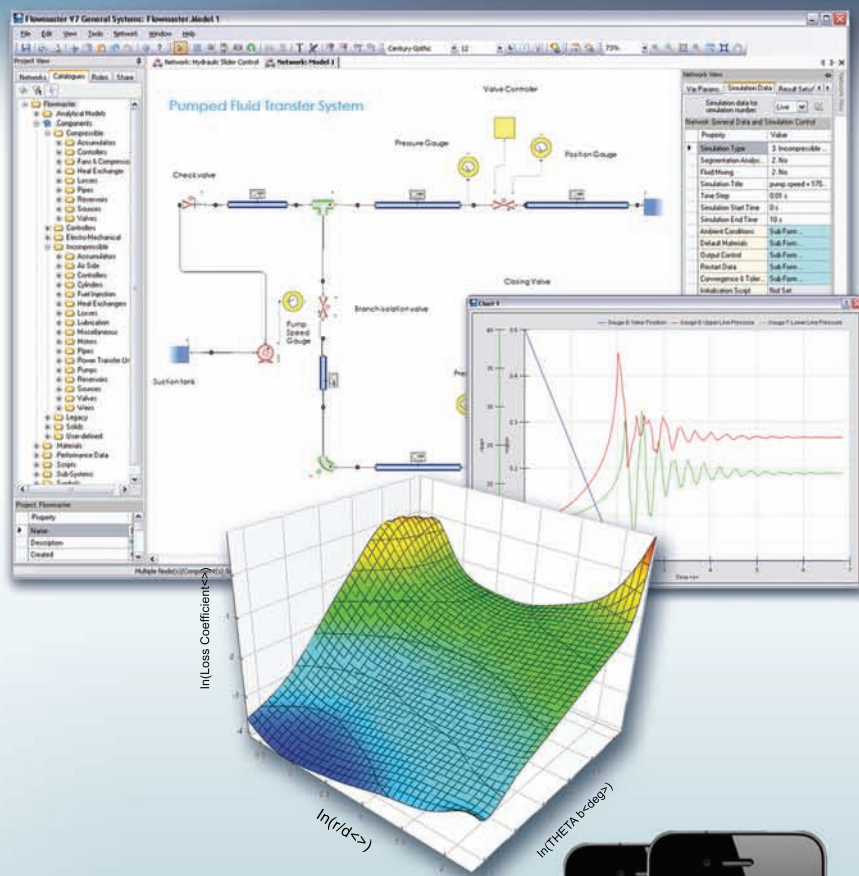
Transient solver

In-built  
empirical data

Integrated  
batch processing  
of simulations

Complete  
traceability  
of data history

Automatic  
component sizing



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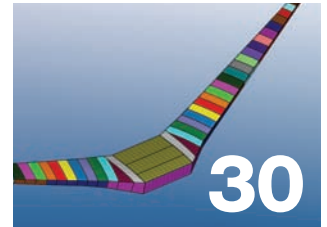
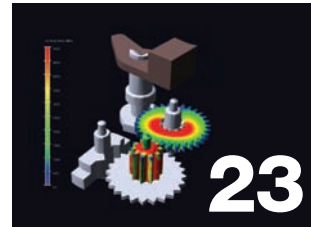
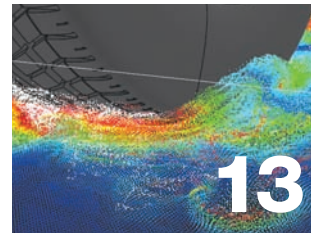
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## simulating REALITY

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# A Brand That Delivers Certainty



“When product designs are modeled and simulated on the computer, there is one thing that really matters to engineers... Certainty.

We rely on software to help us design safer products. We rely on it to tell us whether our products will withstand real life environmental and mechanical loading conditions (often times extreme). We rely on it to tell us if the design will last as it undergoes a series of loads throughout the product's expected lifespan. We trust that the software we use will give us accurate performance assessments of the products the world uses every day to travel in, play with, generate energy with, and even the ones used inside and outside the human body to keep us living longer and enjoying a better quality of life.

With an engineering simulation market that is growing rapidly and expected to reach \$2.9B in size by 2012, it means more product manufacturers are relying on computer aided engineering (CAE) technology everyday to develop products that are safe, reliable, higher quality, better performing, and longer lasting. It is our mission at MSC Software to provide the means to do it.

As part of this issue of Simulating Reality, we wanted to discuss the importance of certainty in a brand, by once again, providing examples through the voices of our valued customers.

Over the years I've watched manufacturers continue to use MSC because it is a brand that personifies certainty: certainty in computational analysis results the world can rely on, with the people and expertise to support the toughest engineering problems out there.

In this issue, we spotlight customer use cases that discuss continuous reliance on simulation software to make better decisions, reduce costs of physical testing, or gaining confidence in results through new methods of correlation between virtual and physical test data.

On page 14, AeroVironment says “MSC Nastran results matched physical test data so well it was hard to believe.” In this article, you can learn more about their use of analysis to test an unmanned aircraft with a wingspan of a Boeing 767, but with less than 10% of the weight.

On page 18, Setforge Engineering says: “We were able to compare a virtual video of the deformation generated by Patran with real video footage shot in one of our plants. “The match was impressive.” These are just a couple of our customer spotlights you might find of interest.

Finally, don't forget to check out this issue's feature story entitled “There is a Better Way,” which presents MSC's new addition to the portfolio - Computational Fluid Dynamics (CFD). We are pleased to offer XFlow, an innovative CFD software solution, giving our customers more physics to help solve a greater number of engineering problems – with certainty, as always.

”

Sincerely,

A handwritten signature in black ink that reads "Leslie Rickey".

Leslie A. Rickey,  
Editor

# Empowering Engineers Through Better Simulation

## MSC ADAMS

### Brings Interoperability & Speed

The latest version of Adams 2011 brought productivity enhancements for users, including improved interoperability for direct import and export of CAD formats, updated SimManager integration for archiving and managing Adams models and simulation results, a run-time clearance feature that provides solve time clearance analysis, and a library of run time solver features.

#### CAD Interoperability Benefits:

- Ease of Use
- Eliminates need to pass CAD geometry through neutral formats
- Reads CAD assemblies into Adams and creates Adams parts
- Defines an accurate geometric representation of the system

#### SimManager Integration Benefits:

- Integrated environment for Adams Data and Process Management
- Publish and Retrieve, Manage your simulation data from within the Adams interface
- Track audit trail history of model and result pedigree
- Distribute simulation across attribute teams
- Capture and leverage expertise

#### Run Time Clearance Feature Benefits:

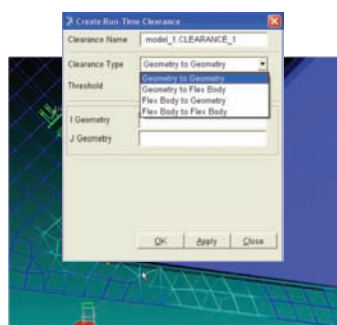
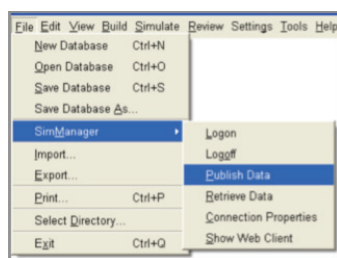
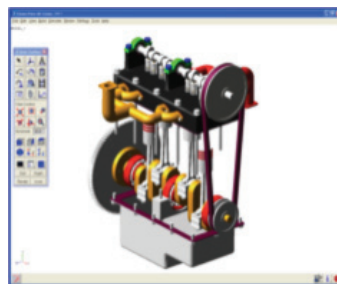
- For customers who want to do design iterations based on distance
- Find interference quickly and fix it

#### Adams C++ Solver Performance Benefits:

- Faster delivery of new features
- New features drive speed and robustness

To learn more about the Adams 2011 Release including additional enhancements for the automotive industry, go to:

[www.mscsoftware.com/adams](http://www.mscsoftware.com/adams)



## MSC SIMXPRT

### Improves User Efficiency

Usability and quality were the focus of the latest version of SimXpert 2011. At the request of our user base, this release delivered improved ease of use along with CAD and meshing enhancements, and comprehensive multidiscipline support. New features included CAD 'defeaturing' tools and improved CAD support, a new distene mesher, performance improvements, a new model browser, and comprehensive MD Nastran multidiscipline solver support.

#### CAD Support and new CAD 'defeaturing' Tools Benefits:

- Import of geometry from your favorite CAD solution including SolidWorks and Inventor
- Greatly enhanced CAD cleanup capabilities
- Reduced time to prepare mesh ready geometry

#### New Distene Mesher Benefits:

- Enhanced TET meshing robustness
- Iterative convergence
- Mesh quality and usability greatly improved

#### New Model Browser Benefits:

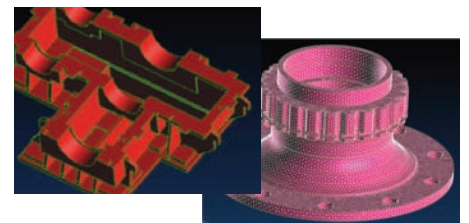
- Faster loading of entities in the model browser
- Synchronous highlighting saves time
- Efficient sub-assembly management

#### Multidiscipline Support Benefits:

- Innovate with the latest features in MD Nastran, Adams, and Easy5 inside SimXpert
- Most comprehensive support for multidiscipline analysis
- Extended contact capabilities to support thermal contact
- Coupled thermal-mechanical analysis
- Incorporation of user-subroutines for customization

To learn more about the latest SimXpert 2011 Release, go to

[www.mscsoftware.com/simxprt](http://www.mscsoftware.com/simxprt)





# MSC PATRAN

## Expands on Ease of Use

The latest version of Patran provides a variety of usability improvements. Users were given a new modern user interface, more mouse control, better performance when working with large models, improved features for SimManager integration, and enhanced solver support.

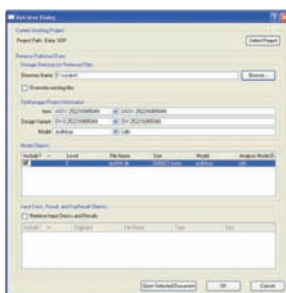
### Modernized User Interface:

- Windows 7 like Ribbon User Interface increases productivity
- Greater mouse control/actions for interactive view port
- True 64-bit support on Windows and Linux improve performance when working with large models



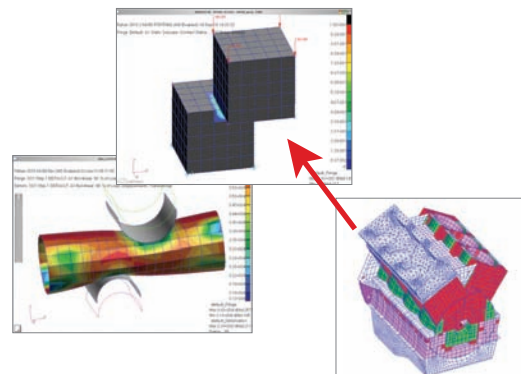
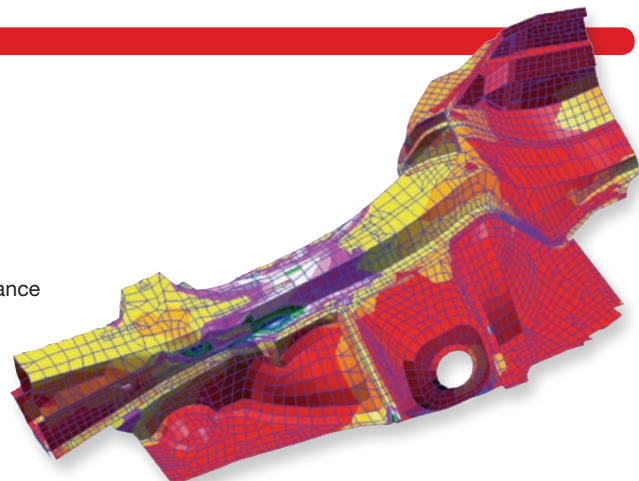
### SimManager Integration Benefits:

- Publish and retrieve Patran database and related files
- Open database directly in Patran
- Manage simulation data and processes seamlessly within Patran



### Enhanced Solver Support Benefits:

- Improved contact support
- Better composites support
- Enhanced post processing
- New contact results visualization
- Rigid body Results animation



To learn more about the latest Patran Release, go to [www.mscsoftware.com/patran](http://www.mscsoftware.com/patran)

# MSC NASTRAN

## Solves Larger Problems

The latest versions of MSC Nastran and MD Nastran 2011 delivered significant performance gains through efficient numerical methods and High Performance Computing (HPC) methods. New features were also introduced for improved optimization, aeroelasticity, and rotordynamics simulations.

### High Performance Computing Benefits:

- Improved Shared Memory Parallel (SMP) scalability for better performance
- Faster solution run times
- Up to 5X speedup
- Improved productivity
- Ability to simulate large models

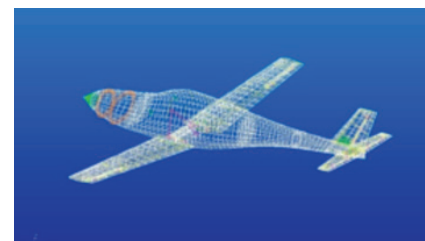
### Optimization Enhancement Benefits:

- Flexibility to use 3rd party or internally developed optimizers
- Users are free to pursue optimization methods of choice
- Complements and extends MSC's optimization capabilities

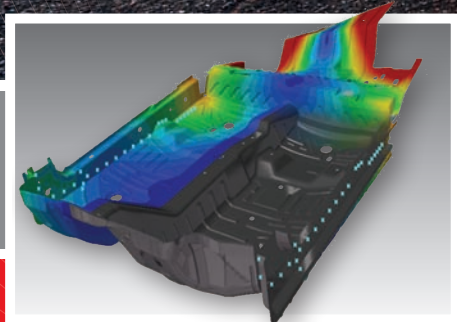
### Aeroelasticity Enhancement Benefits:

The CFD model for an aeroelastic analysis often consists of thousands and even more than a million aerodynamic grid points. This presents a challenge to the splining methods that were originally developed to handle smaller number grid points. In order to handle larger model with greater efficiency, new capabilities have been introduced in this release, which include:

- Implementation of an automated partitioning concept that breaks a single spline into a number of smaller splines
- Ability to restrict relaxation to the displacement instance of the spline while not applying it to the force instance



To learn more about the latest MSC Nastran and MD Nastran 2011 Release, go to: [www.mscsoftware.com/nastran](http://www.mscsoftware.com/nastran)



# 2011 Users Conference

**October 4-6, 2011**  
**Hilton Orange County**  
**Costa Mesa**

3050 Bristol Street  
Costa Mesa, CA 92626

## Why Should You Attend?

- Exchange Ideas with Other Users
- Technical Training on The Latest CAE Technologies
- Meetings with MSC Software Developers
- Professional Networking with Your Peers

## 5 Tracks To Choose From:

- Manufacturing
- Process and Automation
- Structures
- Systems and Motion
- University & Education

**Now Accepting Abstracts!**

## EXPLORING THE HORIZON OF SIMULATION

MSC's Users Conference is the premier event in the simulation and analysis community, bringing leading academics, engineers, technologists, designers, executives and managers from all over the world to exchange information and ideas, network with peers from industry, and gain access to the software developers who are redefining CAE.

**MSC**  **Software®**



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# The 3 P's To Ensure Users' Success



*Dominic Gallelo*  
*President & CEO*  
*MSC Software*

“ Delivering better & new simulation behaviors to our users is the most important thing that we do at MSC every day. Over the past year, we have focused in particular on three areas that we felt were fundamental to achieving our goals - People, Process and Partnership.

**People** - Ensuring that you have the right team on the field is a key to any winning team. Over the past year, we took a skills inventory and aggressively hired talent to complement our team – thereby ensuring that we deliver on the products and solutions that our users expect. At the highest level, new members of our team contribute to enhancing our current and future products ease of use, performance, quality, capability and technical support. Many of our hires come from masters degree, PhD and post doctorate programs where they bring with them know-how on the edge of how simulation will be done in the future. This new set of outstanding brainpower is eager to contribute to the future of simulation in the areas of high performance computing, rotor dynamics, fatigue, acoustics, materials simulation and more. We are also enhancing our field and technical support teams to ensure that we continue to provide deep engineering knowledge to help our users to solve their engineering challenges.

**Process** - This spring we began rolling out our new Application Lifecycle Management System (ALM). Using a combination of licensed and in-house developed technology, our ALM will speed our development, better manage our processes and provide us the visibility to continue to drive product quality improvement. Of course, having a modern development platform on its own can never ensure user satisfying functionality and quality. Equally important, we are asking you to read our specifications before we build and we are implementing the most rigorous code development and testing process in perhaps the history of MSC. Some results will come quickly with better visibility into the status and issues of development and some will take some time to ensure that the design is complete and responsive to customer needs. We are confident however that we can deliver much more in a shorter period of time as a result.

**Partnership** - Innovation will happen and it will likely happen through collaboration and technology. We have been aggressive in establishing new partnerships that will benefit customers, either in the short term or in the longer term. Our partnership with Next Limit brings an innovative kind of CFD to our users, and will be coupled with MSC structural and motion solutions. A new Registered Consultant Program brings a new set of industry expert resources to help our customers with their toughest simulation projects. A Research Assist Program coming this summer will focus on helping some of the best researchers in the industry to develop new solutions which could eventually have breakthrough results for our customers. And finally, MSC is offering our software at no charge to students anywhere in the world. As expected, the response from the world's next generation of engineers has been great!

We have made tremendous progress on the 3 P's in a very short period of time. Our users are already seeing the benefits and they can expect more. Thank you for your trust in MSC and our team!

”

Dominic Gallelo

[dominic.gallelo@mscsoftware.com](mailto:dominic.gallelo@mscsoftware.com)

# MSC Software® NEWS

Collaborating with Global Users



## MSC AMERICAS

### Bringing The Experts to You

MSC has been bringing our experts to you through Seminars, Technology Days, Tradeshows and Webinars. As a company with a half-century of engineering experience in analytical tools, we know that engineering is not just about software, it's about the engineers who use software to develop results.

In the first half of 2011, we put our application engineers on the road to help you solve problems. Our technology day workshops offered a unique experience for engineers by allowing you to meet the experts, get hands-on experience, and an opportunity to take home a 30 day evaluation license of the software.

### How Well Have Our Technology Days been Received?

We covered 15 cities in the Americas in the first half of 2011 and helped over 1,000 engineers learn how to use MSC's products to solve their engineering problems in areas such as Fatigue/Durability analysis, Nonlinear Elastomers, Vehicle Suspension, Structural Analysis and Mechatronics (Motion and Controls).

In Mexico, The Sustainable Economic Development Secretary for the State of Guanajuato created a Dedication Ceremony for a MSC Software Lab at their Technology Training Center.

### MSC Software Visits The White House to Help Make Small Businesses More Competitive

In March, MSC visited the White House in Washington DC, USA, to support the Council on Competitive Initiative to make Small Businesses More Competitive through Game Changing Technology.

The objective of the meeting was to create a partnership with Private Sector (OEM's, Supply Chain Manufacturers, Software Providers), and Public Sector (Universities and HPC Providers) to develop an ecosystem on the cloud that allows supply chain manufactures to use Modeling and Simulation to drive innovation. In the meeting the public sector put up \$2M and the private sector (big OEM's) contributed \$2.5M to kick off this project. MSC Software was the only software company invited to the meeting.



A few of the big names in attendance were:

- U.S. Chief Technology Officer, Aneesh Chopra\*
- Assistant to the President for Manufacturing Policy, Ron Bloom\*
- Assistant Secretary of Commerce, John Fernandez\*
- NASA CTO, Bob Braun\*
- Lockheed Martin CTO, Ray Johnson
- Associate Director of Innovation & Industry Services for NIST, Phillip Singerman
- GE CTO, Christine Furstoss
- P&G CTO, Bruce Brown
- P&G Director of R&D Modeling and Simulation, Tom Lange
- Senior Director of Ohio Supercomputing Center, Ashok Krishnamurthy
- Academic Account Manager & Program Coordinator, MSC Software, Casey Radigan\*
- Senior Marketing Manager, MSC Software, Tony Davenport\*

(\*In picture)

To Read more, please go here to find an article from the Council on Competitiveness:

<http://www.mscsoftware.com/council>

## MSC JAPAN

### 2011 Japan User Conference

The annual Japan User Conferences took place in Tokyo, Nagoya, and in Osaka. The events attracted 394 participants, and 33 customer keynotes/papers. Among them, Toyota, Honda, Nissan, IHI, JAXA and many others shared real world experiences in the area of

simulation modeling and analysis. Sponsors for this year's conference were NEC, Fujitsu, ISID and 8 other partners.

Participant responses were very positive, and feedback indicated the user conferences were successful in showing the Japan market consistent progress toward expansion of MSC's Multidisciplinary (MD) solutions and product development initiatives.





## MSC INDIA

### Auto Suppliers Meet

With renewed focus on "Expanding the Horizon" of simulation into Small Medium Business (SMB) segments, an MSC Software Auto Suppliers Meet was conducted in Chennai, India. The event was aimed at generating awareness within the Auto Supplier community for MSC's broad range of Simulation software offerings and their application advantages during product development. A total of 58 attendees from 20 companies participated in the event, returning home with valuable knowledge learned during interactive sessions with MSC technical experts.

The event also generated interest among some participants on the topic of 'Durability Co-simulation', where the simulation technologies of MSC Nastran, MSC Adams and MSC Fatigue are combined to perform complex durability analysis.

### Online Certification Program

MSC India launched a new program called the MSC Software Online Certification Program. The program is intended to certify students and professionals on popular MSC products like MSC Nastran & MSC Adams. Companies also benefit by asking their employees to participate in the program for internal knowledge sharing and audit purposes.

### Channel Partner Summit

To widen our market footprint, MSC is expanding its coverage in SMB segments and emerging markets outside of traditional business areas like Automotive and Aerospace through its Channel Partners. MSC India organized an "MSC India Channel Partner Summit" at Bangalore to empower and recognize its business partners. The event theme was aptly in-line with the MSC corporate theme of "Engineering Your Success." This Summit was the launching pad for MSC India to announce its engagement with four new partners for wider coverage in emerging markets.

### Infotech Day

Infotech Enterprises is one of the largest Engineering Service Providers in India, and also one of MSC India's biggest customers. Their clients include GKN Aerospace, UTC, Phillips, and Boeing. An exclusive seminar focused on MSC product updates, primarily for MD Nastran & SimXpert, was conducted to help the team pursue new projects around multidiscipline simulation as well as simulation automation. The event was attended by 80 employees of Infotech which included Business Development Managers, Key Account Managers and Users.

## MSC CHINA

### Wind Energy Seminar

The MSC China team held a wind energy seminar in Shanghai to address the fast growing China Wind Energy Market. The event was aimed at generating awareness among wind energy integrators and suppliers of MSC's wide range of engineering software and solutions for this market. Over 80 attendees from 35 companies joined this event. The event also generated significant interest among turbine manufacturers for MSC Nastran, Patran, Adams, and other simulation tools.

### 2011 Channel Conference

In order to widen our market footprint and provide better engineering services, MSC China is rapidly expanding its partner network. The MSC China team organized an annual "MSC China 2011 Channel Conference" in Beijing to empower and recognize its business partners. During the event, MSC recognized 4 outstanding performance partners, and also welcomed over 10 new partners. The MSC Business Partner recognized as the golden partner was Beijing Rainfe Technology Co. MSC Business Partners recognized as silver partners were Beijing DaHeng software Technology Co. Ltd, Shanghai HePu Information Technology Co. Ltd, and Beijing King Sensor Technology Co. Ltd.

### Campus Campaign

Creating future users of MSC Software products is a key initiative around the world. MSC China is putting forth significant effort in getting MSC products into the hands of more students, and therefore launched a new China campus campaign to promote the MSC Student Editions. Over 30 schools are encouraging students to do more exercises and assignments using MSC's Students Editions.



## MSC KOREA

### Korea User Conference

The Korea User Conference took place in Gyeongju. The event attracted 192 attendees and a customer keynote from the Korea Aerospace Industry, along with 28 customer technical papers. Attendees gave positive feedback upon leaving the conference and said it was an excellent opportunity to hear so many new insights around simulation and analysis from MSC and other companies.



### C&G TV: Nonlinear Seminar

An online seminar was held by C&G TV. C&G is unique publication focused on CAD/CAM/CAE in Korea. The seminar subject was 'Nonlinear Analysis' technology trends and examples in industry. A total of 120 attendees from 96 companies participated in the seminar, providing a great platform for introducing MSC nonlinear technology to new customers. Four more seminars are scheduled this year with additional simulation topics planned.

## MSC EMEA

### MSC Software is Bringing the Experts to You

Throughout the first half of the year, MSC continued to address the needs of our users in EMEA (Europe, Middle East, and Africa). User Days took place in several countries, attracting many attendees, some of which also came to our Motion and FEA day, which offered a tour of Polestar Racing in Göteborg, Sweden. The team also hosted a Users Conference in Turkey. Highlighted during this event were new features of Marc, Nastran and Adams, and numerous MD Nastran customer case studies. Technology Day Workshops across EMEA took place, as well as a Wind Turbine Day in Hamburg, Germany, focusing on MSC capabilities for modeling and simulating wind turbines using MSC's Advanced Wind Turbine Modeling solution. Additionally, two product centric user groups were conducted, one in Munich for Adams, and another for MSC Nastran, where lively discussions took place around composite modeling and simulation.

# On a Roll in Creating Future Users



Albert Einstein once said, "Education is what remains after one has forgotten what one has learned in school." Do we remember every lecture we sat through during our education? Do we apply principles that we learned for a random pop quiz our sophomore year in college? What we remember, what we learn, happens outside the class room. Experience is the best teacher.

Our objective is to give students an opportunity to gain real CAE experience with MSC Student Editions. The Student Edition has been downloaded by students all over the globe, and has received rave reviews from satisfied users. A student from Cal State Poly said, "The benefit of the student edition is that it offers me a platform that I can use as a learning tool for Finite Element Analysis (FEA) and Multibody Dynamics. It also allows me to use the program at home, so I can "tinker" and learn with it on my own time."



**To download MSC Student Editions, visit:**  
**[www.mscsoftware.com/student-center](http://www.mscsoftware.com/student-center)**

***See our Student Interviews on Page 32 >>***



## what's your CAE proficiency?

try the

**MSC COMPETENCY CHALLENGE**

Knowledge of MSC Software is an increasingly valuable asset in today's world. Companies are competing for the services of well-trained users of MSC Software products, such as MSC Nastran and Adams, to accurately and reliably predict how products will behave in the real world to help engineers design better, more innovative products - quickly and cost effectively.

MSC Software's competency tests give users the opportunity to measure their existing MSC product knowledge against a global standard, further develop their skills, and improve their chances of finding MSC Software simulation jobs in today's competitive marketplace.

### HOW IT WORKS:

Participants in the MSC's Competency Challenge will take an online multiple-choice test which examines their understanding of the Simulation technology concepts and in particular with MSCs product knowledge and functions.

Scores will be displayed immediately after completion of test. You can take as many 'practicing' tests as desired. If you achieve a score of 80 % or above, you can choose to have your Competency Challenge results published in our 'User Recognition' web-database to compare your knowledge to fellow MSC users. Note that you can take as many 'practice tests' as desired.



**To learn more, visit:**

**[www.mscsoftware.com/competency](http://www.mscsoftware.com/competency)**

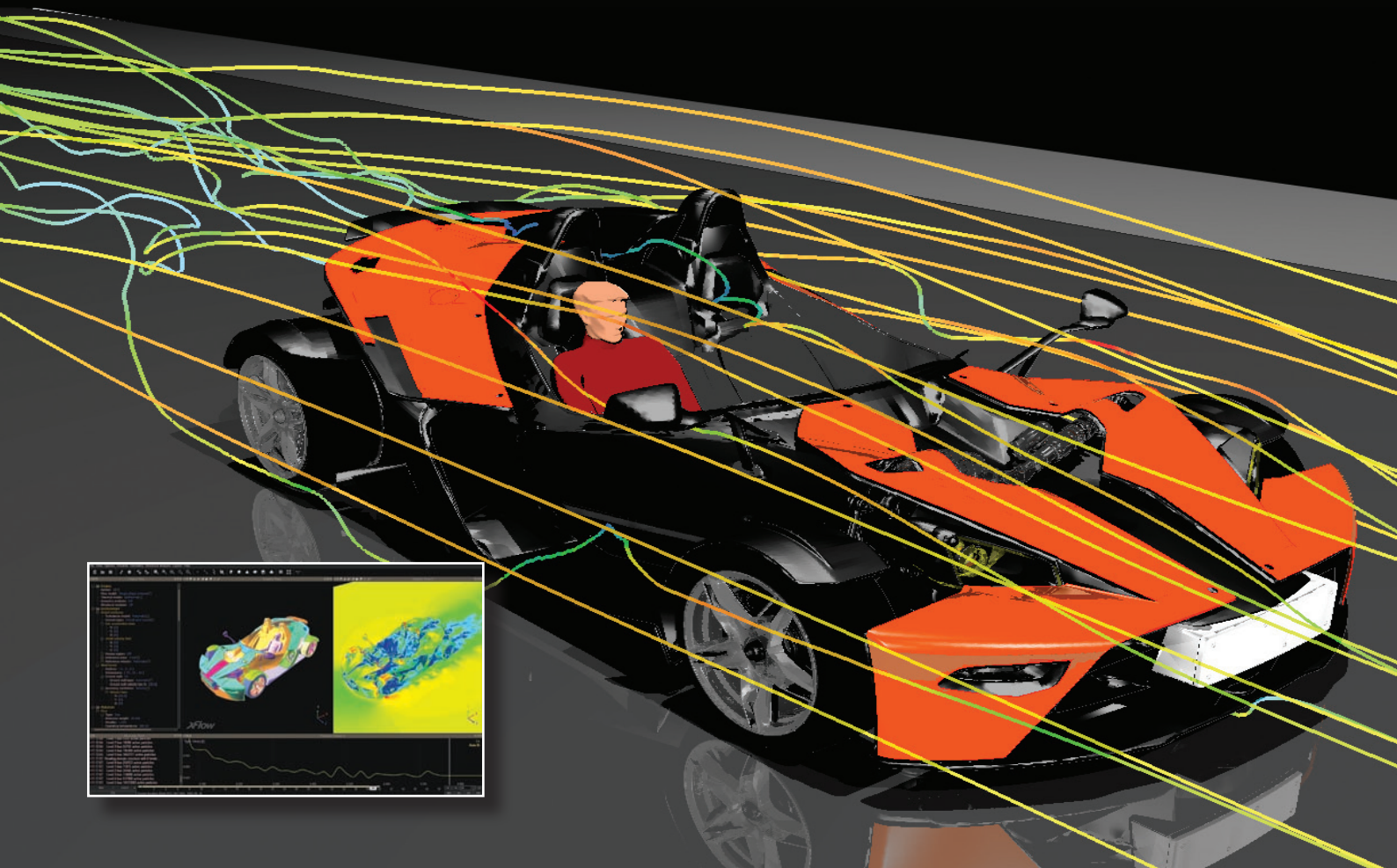
Official MSC product certification is currently only available to users in India. This will be soon available to users in other parts of the world.





# XFlow

Innovative CFD Solution For MSC Users



## “THERE IS A BETTER WAY”

In May 2011, MSC Software announced a strategic market development partnership with Next Limit Technologies for XFlow™, a new state of the art Computational Fluid Dynamics (CFD) solution.

Next Limit has been developing and validating XFlow for a number of years and recently launched the first commercial version, XFlow 2011.

With this new offering inside the MSC product list, MSC becomes the only company with a complete simulation portfolio with structures, CFD, multibody dynamics, and systems and controls.

Developed for engineers and analysts who require quick and accurate feedback on Flow, Thermal, and Acoustic behavior, XFlow is a CFD software

system that provides the ability to solve complex problems involving Moving Boundaries, Free Surface and Fluid Structure Interaction on complex geometric domains.

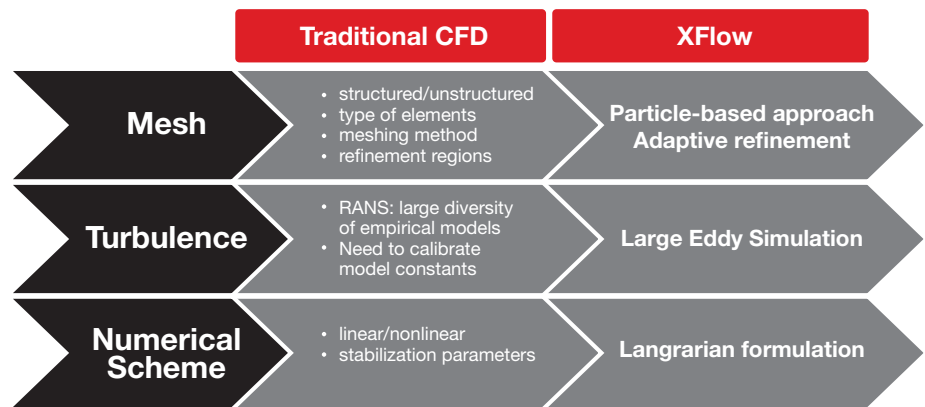
In this article we explain more about the approach XFlow takes to CFD, and why we selected XFlow to be the CFD solution for MSC customers. >>

## The Challenge of Traditional CFD

Companies today are trying to keep the product development cost down, shorten the time to market, increase sales, increase profitability and reduce warranty costs for their products. They are doing all this while trying to bring innovation to their products. XFlow helps you achieve all this by eliminating many traditional CFD barriers.

In a product development cycle, getting reliable results faster is the key to building better products and taking them to the market faster. Most commercially available technologies for fluid flow and heat transfer modeling are traditionally mesh-based. Traditional CFD poses severe difficulties dealing with complex problems involving changes in the topology of the domain (for instance a breaking wave) or involving moving boundaries (like you have with a wind turbine), and fluid-structure interaction (like deployment of a parachute).

Furthermore, generating a good mesh usually requires a large amount of engineering time in CFD analysis. In mesh-based technologies, the reliability of the solution highly depends on the quality of the mesh – and also depends on the ability of the engineering team to choose the right models for meshing, turbulence and numerical scheme. This can lead to long cycle times to get the “correct” mesh, turbulence models before the engineering team can look at the results and come up with alternate design solutions for their products.



**XFlow eliminates traditional barriers for engineering teams.**

## XFlow's Innovative Approach To Traditional Barriers

The motivation for XFlow is to overcome these traditional barriers. In particular, XFlow is a unique general purpose commercial software of fluid flow and heat transfer simulation based on methods which offer new computational horizons for problems that could not be solved with conventional CFD software so far, especially in transient problems, free-surface analysis, moving parts and fluid-structure interaction.

### Particle-Based, Meshless Approach

The approach within XFlow is particle-based and fully Lagrangian which means classic fluid domain meshing is avoided, and constraints related to geometries and surface complexity are removed. Complex geometries are easily handled (CAD data can be used for simulation), so there is huge reduction in pre-processing time. XFlow can handle moving bodies and deformable parts.

### Adaptive Wake Refinement

XFlow's engine automatically adapts the resolved scales to the user's requirements, refining the quality of the solution near the walls and dynamically adapting to the wake while the flow develops. XFlow is designed for the analysis of dynamic/transient problems.

### Particle-Based Kinetic Solver

XFlow features a novel particle-based kinetic algorithm that resolves the Boltzman and the compressible Navier-Stokes equations. The solver features state-of-the-art LES (Large Eddy Simulation) turbulence model which avoids the calibration of the usual turbulence model constants as required with the Reynolds Averaged Navier-Stokes (RANS) approach.

### Near Linear Parallel Solver

XFlow is fast and efficient, even on a standard desktop PC. High performance computes are not required. XFlow is fully parallelized for multi-core technology with near-linear scalability.





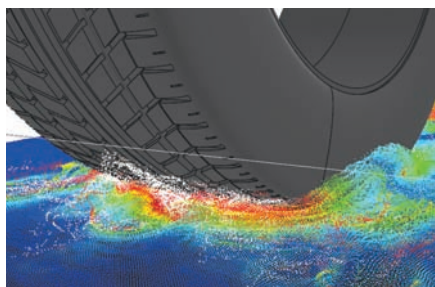
## Advanced Analysis Capabilities

With the approach XFlow takes to the traditional CFD problems, this opens the door to advanced analysis possibilities including:

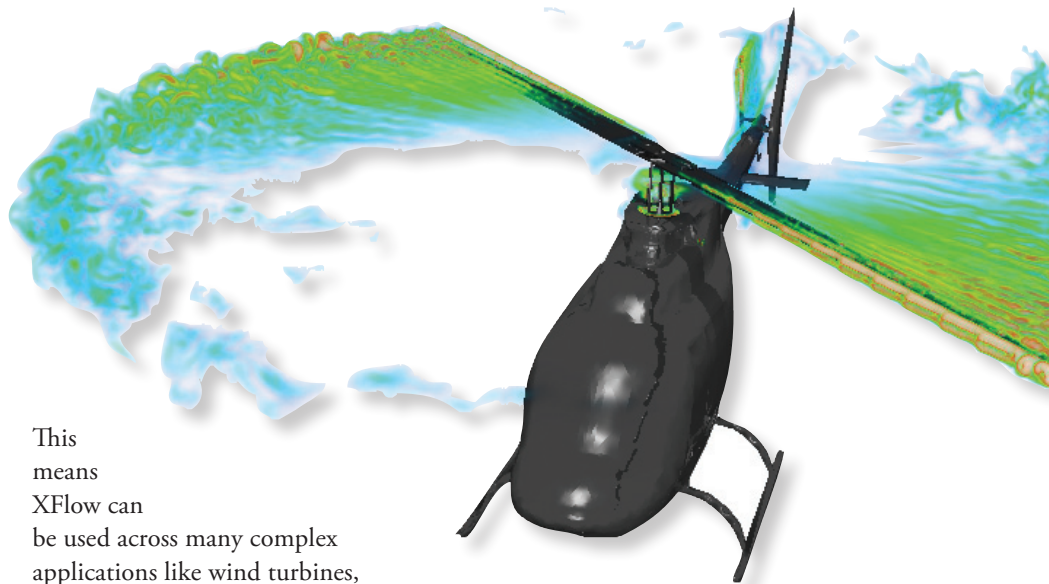
- External and internal aerodynamics
- Free surface flows
- Thermal analysis: convection, radiation, conjugated heat transfer
- Flow through porous media
- Non-Newtonian flows
- Moving parts, forced and constrained motion, and contact

Focusing on this last point, being particle-based, XFlow greatly simplifies the setup of complex analysis allowing the presence of moving parts, hierarchical structures, forced or constrained motion, 6-DOF, and contact modeling.

The analysis of moving geometries in traditional CFD solutions has some classic problems. Mesh based approaches to these moving geometries and moving boundaries include remeshing, deforming the mesh, multiple reference frames and sliding meshes.



XFlow's treatment of moving geometries is straightforward. The statistical distribution functions coming from the boundaries are reconstructed taking into account the wall distance, the velocity and the surface properties. The set of statistical distribution functions are reconstructed each time-step based on the updated position of the moving boundaries. As the physics are not implemented using surface elements, XFlow relaxes the requirements imposed to the geometries and is tolerant to crossing or complex surfaces.



This means XFlow can be used across many complex applications like wind turbines, aircraft landing gear deployment, manufacturing production lines involving complex motion, and even automotive water drive through analysis.

XFlow technology helps a wide range of industries:

- Automotive
- Aeronautics
- Marine
- Civil engineering
- Energy
- Bioengineering
- Defense
- Manufacturing
- Electronics

## Future Solutions for MSC Customers

The addition of XFlow to the MSC product portfolio is only the first step. True connectivity with current MSC products is planned. Integration with MSC Nastran, Marc and Adams will enable coupling of fluids with structures and multibody dynamics. For example with Adams, with XFlow being so effective in handling moving parts and moving

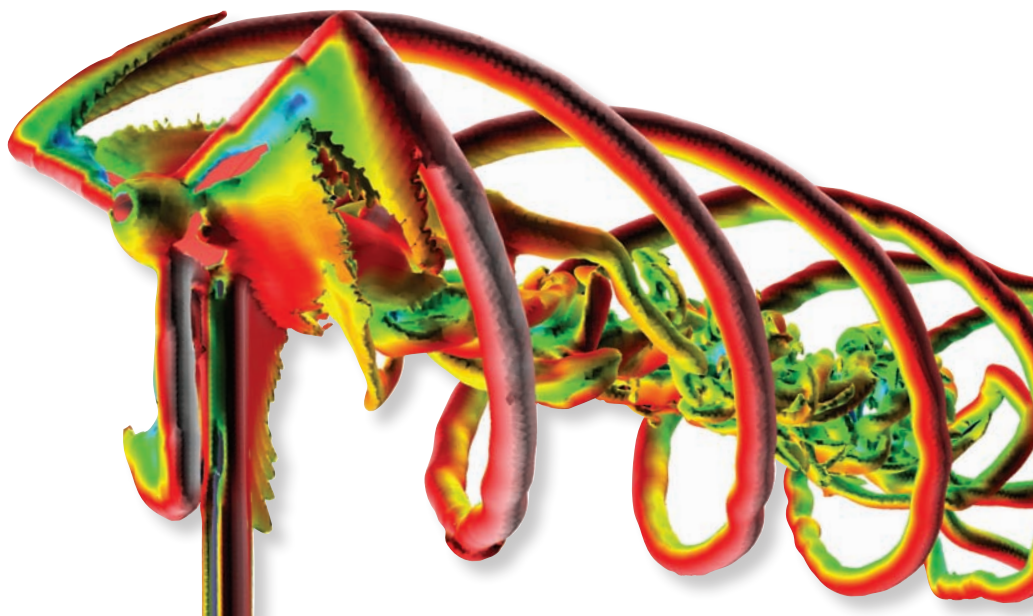
**“This technology is the future of CFD, and brings new possibilities for new complete simulation and analysis solutions for our customers.”**

boundaries, applications such as a full vehicle manoeuvre in Adams with full aerodynamic and cross-wind effects will be a solution which only MSC can deliver.

“We selected XFlow due to its superior visualization features and innovative approach to modeling CFD problems,” says Ken Welch, VP of Product Management at MSC Software. “This technology is the future of CFD, and brings new possibilities for new complete simulation and analysis solutions for our customers.” ■

See why with XFlow “There is a better way.” To schedule a demo, visit:

<http://www.mscsoftware.com/xflow>





# Optimizing Aircraft Performance

MSC Nastran Results Correlate  
“So Well It Was Hard To Believe”

## AEROVIRONMENT

**T**he Global Observer is an unmanned aircraft with the wingspan of a Boeing 767, but less than 10% of the weight designed to provide communications and sensing for flights lasting up to one week at up to 65,000 feet. With a maximum wing loading of only 3.5 pounds per square foot, the wingtip deflects greater than 22 feet at its design limit load.

MSC Nastran was utilized to develop nonlinear stress, structural dynamic and aeroelastic finite element models. The structural dynamics model was correlated to a ground vibration test, both of which had to accommodate the apparent mass of the air, which is atypical. The ultimate test of the nonlinear stress model was correlated with the static wing load test, performed last summer. “Correlation with static load testing was so good that at first I did not believe it,” said D.J. Taylor, Principal Engineer for AeroVironment, the company developing the Global Observer. “All of the MSC Nastran models have proven valuable for addressing the various modifications and design changes inherent in a proof of concept / prototype effort, and will be even more useful in optimizing a production version.”

### Unusual Design Provides Unique Capabilities

The Global Observer completed its first flight August 5th, 2010 at Edwards Air Force Base. The hybrid-electric aircraft flew for the first time under battery power and will ultimately carry a liquid hydrogen-fueled propulsion system to power it through a high altitude, long endurance joint operational utility assessment planned for 2011. The Global Observer aircraft is designed to fly at an altitude of 55,000 to 65,000 feet for 5 to 7 days. In addition to flying above severe weather and altitudes that conventional aircraft fly at, operation at this altitude permits communications and sensor payloads on the aircraft to service an area on the surface of the earth up to 600 miles in diameter. The system is intended to provide mission capabilities that include persistent communications relay, robust observation over areas with little or no existing coverage, the ability to relocate as required by theater commanders, dedicated communications support to other unmanned aircraft systems and tactical, on-station weather monitoring and data support.

The unique capabilities of the Global Observer are provided by its unusual design in which a plane with a 175 foot wingspan is propelled by less than 100 horsepower. The complex design of the primary structure provides maximum strength and tailored stiffness at minimum weight, but also presents an enormous analysis challenge. The primary structure utilizes several combinations of graphite-epoxy, honeycomb and foam core materials that are highly tailored to meet the strength and stiffness requirements while simultaneously minimizing weight. The wing was tested to design limit loads and the fuselage tested to destruction.

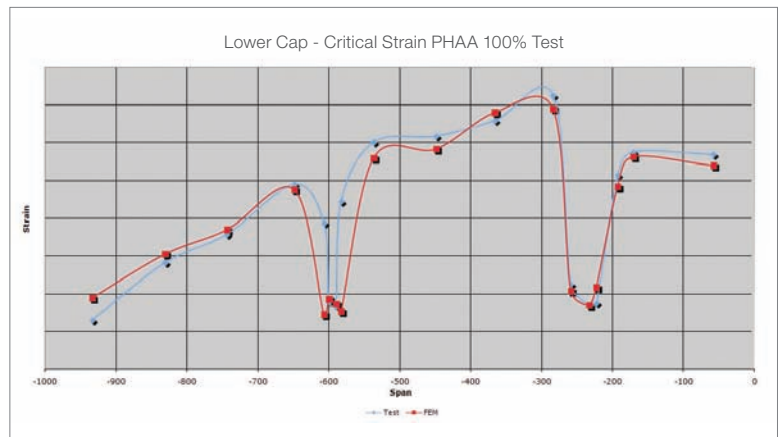
“We selected MSC Nastran to model the Global Observer because of MSC Nastran’s unique aeroelastic

**“Considering the magnitude of the analysis challenge and the potential for error in both the analyses and the test, the correlation is excellent.”**





**Figure 1: 175 Foot Wingspan of the Global Observer**



**Figure 2: Physical measurements and finite element analysis predictions for strain on the lower spar cap**

capabilities,” Taylor said. “Most important in this project is providing an aeroelastic solution that is coupled to a high fidelity structural model. Overall, MSC Nastran is a very good product that is upgraded regularly. Just as important is the quality of the support. Our MSC application engineer visits us at least once a month to see how we are doing and help us with any issues. When necessary, we can talk to experts like Dean Bellinger, Technical Engineer at MSC Software, who helped us with this model on several occasions. Our ability to model this plane was enabled by the support, on-site visits and consulting services provided by MSC.”

## Modeling the Global Observer

The first step was importing the solid CAD models into the MSC Patran modeling environment. MSC FlightLoads was used to generate aerodynamic loads for input into the stress model. For the ground-generated loads, an optimized composite landing gear model was used. The generation of the various structural models relied heavily on the extensive composites modeling capabilities of Patran. In general, standard elements and standard modeling techniques were used throughout. Composite shell elements with offsets were used to model the thin laminate structure. Solid elements were used for thick laminates and for the core. Patran can post-process up to 500 lamina. Breakout models were used for the rib-skin, rib-spar interfaces, control surface interfaces and motor mount interfaces as well as others. The software automatically interpolates between the relatively coarse mesh density of the global model and the much finer mesh density of the breakout model. This approach greatly increased

the accuracy of the results while keeping solution time at a reasonable level.

A Department of Defense (DoD), National Aeronautics and Space Administration (NASA) and AeroVironment team performed a series of wing load tests using a specialized fixture to apply loads to the 175 foot wing. The purpose of wing load testing was to demonstrate that the wing can withstand the stress experienced as a result of normal operation in turbulent air as well as requisite aircraft maneuvers. Figure 2 shows the finite element analysis predictions compared to the physical measurements of the strain along the length of the spar caps.

## Correlation Demonstrates Accuracy of Model

“The correlation between the simulation prediction and the physical measurements was extremely good considering the complexity of the structure,” Taylor said. “The difference between the predictions and measurements was higher at the wing joints at spans -223, -583 and -697 inches because the global wing nonlinear model did not attempt to capture the detailed features of the structure at these locations. Disregarding these points, the error averages about 5%. This is remarkable considering the potential error of the instruments used to measure strain in the wing tests and the complexity of the structure and materials. The difference between the simulation and physical measurements for the strain of wing skin was slightly higher. The skin is harder to model accurately. Considering the magnitude of the analysis challenge and the potential for error in both the analyses and the test, the correlation is excellent.”

The MSC Nastran models of the Global Observer have been used extensively during the test program. “We are making changes regularly to address issues that surface during the various test programs,” Taylor said. “The MSC Nastran models have helped considerably in addressing these issues. For example, we might need to drill an unplanned hole for instrumentation at various locations on the structure and need to know if it may have any structural implications. Before we perform any modification, we look at the analysis or rerun the analysis with the proposed modification to ascertain the structural implications. As we transition to production, the MSC Nastran models will be used even more extensively, specifically in an optimization sense.

The correlated MSC Nastran models give us a high level of confidence for our future design efforts on Global Observer and we fully intend to vigorously exercise the parametric design and optimization tools built into the MSC environment to take weight out of the aircraft to further enhance its performance.” ■

This article was based on an interview with D.J. Taylor, Principal Engineer for AeroVironment.

Special thanks to Jerry Fireman with Structured Information, for his Writing Services.





# Certified To Fly

ADA Certifies Aircraft with a New Store Using Measured Modal Parameters



## AERONAUTICAL DEVELOPMENT AGENCY (ADA)

**F**ighter aircraft typically carry a number of different under-wing external stores such as fuel tanks, bombs and missiles. The geometrical and inertial parameters of these stores have an influence on the flight envelope and the flutter characteristics of the aircraft. An imported aircraft is certified by the Original Equipment Manufacturer (OEM) for the carriage of certain stores within a specified envelope. However, if the country which has acquired the aircraft decides to integrate a new store, then it has to either approach the OEM to help in the certification process or devise a mechanism to carry out the exercise itself. The former approach has a twofold disadvantage, including violation of secrecy and also the prohibitive cost. Hence, it is imperative that an independent approach, along with the local certification authorities, be evolved to achieve the required objective.

### Assisting with Flight Certification

One of the aircrafts in the inventory of the Indian Air Force had to be integrated with a new store which the aircraft under consideration was not certified to fly with. At this juncture the Aeronautical Development Agency (ADA), located at Bangalore, was approached for assisting in obtaining the necessary flight certification. ADA was established in 1984 to oversee the design and development of the Light Combat Aircraft, Tejas. During the

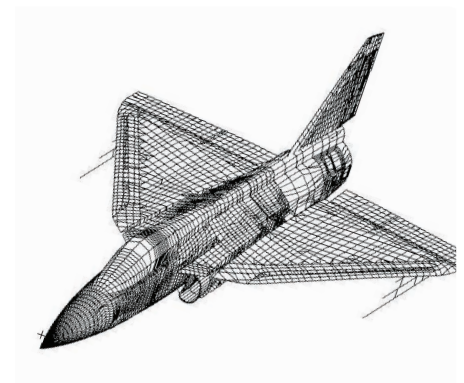
course of this program, ADA has acquired expertise in various areas of Computer Aided Design (CAD), Computer Aided Engineering (CAE), Computer Aided Manufacturing (CAM), Avionics, Systems, Independent Validation and Verification and Flight Simulation.

One of the areas in which ADA is acknowledged as an authority in the country is in the area of Loads, Structural Dynamics and Aeroelasticity. The group which is responsible for this task is part of the Airframe Directorate of ADA. This group was charged with the responsibility of formulating a strategy for obtaining the clearance for integrating the new store on the aircraft under consideration. The task of formulating the strategy and implementing it to certify the aircraft with the new store was completely handled by Mr. Dhandabani V., Dr. Hemalatha E. and Mr. Kamesh J V. of ADA, and Shripathi V. of CSM Software, Bangalore, India. CSM software is a provider of Engineering Services and also a business partner of MSC Software. Through its partnership with MSC Software, CSM has helped many companies accelerate innovation and generate a higher return on investment.

This case study primarily deals with the clearance of the Altitude – Mach No. envelope of the aircraft, with the new store, which is essentially based on flutter computations.

### The Novel Methodology

The method developed by ADA takes advantage of the fact that flutter computations are carried out in the modal domain and that modal parameters can also be generated by Ground Vibration Tests (GVT). GVT data is normally used to measure Aircraft modal characteristics and to verify and update analytical vibration models. In GVT testing, soft support systems are used to simulate the unconstrained boundary conditions that an aircraft experiences during flight. The aircraft is excited through the use of electrodynamic shakers. Accelerometers are used to measure the response of the structure. A data acquisition and analysis system is used to acquire the data and extract modal parameters from measured data.



Full FE model of the aircraft on which the method was validated

ADA analysts validated the new method on an aircraft (Aircraft-1) for which a complete FE model was available. They created a dummy FE model of this aircraft in MSC Patran with a small number of nodes; one for each accelerometer used in GVT. The nodes were connected with 2D CQUAD and TRIA elements. Mode shapes were visualized in Patran to check the quality of the data and the import process.

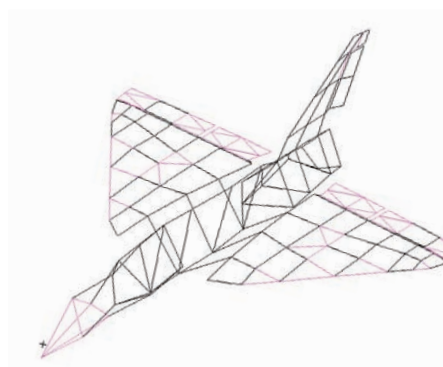
MSC FlightLoads was used to create a 2D aerodynamic model using plan form geometry. The aerodynamic and structural models were then coupled for flutter computations at the required altitude and speed levels. MSC Nastran Aeroelasticity I and II were used to determine the unsteady air loads due to the structural vibration modes at various altitudes and speeds.

The MSC Nastran Direct Matrix Abstraction Programming (DMAP) module was used to update the structural model by replacing the modal mass, stiffness and mode shape matrices with the data measured in GVT. The DMAP module provides the ability to modify MSC Nastran's prewritten solution sequences or write customized solution sequences to solve specialized problems. DMAP delivers a high-level, flexible, and powerful programming language that allows users to expand MSC Nastran's capabilities by writing their own applications and installing their own custom modules. DMAP has its own grammatical rules and compiler built inside of MSC Nastran that provide matrix operations for the manipulation and creation of data blocks for use by MSC Nastran or other programs.

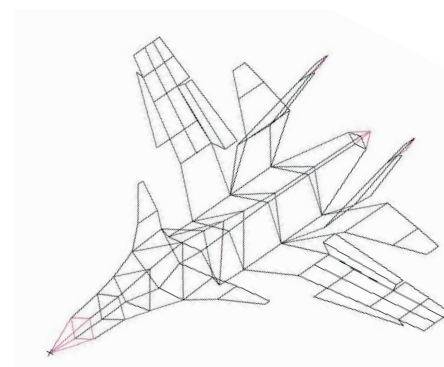
Altitude	Flutter Characteristics (Mach)		
	Store 1	New Store	Store 2
Low	2.66	1.68	1.52
Medium	3.01	1.89	1.55
High	3.57	2.31	1.69

**Flutter speed and frequency for aircraft requiring flutter clearance**

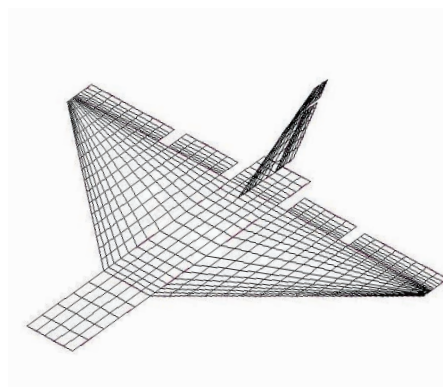
The methodology described above was used to predict the flutter characteristics of the aircraft for which FE data was available using MSC Nastran for flutter analysis. The flutter results using GVT data also matched up well to those obtained from the FE model. The Mach numbers show the speeds at which the analysis predicted that flutter would occur.



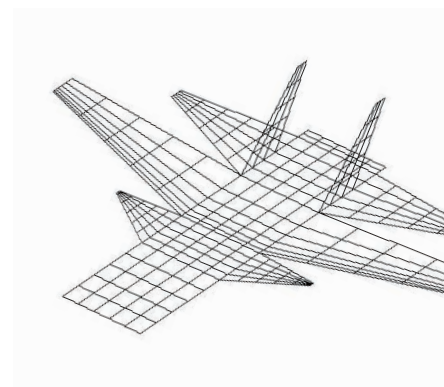
**FE model of the aircraft generated from accelerometer locations in GVT**



**Dummy finite element model of aircraft requiring flutter clearance**



**Aerodynamic model of aircraft used for validation**



**Aerodynamic model of second aircraft**

Altitude	Flutter Characteristics			
	Detailed FE Flutter Analysis		Model Based on GVT Data	
	Mach	Freq (Hz)	Mach	Freq (Hz)
Low	1.39	12.7	1.41	13.04
Medium	1.69	12.7	1.54	12.5
High	2.18	12.7	1.88	13.03

**Flutter results based on full FE model vs. results obtained from GVT data for the validation study**

## Application of the Methodology to Aircraft under Consideration

The excellent correlation between FE based flutter analysis and flutter analysis based on GVT data validated the use of this method on the second aircraft, the one with a new store requiring flutter clearance. The same method described above was used to calculate the flutter characteristics of this second aircraft. The image above show the primary flutter speeds and frequencies obtained from the analysis at different altitudes for the new store. The results show that the flutter speed of the new store lies between two previous certified stores, Store 1 and Store 2, in the majority of cases. Based on this study the certification authorities cleared the aircraft for carrying the new store.

**“The excellent correlation between FE based flutter analysis and flutter analysis based on GVT data validated the use of this method on the second aircraft, the one with a new store requiring flutter clearance.”**

The method of using GVT data to drive a FE analysis has been used previously but this application is believed to be the first time that flutter clearance has been based on GVT data. This approach made it possible to quickly and efficiently evaluate the flutter performance of the aircraft with the new store. ■

This article was based on an interview with Dr. Hemalatha E. of ADA, Shripathi V. of CSM Software. Special thanks to Jerry Fireman with Structured Information, for his Writing Services.



# Simulating Manufacturing Processes

## Setforge Simulates the Forging Process & Reduces Maintenance Costs

### SETFORGE ENGINEERING

#### The Challenge

An acknowledged specialist in the manufacture of forged products, Farinia Group set up its Setforge Engineering unit to provide its other companies and their customers with leading-edge expertise in forging technologies. One of the major missions undertaken by the unit's engineers and project managers was to find a way of successfully simulating the electro-upsetting process, used to make very long sectional parts.

#### The Solution

To define an initial digital model and simulate the electro-upsetting process, the company used MSC Patran, a multidisciplinary pre- and post-processing environment, in combination with MSC Marc, advanced nonlinear analysis software, both components of the AFEA bundle from MSC Software.

#### The Know-How

French group Farinia acquired Setforge in March 2009. Farinia already owned a number of forges as well as foundry and machining facilities, and the acquisition of Setforge made it France's Number 1 forging specialist and one of the leading European groups in the sector.

Farinia adopted the name Setforge for its forging business, and with seven French plants, the division provides nationwide coverage for all hot and cold forging techniques including crank, screw and hydraulic presses, and hammers, while presenting a diversified services portfolio supporting:

- A range of metals including steel, stainless steel, titanium, brass and aluminum
- Industries including automotive (cars and trucks), aerospace (notably for high-value materials), civil engineering, energy, construction, and other sectors
- All production volumes: from one-off parts to multi-million unit runs.

Soon after reinforcing its forging business with the acquisition of Setforge, Farinia Group decided to set up an eighth entity, Setforge Engineering. From its base at the L'Horme plant in the Rhône-Alpes region of south-east France, the unit provides the group's forges with capabilities in joint development and R&D, while monitoring the state-of-the-art in forging technology.

Each plant answers customer inquiries at its own design office, but can also draw on a pool of human and material resources to address more specific demands, as well as offer appropriate, economically viable alternative processes. All forging technologies have their advantages and shortcomings, and all are subject to competition from other manufacturing processes.

#### Electro-Upsetting Technology

Long sectional parts like driving wheel shafts, axles, spindles and cylinder rods are among the mechanical parts for which all conventional forging techniques have their limits, notably the risk of buckling. This is why industrial customers do not always source this type of product from forges.

However, one forging technique is particularly good at this type of work. It consists of using the Joule effect by sending a strong electric current through a length of around 10 cm of the stock or "billet" to maintain one end at forge temperature, and then applying a hammer blow that shapes the stock against the anvil. This is the technique known as electro-upsetting. It delivers several advantages over other manufacturing processes such as machining. These include raw material savings and better fiber quality. The initial diameter can be multiplied by a factor of up to twenty.

In reality, the electro-upsetting is not the first stage in the manufacturing process, as induction is used to raise the temperature in

the area concerned by the operation. Neither does it yield the finished shape. However, it does go a long way to producing the finished part, the last stage being conventional stamping.

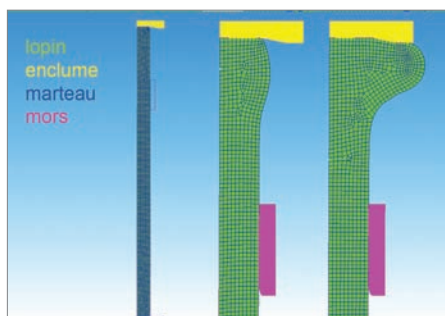
Within Farinia Group, the companies Barriol & Dallièr Industries and Setforge Electroforge are experts in electro-upsetting and have their own production resources. Electro-upsetting is a proven technology, but the group felt that it was strategically important to gain more insights into the influence of a number of associated factors, and this is where the team at Setforge Engineering came in.

#### Simulation Resources

When Setforge joined the group, Farinia took the opportunity to review its simulation resources. Nicolas Behr, Chief Project Engineer at Setforge Engineering explains: "We realized the limits of the tools we were using and that their maintenance cost was too high relative to their capacities. What's more, because of some of the methods used by the group – especially electro-upsetting –



The part is shaped firstly by upsetting (in the background).



**The billet (in green) is heated to the temperature of the forge between the jaws (in mauve) and the anvil (in yellow) and is crushed between the hammer (in blue) and the anvil**

we had to model and simulate the nonlinear multiphysics phenomena that characterize these technologies.”

Setforge Engineering chose the Patran and Marc simulation solutions from MSC Software because they met these requirements, and then asked the MSC Software engineering services team in Lyons to conduct a mission. “We were still learning how to use these solutions, and this initial study looked complex. We thought it would be better to bring in the specialists”, admits Nicolas Behr.

“Electro-upsetting is affected by electrical, thermal and mechanical phenomena involving complex sets of parameters. We asked MSC Software to develop a first model to see whether the results of the simulation matched our experience on the shop floor.”

Alain Crozier, Senior Technical Consultant in the MSC Software team explains what is so special about the missions undertaken by the entity: “Our customers have experience and know-how in what they do and we have experience and know-how in simulation. Putting the two together delivers results. Our methods of investigation and the way we present our results also enable our customers to develop their skills in using the software.”

Parts shaped by upsetting are axisymmetric – though the finished part may not be – so a 2D representation is enough to work on. It is not the geometry that makes modeling these parts so complex; it is defining the parameters that will affect the calculation. These include:

- The electrical, thermal and mechanical properties of the material
- The laws governing the material flow
- The mechanical contacts and forces applied
- The power, electrical intensity and electrical process control
- The characteristics of the interaction with the environment (the temperature of the part can rise to 1,000°C at some points)

## The First Model

Setforge Engineering asked to see a presentation of the model and the simulation 30 days after the start of the mission.

“Not only did the MSC Software team in Lyons do the job within the timeframe but the results proved that we had made the right choice”, says Nicolas Behr. “We were able to compare a virtual video of the deformation generated by Patran with real video footage shot in one of our plants. The match was impressive.”

The team at Setforge Engineering can now tweak the parameters in the first model to analyze more closely the influence they have on the process.

Other steps are now needed and Setforge Engineering, in agreement with the management of the Farinia Group, has decided to continue working with MSC Software to improve the digital model and fine-tune the simulation.

The first test showed that to reflect the reality of the process more accurately, the parameters would have to be enriched.

“Of course, our first iteration was a relatively simple digital model,” explains Alain Crozier, “but the results were encouraging and enabled us to identify ways that we could improve it. For example, we think that we should consider the heat distribution in the tools during the material flow. We also worked on the assumption that the initial temperature in the deformed zone of the billet was homogeneous, while in reality the temperature is raised beforehand by induction. Because Marc also supports electromagnetic phenomena, it will be interesting to see whether this gradual and probably non-uniform rise in temperature has an impact on the result.”

The simulation was carried out using standard versions of Marc and Patran software with no need for custom developments.

The deformations were on such a large scale that we had to automatically regenerate a mesh of the billet during the simulation. This is a standard function of Marc and Patran.

The results are displayed in a range of different formats including:

- Time-dependent deformed shapes and real-time animations.
- Change of voltage and electrical intensity in the part
- Temperature gradient
- Mechanical deformations and constraints on the billet

## Perspectives and Benefits

Even though this first simulation is only the first step towards a more comprehensive model, Setforge Engineering is already anticipating the potential gains.

“Right now, to prove feasibility and look for ways to optimize the upsetting process, we still have to use physical tests which are costly in terms of materials and tying up personnel

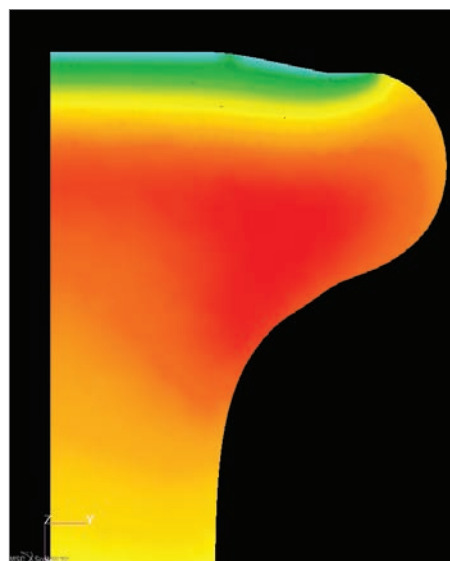
**“We now know that we can also gain a lot from using the solutions from MSC Software, from their teams’ know-how, and from their ability to listen to and collaborate with their customers.”**

and machines”, explains Nicolas Behr. “We know that we can impact a very wide range of parameters and that is why we are optimistic about the gains that the MSC Software solutions can deliver. Through a better understanding of the technology, we also hope to offer this production method more often as an alternative to other competitive processes.”

Setforge Engineering also uses Marc and Patran for other applications and provides technological guidance for the factories and their customers. The simulations and graphic results will be especially useful in illustrating the technical arguments used to support their recommendations.

“For all our projects, we aim to achieve the best cost/performance ratio by drawing on the forging skills that we have within the Group,” concludes Nicolas Behr. “We now know that we can also gain a lot from using the solutions from MSC Software, from their teams’ know-how, and from their ability to listen to and collaborate with their customers.” ■

This article was authored by Nicolas Behr at Setforge Engineering (Farinia Group) with input from Alain Crozier, MSC Software France office



**Temperature gradients upon completion of the deformation**



# MSC Software TECH TIPS



## Fatigue



By Joe Satkunananthan  
Manager, Marc Technical Support Americas  
MSC Software

### Types of Fatigue Analyses

**What kinds of fatigue analyses can be performed using MSC Fatigue software?**

- Total Life (Stress-Life) fatigue analysis – also called S-N Analysis
- Crack Initiation (Strain-Life) fatigue analysis – also called E-N analysis
- Crack Growth (Linear Elastic Fracture Mechanics) analysis – also called LEFM analysis.
- Factor of Safety analysis for Total Life and Crack Initiation analyses.
- Weld Analysis (Spot weld and Seam weld)
- Rotating Structure analysis using the wheel module
- Duty Cycle Analyzer
- Vibration fatigue analysis (In time and frequency domains)

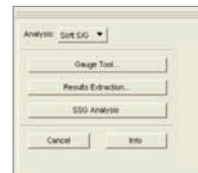
**What situations dictate the use of different fatigue life analysis?**

- Total Life (S-N)
  - Components need to survive high cycle fatigue life
  - Where there is very little or no plasticity, since this method is based on nominal stress
  - Components where crack initiation, crack growth is not appropriate (composites, welds, plastic and other non-ferrous materials)
  - Spot weld analysis and random vibration induced fatigue problems
  - When S-N data available and E-N data not available
  - When components need to be designed for fatigue using Standard data such as MIL handbook
- Crack Initiation (E-N)
  - Most defect free, metallic structure or components
  - Components that experience short lives (low cycle fatigue) where stress levels are close to or above yield stress
  - When crack initiation is the important failure criterion – safety critical components
  - Identifying the locations where crack would initiate to consider crack growth analysis
  - Evaluating the effects of different materials and different surface conditions
  - Components made from metallic isotropic ductile materials which have symmetric cyclic stress-strain behavior
- Crack Growth
  - Pre-cracked structures or structures which much be presumed to be cracked during manufacturing for example due to welding process
  - Pre-prediction of test programs to avoid testing components where cracks will not grow
  - Planning inspection programs to checks are carried out with the correct frequency
  - To simply determine the amount of life left after crack initiation
  - Components which are made from metallic isotropic ductile materials which have symmetric cyclic stress-strain behavior

### Test Correlation Tool

#### Software Strain Gauge (Soft S/G) tool in MSC Fatigue

MSC Fatigue has a special tool called Software Strain Gauge (SSG). This tool can be used to correlate measured responses in a test with those extracted from finite element analysis. This is done by simulating strain gauges to the surface of the finite element model in the same position as the real strain gauges used.



In Patran, you can find the Software Strain Gauge (Soft S/G) in the MSC Fatigue Main Interface form.

Once the Analysis is set to Soft S/G, the following two basic steps should be executed in order to properly use this tool:

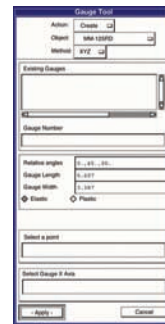
1. Create (or Modify) the gauges
2. Extract results from the finite element model to gauge elements

For further details, refer to MSC Fatigue User's Guide Chapter 11.

### Creating and Modifying Gauges

The gauge tool allows you to create, modify and delete software strain gauges from your model. The gauges are simply made up of rectangular shell elements placed on the finite element model. In the orientation of the actual strain gauge as defined in the gauge definition file (gauges.def).

Creating a gauge is quite simple. Just follow these steps.



**Step 1** - Set the Action to Create and pick the gauge type from the Object menu.

**Step 2** - Give the gauge a number.

**Step 3** - Toggle this switch to either Elastic or Plastic. Plastic enables the elastic-plastic correction in subsequent analysis with SSG.

**Step 4** - Select the point on the model here the strain gauge is to be placed.

**Step 5** - Select the x-axis definition for the gauge according to MSC Patran conventions. Then press the Apply button. After this, one more step is necessary.



**Step 6** - When you press the Apply button, the form updates itself and now requests that you select some shell elements or solid element faces around the point of interest. This defines the surface on which to create the strain gauge.

Press the Apply button a second time and the gauge will be created.

The following hints and recommendations are made when trying to create gauges.

1. The elements selected to define the surface where the gauge will be placed must describe an area larger than the gauge footprint, otherwise the creation will fail and an error message will be issued.
2. Do not try to place gauges on top of "sharp" geometric features such as corners. The surface where the gauge is to be placed should have a radius of curvature which is large relative to the gauge dimensions.
3. Select as few elements as possible, but sufficient to define an area larger than the gauge. Selection of extra elements will result in longer creation times.

# Nastran



By John Lee  
Sr. Manager, FE Technical Support Americas  
MSC Software

## Optimization Techniques

Optimization Studies using External  
Superelements with MSC Nastran

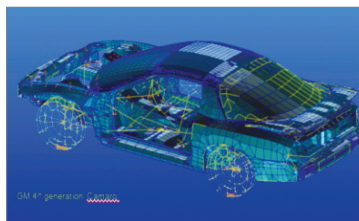
### Automatic External Superelement Optimization (AESO)

Optimization is an efficient and automated tool for designing structures. This tool has been available since very early versions of MSC Nastran. Constant enhancements, as related to this capability, have been added to subsequent versions of MSC and MD Nastran.

A typical optimization statement consists of an objective function (the most critical goal - minimizing the weight), constraints (stress not to exceed certain levels), and design variables (areas that you can change - example, thickness of a panel). As a structural analyst who has never used optimization before, if this sounds familiar to you, it's because you have been using this same process—it's just that it's a manual process (multiple re-analyses), rather than an automatic process using optimization.

In Nastran MDR2 (v2007), an automated external superelement analysis method was introduced that automatically creates the external superelement, along with the design model that is needed for subsequent optimization analysis. This combination (whether it's the automated method AESO or the manual method) is a powerful tool that is under-utilized. The article shows the benefits of performance gain when using this feature.

A GM 4th generation Camaro is used for this study.  
The model information is shown below.



Total # of DOFs	126,278
DOFs in the residual	315
# of elements	30,886
Input load	random
# of frequencies	61
# of response points	3
# of design variables	9

### Model Description

For this problem, we are interested in minimizing the PSD response at the driver's and passenger's seat due to a random input at the wheels. The design model consists of the support structures for the engine mount.

	Initial Objective Function	Final Objective Function	# of Design Cycles
One shot run	0.153	0.133	9
AESO Assembly Run	0.153	0.131	10

### Results

# of times analysis is performed	One shot run	One shot run - total elapsed time (sec)	AESO External SE Reduction Run - elapsed time (sec)	AESO Assembly Run - elapsed time (sec)	AESO Run - total elapsed time (sec)
1	1503	1503	187	65	252
2	1503	3006	0	65	317
3	1503	4509	0	65	382
n	1503	(n*1503)	0	65	187 + (n*65)

### Performance Summary

The elapsed time for the one shot optimization run is 1503 seconds. The elapsed time using the AESO method is 252 seconds (187 seconds for the reduction run plus 65 seconds for the residual optimization run). This is a performance increase of 6 to 1. This performance ratio is even more drastic as the number of times that you have to redo the analysis for the design model increases. For example, if you have to redo this analysis for the design model 10 times, the performance ratio becomes 18 to 1 (15,030/837). How often do we only analyze the structure once?

# Adams



By Kent West  
Manager, Adams Technical Support Americas  
MSC Software

## How To Save Time

Save Time Using Analytical Contacts in MSC Adams

Did you know that Adams/Solver considers some types of geometry as perfect, analytical shapes in CONTACT statements? Most contact geometry in Adams is wrapped with a fine mesh; this mesh is used to efficiently calculate geometry proximity during solution for the CONTACT force element. Recent Adams/Solver releases have introduced the idea of analytical contact geometry. Analytical geometry representations are superior to meshed equivalents for most applications, especially rolling applications. A good example is the crane in Figure 1, having a main (red) roller that rides on a supporting beam section: representing the roller geometry as a perfect cylinder, rather than a meshed representation, will produce smooth forces and faster, more robust, simulations.

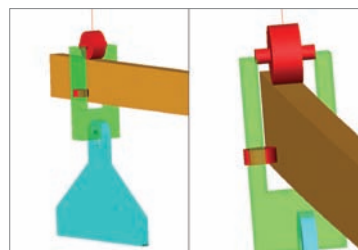


Figure 1

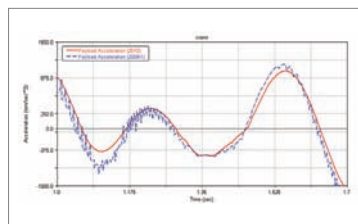


Figure 2

Figure 3 shows the CPU usage for this model in Adams 2010 and 2008r1: note how the 2010 simulation completes in half the time required by 2008r1.

Table 1 lists the available analytical geometry types. Note carefully that only the I-geometry (first geometry) in the CONTACT statement will be considered as analytical. The J-geometry (second geometry) is always meshed, as is any imported (external) geometry. Ideal

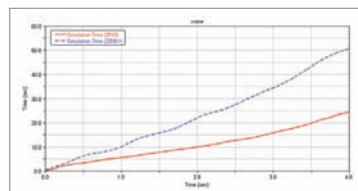


Figure 3

Cylinders were introduced as analytical contact geometries in the 2010 release of Adams. Figure 2 shows the acceleration time history for the roller above in Adams 2008r1 and Adams 2010; note the smooth profile in the 2010 results due to the perfect cylinder representation. Faceted geometry, as for the cylinder representation in 2008r1, can produce undesirable high frequency content as the facets come in and out of contact in a discrete manner.

The smoother forces from analytical contact geometry not only look better in post-processing, but lead to faster, more robust simulations.

geometry with features (holes, chamfers, etc) is similarly meshed by default. Building a model carefully to take advantage of the analytical contact geometries should result in significant simulation time savings, more robust solutions and smoother contact forces.

Adams Release	Analytical CONTACT Geometries
2010	Sphere, Ellipsoid, Cylinder, Box
2011	Sphere, Ellipsoid, Cylinder, Box, Frustum, Torus

Table 1

For more MSC Software Tech Tips, go to:  
[simcompanion.mscsoftware.com](http://simcompanion.mscsoftware.com)



# High Performing Mechanisms

MSC Adams Helps Reduce Expensive Trials  
**SYSTEM DESIGN EVALUATION LTD.**



In the design of any new high explosive ammunition, the most complex and often problematic component is the fuze system. The fuze must incorporate a Safe and Arm device to ensure that the projectile may only enter the armed state following exposure to firing forces and after reaching a safe distance from the muzzle of the weapon. Engineers at System Design Evaluation Ltd. (SDE) in Hertfordshire, UK have constructed rigid and flexible body MSC Adams models to study the motion and strength of the design of fuze mechanisms to identify potential design issues and assist with analysis of trials results.

“Conducting live firing ammunition trials is an expensive business,” said Eva Friis, Project Manager for the APEX ammunition development programme at Nammo Raufoss, Norway. “Analysis of recovered fuzes to determine the cause of failure is little short of forensic science and it is difficult to know how the forces imposed during recovery of the projectile affect the results. The Adams simulations have provided an insight into the operation of the fuze and enabled the team to highlight and address weaknesses with the design before manufacture and physical testing.”

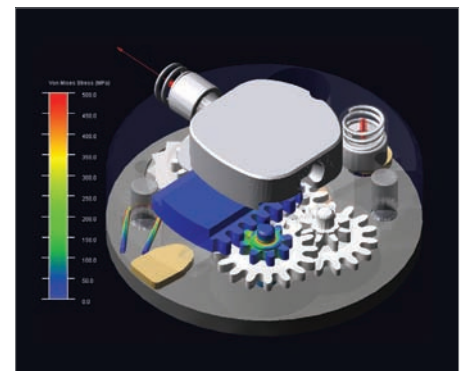
## Physical Testing Does Not Give The Whole Picture

The Nammo 25mm APEX projectile is a next generation armour-piercing, high-explosive ammunition designed for use with the US F-35 Joint Strike Fighter aircraft. The projectile leaves the muzzle of the 4-barrelled GAU-12 weapon system with a velocity of around 1,000m/s and experiences a peak setback acceleration of almost 80,000g. Under these conditions, coupled with severe space restrictions, it is almost impossible to instrument the fuze in order to gain an understanding of the operation and interaction of components inside. Therefore, while physical testing can be used to confirm functionality of the fuze, it often offers only limited information for post analysis in the event of a failure to function.

Adams modeling has proven invaluable in providing information to assist with the diagnosis of evidence gained from recovery tests. In one case, examination of the internal components of the fuze after recovery tests showed markings which indicated a malfunction had occurred. A detailed flexible body Adams model of the design was developed, and analysis confirmed the nature of the problem and sequence of events within the fuze mechanism; huge centrifugal forces due to

projectile spin resulting in deformation of internal components sufficient to result in the unlocking of two retaining gears.

Computer modeling of ammunition fuzes has not been without challenges. Safe and Arm devices are often mechanical and operate using clockwork escapement mechanisms, similar to those found in wrist watches. Such mechanisms rely heavily on 3D contact, leading to extended run times. Further, fuze arming times are largely dependent on the definition of frictional algorithms within the models. SDE has worked closely with fuze manufacturers to overcome this and validate models against static spin tests thereby providing a firm basis from which to investigate further design permutations.



**Adams flexible body modeling of a high explosive projectile fuze Safe and Arm Device to examine kinematic functionality and strength of design**

## Finding The Right Software Tool

Engineers at SDE began providing computer aided engineering support to the Nammo Raufoss APEX development programme in 2004 during the conceptual design phase. Early Safe and Arm fuze modeling work was undertaken using rigid body kinematic analysis software. However, customer requirements to undertake combined analyses of component strength within more complicated assemblies prompted a search for replacement software. Numerous commercially available packages were evaluated but none were found to offer the flexibility of Adams in allowing rapid and fully integrated analysis of both the kinematic functionality and strength of design of complex mechanical systems.

The flex to flex contact capability provided by Adams has aided significantly in simplifying the modeling of the escapement systems commonly found in mechanical Safe and Arm devices.

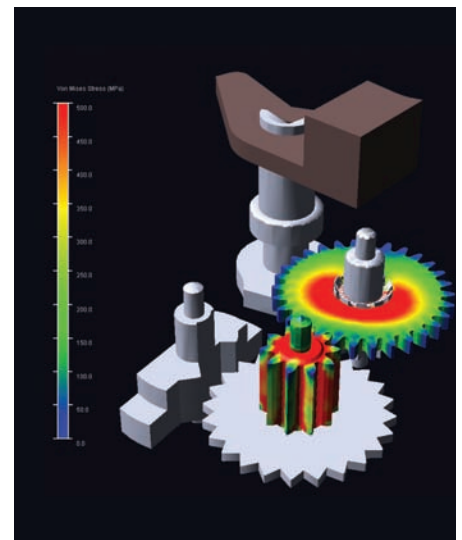
**“Adams has provided significant guidance to the design and development effort, reducing the number of expensive trials required and, therefore, the overall cost of the development programme.”**

In particular, due to the reciprocating nature of the regulator component, considerable forces may be dissipated throughout the gear train. This can sometimes lead to catastrophic failure of the components due to shearing of gear teeth, resulting in premature arming of the fuze. The components of such mechanisms can be modeled as flexible bodies within Adams allowing an assessment to be made of the stresses and strains developed in each part during operation.

The Adams results have not only successfully predicted the failure of components on numerous occasions within various fuze designs, but have also facilitated in the redesign of components to achieve suitable strength. Importantly, by quantification of stresses within components, Adams has assisted in proving compliance with required safety factors, information which is not possible to glean from live firing trials results.

### Adams Used to Assess Fuze Sensitivity

The Apex fuze is designed to provide a short delay, after impact, before initiating the high explosive fill in order to allow the projectile to first penetrate the target and deliver maximum blast and fragmentation effects inside. To achieve this, the impact delay mechanism must be robust but sufficiently sensitive to normal and oblique impact angles. SDE have used Adams, coupled with hydrocode predictions of axial and spin deceleration, to simulate the motion of the impact mechanism and assess the sensitivity of the fuze to impacts with various target materials at different impact velocities and angles of obliquity.

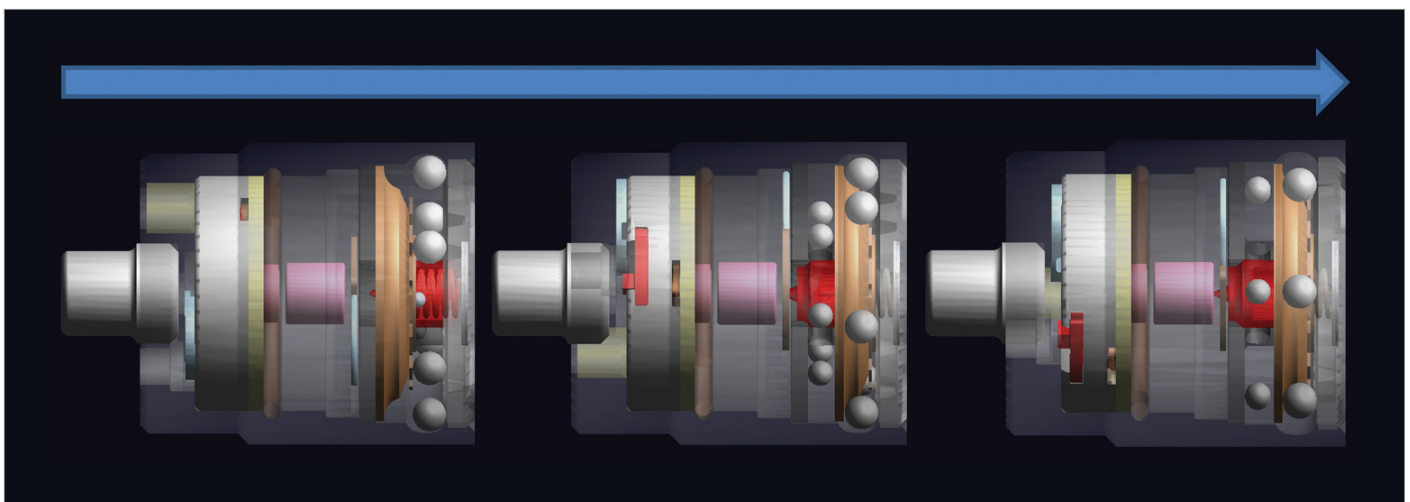


**Detailed Adams flexible-body modeling of a fuze escapement mechanism allows you to see stress results real-time.**

The sensitivity of the fuze is critical to ensuring a high probability of success. Through the use of Adams to simulate and optimize the design of the impact mechanism, the successful function of the Nammo 25mm APEX round against a wide range of targets is ensured.

“Adams has played a significant role in identifying and, importantly, quantifying the magnitude of issues in one of the most technically challenging areas of ammunition design,” concluded Eva. “It has provided significant guidance to the design and development effort, reducing the number of expensive trials required and, therefore, the overall cost of the development programme.” ■

This article was authored by Scott Bradley, Design, Modeling & Simulation Lead, System Design Evaluation Ltd.



**Adams rigid body modeling of a fuze impact delay mechanism to determine sensitivity to impact at various velocities, angles and with different materials**



# Seeing is Believing

## Improving Performance of Optical Systems

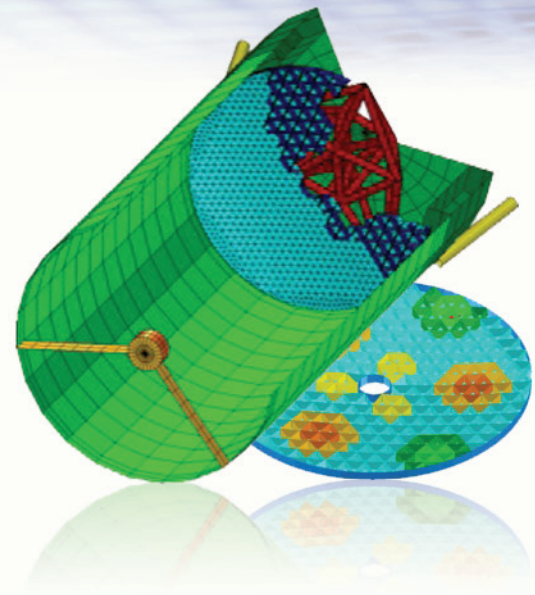
### SIGMADYNE

#### Environmental Factors Degrade Optical Performance

When optical systems become exposed to a non-ideal environment, their optical performance degrades. For example, a lens system which was designed to produce high quality images may produce poor quality images when subjected to the thermal effects of a laser beam. Some of the energy in the beam is absorbed by each lens, causing temperature gradients throughout each lens that deform the lens surfaces. A second effect of the temperature gradients is a change in the indices of refraction, optical material properties that are dependent on temperature. A third and less important effect is that the temperature gradients induce stresses that also change the indices of refraction. These combined effects cause image quality to decline.

As any camera buff knows, another common environmental factor affecting optical performance is vibrations. Any optical imaging system which produces quality images in a stable condition will produce lower quality images when subjected to vibrations coming through its support condition. In the case of a handheld camera the source of vibration is the instability of the person holding it. In the case of a high performance imaging system possible sources of vibration are cooling equipment, altitude control gyroscopes, aircraft vibration, and other ambient vibration sources.

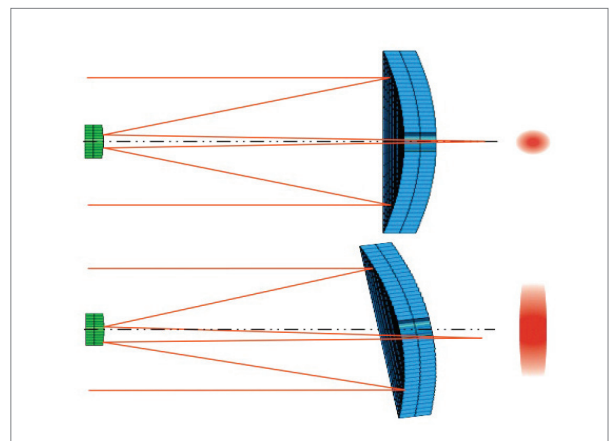
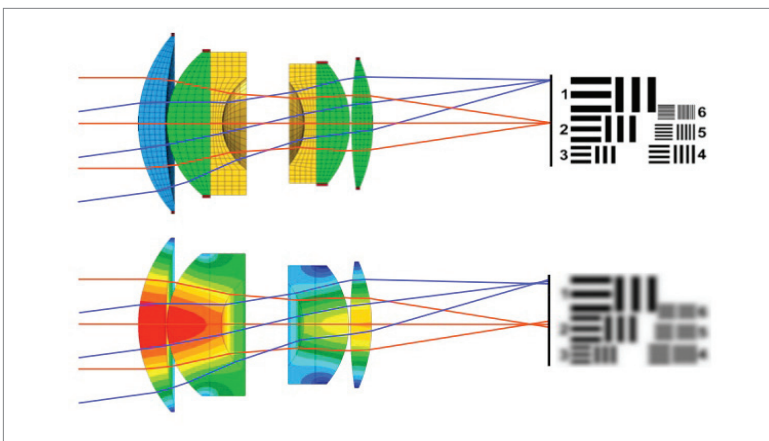
A good design team must be able to predict the effects of the environment on their optical system in order to optimize their design to mitigate such effects. Such performance prediction requires the proper tools. In the examples above,



MD Nastran can predict the mechanical behavior quite well. To predict optical performance, SigFit is required to convert the results from MD Nastran into a form suitable for optical analysis software.

#### Integrated Optomechanical Analysis

Integrated optomechanical analysis combines finite element thermal and structural analysis with optical analysis. In the lens example, the temperature gradients predicted in a heat transfer analysis conducted in MD Nastran are imported into SigFit and converted to index change effects to be passed to an optical analysis. Those same temperatures cause deformations of the optical surfaces and stresses throughout the transmissive optical elements and may be predicted in a thermoelastic analysis using MD Nastran.



These deformations and stresses are processed by SigFit for input to the optical analysis. With these inputs, the optical analysis program can be used to predict the combined effects of the temperature gradients on optical performance.

SigFit handles several practical issues associated with converting finite element data to optical input data, such as coordinate system transformations, unit conversions, and surface numbering. SigFit is most commonly used to generate such output as best fit rigid body motions and polynomial coefficients while accommodating each optical analysis code's conventions of ordering, normalization, and format for the polynomial coefficients.

## Improving the Performance of a Telescope

The greatest power of the integrated analysis approach is best demonstrated by combining SigFit with MD Nastran's optimization capability. In this example, a telescope with an adaptive, lightweight primary mirror is optimized for the best geometry based on optical performance metrics.

The design variables were the mirror front and rear faceplate thickness and the mirror core thicknesses at eight separate regions. This allowed thickness increases near actuators to improve performance.

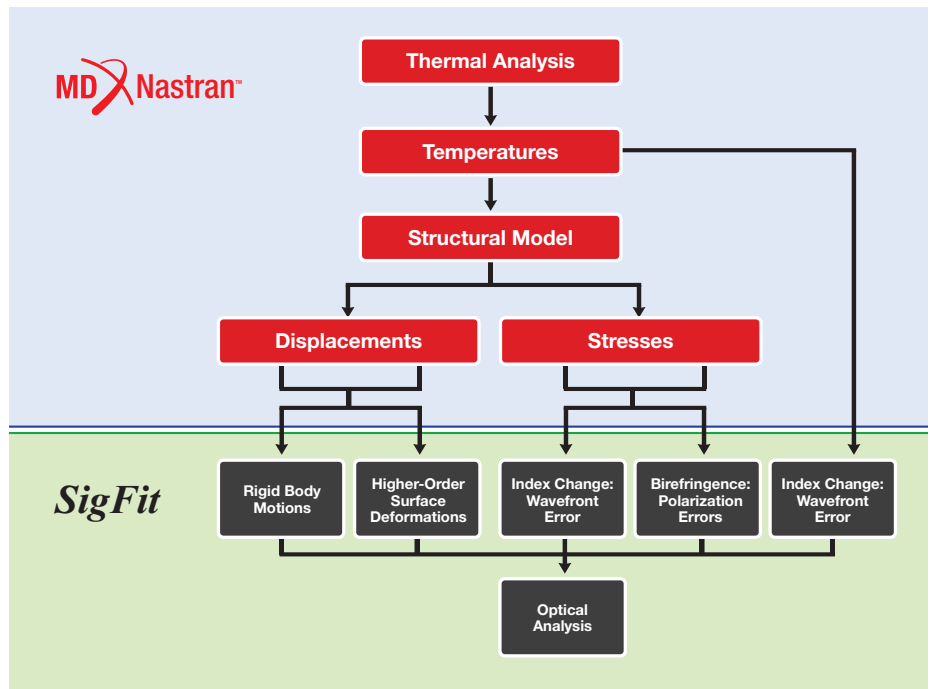
The objective was to minimize mirror weight, while satisfying constraints on natural frequency and launch stress. Constraints on optical performance were included as surface RMS limits in 1g test and an isothermal peak temperature change. The surface RMS constraints were on the adaptively corrected surface. This required SigFit to be called by MD Nastran as a DRESP3 call in solution 200.

As can be seen from the results table, MD Nastran reduced the weight by a factor of two, while maintaining the required optical and structural performance metrics.

## Other SigFit capabilities

SigFit has other capabilities closely coupled to MD Nastran.

- SigFit will calculate line-of-sight equations for an optical system and write those in MD Nastran MPC format using the finite element model's node numbering and coordinate systems.



## "MD Nastran reduced the weight by a factor of two, while maintaining the required optical and structural performance"

- SigFit will write best-fit polynomial coefficients for optical surfaces in MD Nastran MPC format. These coefficients are accurate for thermal or mechanical loads.
- SigFit will write residual surface RMS after selected polynomials are subtracted as MD Nastran DRESP2 entries for use in optimization.
- SigFit's adaptive analysis capability will solve for actuator forces required to minimize surface RMS error. If desired, the genetic optimizer will choose the actuator locations which provide the best corrected surface.
- SigFit will read MD Nastran modes output, then conduct harmonic or random analysis within SigFit to determine optical MTF (modulation transfer function) effects due to line-of-sight jitter effects.

Response	Initial Design	Optimized Design	Requirement
Thermally Induced Wavefront Error	9 nm	20 nm	20 nm
Gravity Release Induced Wavefront Error	54 nm	60 nm	60 nm
Peak Launch Stresses	1000 psi	1000 psi	1000 psi
First Natural Frequency	231 Hz	221 Hz	200 Hz
Weight	20.8 kg	9.9 kg	Minimum
Areal Density	53.0 kg/m <sup>2</sup>	25.2 kg/m <sup>2</sup>	Minimum

Optimized Primary Mirror

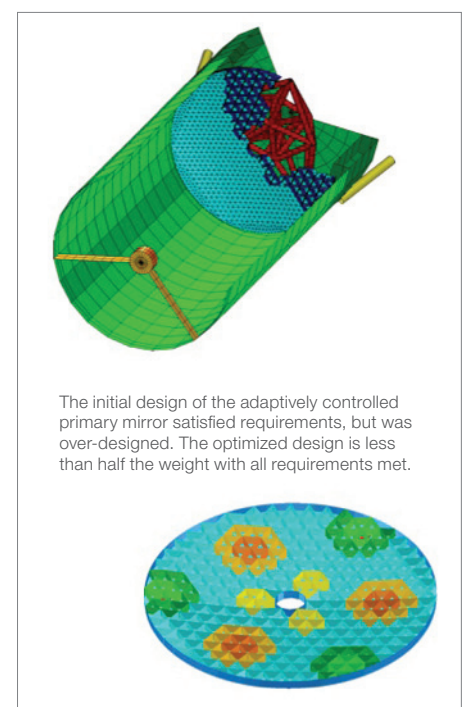
Additional information on SigFit is available at [www.sigmadyne.com](http://www.sigmadyne.com)

## Summary

MD Nastran and SigFit combine to create a powerful tool for improving the performance of optical systems. ■

Reference: Genberg, V., Michels, G., Doyle, K., "Optical interface for MSC Nastran", MSC-VPD04-31, MSC Conference Proceedings (2004).

This article was authored by Dr. Victor Genberg, Sigmadyne



The initial design of the adaptively controlled primary mirror satisfied requirements, but was over-designed. The optimized design is less than half the weight with all requirements met.

Telescope & Adaptive Primary Mirror



*ForceFive is an MSC Software Community Partner who offers Fast Concept Modeller (FCM), an integrated CAD software solution developed to increase efficiency in conceptual design and engineering. The FCM product provides integration with MSC Nastran optimization solutions.*

# Functional Concepts

Integrating Analysis & Optimization into Early Design Process

# ForceFive

## Challenges in the concept development of vehicles

Concept development is all about experimenting and optimizing, giving an initial direction to the product development. But creation of concept geometries alone without functional validation is meaningless. At the start of functional evaluation there might be no geometric model available. Therefore, the functional models are built parallel to the geometrical design. At certain time points, a synchronization of these parallel development activities is required. This is time and resource intensive. ForceFive AG, an MSC Software partner located in Germany has been focusing on providing the Computer Aided Design (CAD) and the Computer Aided Engineering (CAE) worlds with a common working platform. This case study presents a unique solution called the Fast Concept Modeller (FCM), which integrates a design tool for styling and package and concept geometry with direct interface to CAE-processes, along with feedback of optimization results.

## What is FCM?

FCM is an integrated CATIA V5 toolset enabling a new level of efficiency in styling, concept design and engineering. Intuitive modeling and FE analysis are coupled in a very unique way. It has three modules:

**FCM parametric modeler:** is the core module providing an intuitive way to create associative, parametric models with the flexibility required to freely change and manipulate designs. FCM parametric modeler accelerates design and allows for very fast and

easy creation of fully parametric-associative concept geometry. Figure 1 shows how a complete vehicle model can be easily created with a (topological) wireframe structure, watertight surfaces on the basis of few intelligent commands.

**FCM analysis pre-processor:** An add-on to the FCM parametric modeler, the FCM Analysis Pre-processor is aimed at preparing Finite Element (FE) meshes directly from parametric designs created in the CAD system. It offers the ability to save FE data right into the CAD model. CAE attributes including connections only need to be assigned the first time round. When the parts are changed these attributes are automatically updated. Moreover, its direct interfaces to FE and meshing programs allow automatic export of models for crash, Noise Vibration Harshness

(NVH) and static analyses. The analysis loop is fully automated and repeatable.

## FCM structure analysis pre-processor:

An extension to the other modules, the FCM Structure Analysis pre-processor adds 1D meshing from cross section-based beam structures to the FCM-geometry and shell mesh. This unique tool discretizes complex beam structures directly within the CAD system, which are ready for sizing optimization. The FCM structural elements are created, discretized, and their resulting sections and properties can be visualized within FCM itself. Optionally, these 1D beam meshes can automatically be coupled to the 2D shell meshes using RBE2 elements. The complete functional model is exported directly as an MSC Nastran Bulk Data File (FDF).

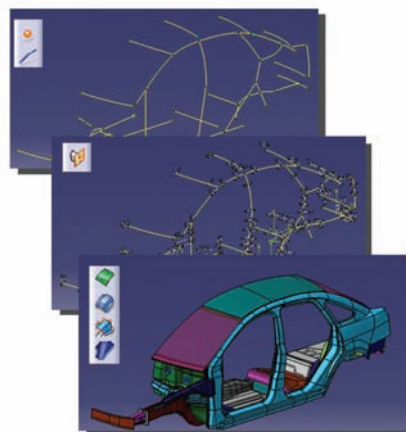


Figure 1: FCM Parametric Modeler

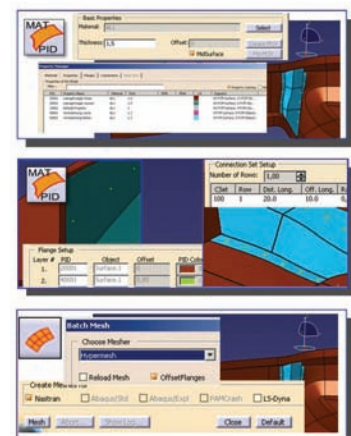


Figure 2: FCM Analysis Pre-processor: assign CAE-properties, define connections; seamless batch meshing

The optimized cross sections are imported and visualized in FCM which can directly drive and automatically update the FCM geometry along with the suggested geometry and property changes, e.g. wall thickness.

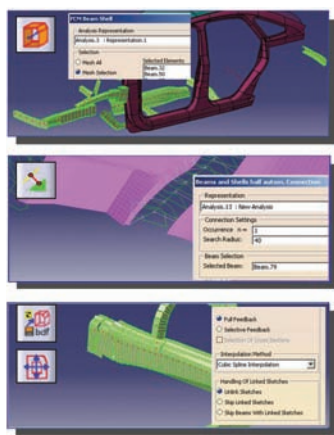


Figure 3: FCM Structure Analysis Pre-processor

### Why Beam Models?

In the early concept phase, although there is no detailed geometry available, the beam models (Fig. 4) can be used to evaluate the principal cross section dimensions for new car designs. The goal is to model the basic topology of the car and to optimize the mass and static and dynamic stiffness of the entire vehicle body.



Figure 4: Vehicle Beam-Shell Model

The advantages of beam models are:

- Simplified modeling of complex structures leads to reduced model size
- Very fast creation of concept variants possible through manual modification within the pre-processor
- Optimization of cross section dimension and thickness for an entire vehicle body with MSC Nastran

### FCM and MSC Nastran Beam-Models with ABCS

Using the Fast Concept Modeller along with MSC Nastran Arbitrary Beam Cross Sections, the actual concept geometry can be converted automatically into beam meshes without any shape approximation or standardization.

The sections are created based on a given element length normal to the geometry and converted according to the rules of beam meshes. Arbitrary Beam Cross Sections will be defined in the Property cards of type PBMSECT for CBEAMs and PBRSECT for CBARS. Because a FCM-Beam is surface based, only the Open Profile (OP) and Closed Profile (CP) types are supported.

“Using the Fast Concept Modeller along with MSC Nastran, the actual concept geometry can be converted automatically into beam meshes without any shape approximation or standardization.”

### Structural Optimization Using Beam Models

To speed up the integration of optimization results into the design process, FCM has the ability to read and display the optimized cross sections from the MSC Nastran-BDF and PCH-files. It can be deployed for shape and topology optimization projects where the result is not just an optimized mesh but CAD geometry itself.

For the first time it's possible to incorporate the optimization results and update the CAD geometry live at the press of a button. (There are different options available to update either selected objects individually or the complete model). Details can be successively added to the optimized FCM-model which can be

used for generating conventional shell models during the product development process.

### Conclusion

Beam and Shell MSC Nastran models are used at BMW for design and optimization of complete vehicle models and their characteristics. Hybrid optimization with dedicated optimization tools and MSC Nastran has proved to deliver much better results than using gradient based optimization solely. The time and effort for geometric model creation and FE model derivation can be reduced dramatically. ■

This article was authored by  
Christian Fritz, ForceFive AG, Germany

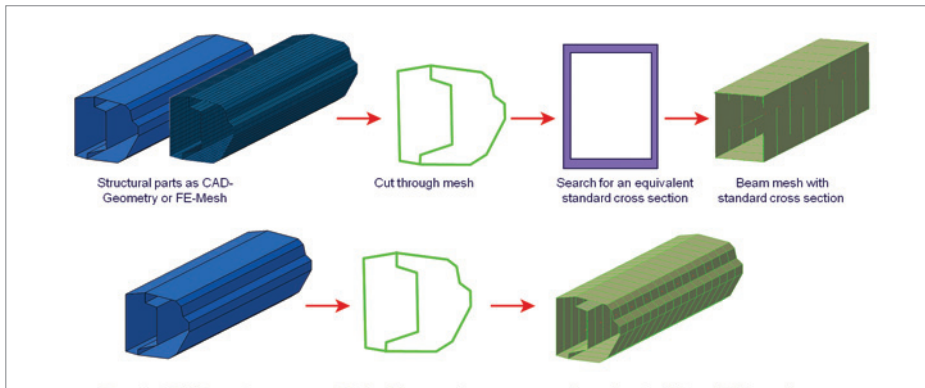


Figure 5: Traditional (above) vs. FCM (below) Methods for Generation of 1D FE-Beam Elements

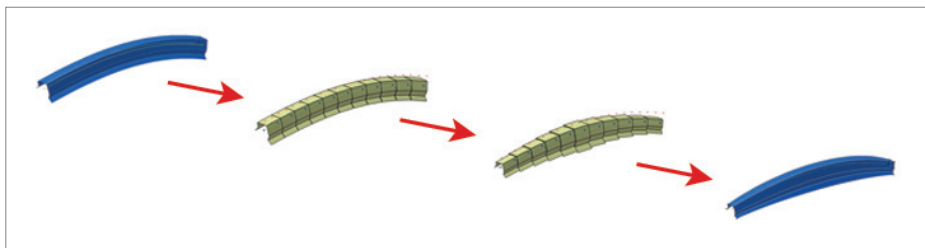


Figure 6: FCM Feedback Process - Live CAD update

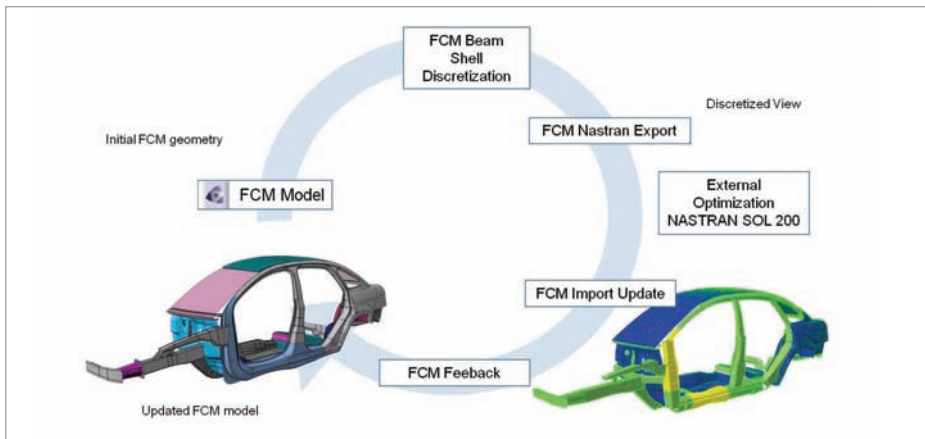


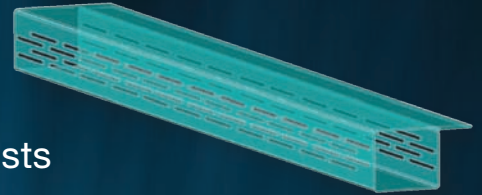
Figure 7: Fully Automated and Repeatable Analysis Loop



*data M is an MSC Software Community Partner who develops software solutions for roll forming simulation. The company's solutions are powered by MSC Marc, an advanced nonlinear analysis solution.*

# Solving the Mysteries of Roll Forming

Simulation of Roll Forming Process Reduces Material Costs



## data M

For many centuries sheet metal forming has been an important part of human evolution. While in former times it was mainly used for open vessels, horseshoes, weapons or knight's armor, the range of use is much wider today. Sheet metal forming is required in nearly all industries. Automotive and chemical industries are only two examples for industry sectors that are strongly dependent upon the process.

### Characteristics of Roll Forming

Roll forming is a specific process within the sheet metal forming industry. Characteristics of that method are high flexibility, low machine and tooling cost, and very good productivity. But like other sheet metal forming methods, roll forming today is still a kind of "black art." It is very difficult to understand what happens to the material during the forming process. Difficulties such as faults appearing and problems in setting up new roll sets on the mill are not uncommon. In a trial & error approach, one has to produce a whole roll set and do the

machine set-up in order to find potential weaknesses in the roll forming process - a costly and time-consuming approach causing undesired machine downtimes.

### Predicting Results with High Accuracy

data M Software Solutions GmbH has been aware of this problem from an early stage and has concentrated its efforts on developing a simulation program to overcome these problems. The result is that it is now possible to predict practical results with high accuracy with the company's COPRA® RollForm Simulation Technology. An essential part of this technology is being supplied by MSC Software through its advanced nonlinear software, MSC Marc.

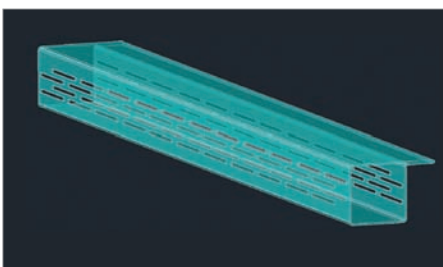
Experienced machine operators, of course, know what to do when a problem occurs, but they cannot explain why they are carrying out specific changes because they do not know the source of the problem. Not understanding the problem means that it is impossible to transfer the knowledge of an experienced operator to another one. A new operator has to go through the same time consuming learning procedure as other colleagues before him: learning by doing.

In a situation like that, the utilization of Finite Element Analysis (FEA) will help to better understand the forming process.

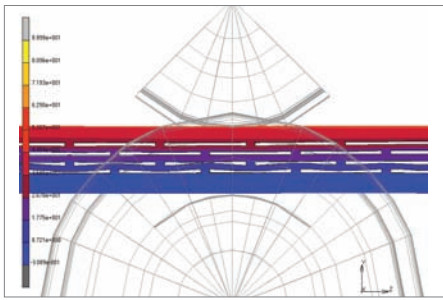
It will not improve the product quality of a company overnight, but it will allow the operator to create a knowledge base on roll forming step by step. And this will help to avoid bad tooling design, machine down times and too much scrap.

With the COPRA® FEA RF module, data M has developed highly efficient software packages tailored to the roll forming industry's needs. The program imports data directly from COPRA® RF DTM, which acts as a pre-processor for the Finite Element Simulation technique. In addition to the COPRA® RF DTM simulation results, COPRA® FEA RF, which utilizes MSC Marc, provides essential information about forces, torques, stresses, and a 3D-visualization of the final product showing possible deformations. As a matter of fact, this module can be regarded as a "virtual roll forming mill" that allows the user to try out new roll sets even before the actual manufacturing process.

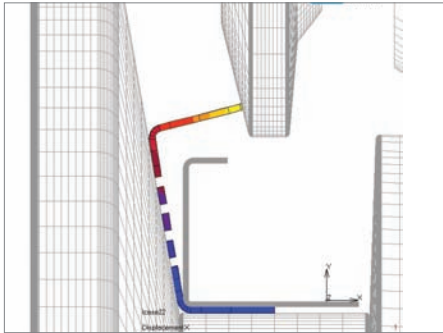
The use of FEA, of course, also changes the actual design process itself. The "classical" design method requires a clearly defined time frame for a roll design, roll manufacturing and machine setup. As soon as FEA is being applied, the classical process changes. The time required for the design may be slightly longer using an optimization process during the initial layout, but increasing the engineering



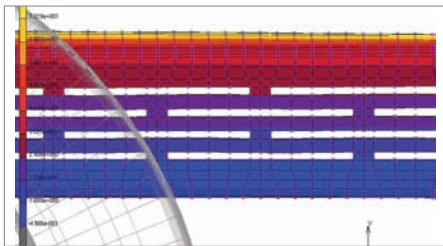
3D picture of the profile



Side view of the roll station. Squeezing of the holes.



Front view of the station. Inside drawing die controlling the bend area.



Detail view of the hole pattern coming out of the machine.

time in many cases drastically reduces the setup time and definitely improves the product quality.

### Optimizing The Process

The following industry example verifies this. It is quite a complex shape with an excessive number of punch holes on the side faces. The profile is required for a ventilation application. The “normal” lead time for the design would have taken three weeks. The final time required including a complete design optimization took more than six weeks – but the machine setup took only half a day!

#### Here is a brief description of the problems found in the initial design and the optimization process:

The initial design is based on the available experience of the roll form designer.

The very first simulation was conducted without the punch holes to get a better impression of the quality of this design. Some improvements could be made, but in total the quality of the profile seemed to be sufficient.

In the next step the punch hole pattern was added to the flat strip and the second FEA was conducted. The result was completely different. Due to the soft side faces caused by the punch holes, the entire section was compressed and the punch hole geometry was totally damaged.

It appeared that the forming strategy used in this case would not deliver the required profile quality. In roll forming, the best quality can usually be achieved if the rolls directly contact the bends that need to be formed. As soon as “air bending” – the forming of the material without direct contact with the rolls – is necessary, a material movement control is no longer possible. In this case, the pressure of the top roll was necessary to properly form the bend, but simultaneously caused the damage of the punch holes.

“...it is now possible to predict practical results with high accuracy with Copra RollForm and MSC Marc.”

The shape of the section did not allow the rolls to contact the bend. Therefore it was impossible to optimize the roll design.

The only solution was the implementation of an alternative forming tool. After checking the options, a drawing die was selected. Using an inside drawing ensured the precise control of the bend position. For the control of the lower bend, no top roll was required; the squeezing of the punch holes could be avoided and the quality was best.

The description above refers to just one of 12 modifications that were applied during the design and optimization period.

Assuming that these modifications had to be tested during the machine setup, it becomes evident that an additional 2-3 weeks would have been spent. Since the optimizations had already been carried out during the design stage, much of the machine downtime and extra cost for material and tool changes could be avoided. ■

For more information on data M's roll forming software, please visit:

<http://www.datam.de/en/home/>

This article was authored by Stefan Freitag, Managing Director, data M Sheet Metal Solutions GmbH, and Lander Arrupe, dataM



MSC Software's

50<sup>th</sup>  
Anniversary  
Celebration

50  
Years

COMING  
SOON

February  
2013





*HyperSizer® is an MSC Software Community Partner providing structural tools, methods research, and software solutions for design optimization. The company's technology provides integration with MSC Nastran, the leading finite element analysis and multidisciplinary simulation software.*

# Light Weight Structures

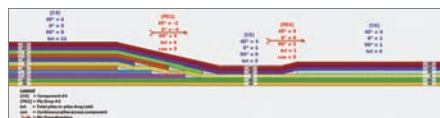
Optimizing Composite and Metallic Structures with HyperSizer & MSC Nastran

## HyperSizer

Since HyperSizer's primary market is aerospace, some of the software's key features are introduced using a sample wing box for a 160 passenger-sized aircraft similar to a Boeing 737 or Airbus A320. Graphically represented by unique color regions on the Finite Element Model (FEM), finite elements are grouped together to represent panels and beams that share the same cross sectional dimensions and materials systems.

Analysis is performed on the structural parts of skin panels, ribs, spars, and caps - called structural components - not on the finite elements. HyperSizer optimizes to determine the lightest weight combination of material systems and cross sectional geometric dimensions (panel height, stiffener spacing) including layup ply angles and stacking sequences. HyperSizer's new laminate sequencing provides real-world

fabrication constraints that ensure efficient and manufacturable designs by minimizing ply drops across panel boundaries and identifying and reducing ply drawing part numbers and fabrication process steps.



Sequenced laminates and drop offs for a composite part.

### The Unified Software Standardizes and Automates the Design Process

**Preliminary Design Optimization** of complete structural designs for aerospace, energy, rail, transportation, and shipbuilding projects is optimized in HyperSizer. The lightest weight panel and beam concepts along with design variables and candidate materials are determined and then mapped directly onto the finite element model. Rapid and very accurate trade studies establish the benefits of recently developed composite material systems and newer 3rd generation aluminum-lithium alloys.

**Final Analysis Margins of Safety Calculations** are performed including hundreds of aerospace industry standard failure analyses to evaluate the strength and stability of entire airframes and engine structures for thousands of load cases. This allows quick

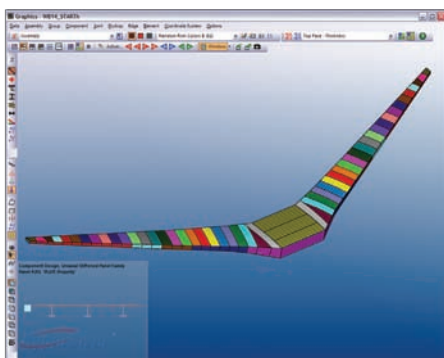
identification and resolution of weak spots throughout the design process.

**Stress Report Documentation** is generated for all failure modes to include the analysis methods and calculations required for FAA airworthiness certification. Summary tables of controlling margins of safety, load sets, and failure modes are included for project reporting and assessment.

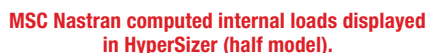
**Test Data Validation** for failure analyses is established by storing the specimen test failure load in the database. By correlating test data failure loads with the analytical predictions, the user is able to quickly establish and permanently maintain within the test database a record of prediction accuracy required for airworthiness certification.

### How Does HyperSizer Improve the Wing?

The wing model has applied external loads such as aero pressures (PLOAD4), inertia (GRAVITY), and control surface concentrated forces (FORCE). These are then resolved into internal loads such as shell element membrane and bending unit forces  $N_x$ ,  $N_y$ ,  $N_{xy}$ ,  $M_x$ ,  $M_y$ ,  $M_{xy}$ ,  $Q_x$ , and  $Q_y$ . HyperSizer extracts these FEA computed internal loads, per structural component, and uses industry standard failure methods such as stiffener flexural torsional buckling, skin postbuckling, crippling, stiffener bonded joint, and damage tolerant laminate strength to quantify safety factors and eliminate negative margins for thousands



Wingbox FEM. Colors represent structural components of the lower surface.



**Optimize the panels and beams** by entering a range of cross sectional dimensions and available materials and laminates to define the pool of candidates in the design space. Based on your defined range of variables, HyperSizer generates permutations of all possible candidates and analyzes them to find

**Iterate with MSC Nastran using HyperFEA®** to execute the solver and to control the iterative load path convergence. After HyperSizer has optimized the design of the vehicle, generalized thermoelastic stiffness terms are imported back to the FEM for another iteration of computed internal load paths. HyperFEA automatically submits HyperSizer and MSC Nastran solutions and monitors their completion and data exchange during iteration cycles. This automated iteration utility is called HyperFEA and is included in HyperSizer. After the design has been closed and validated, the last step is to make the final report.

**Generate stress reports** that include the calculations for all HyperSizer-computed margins of safety, material properties, design-to loads, and optimum design dimensions for all wing structural components. These comprehensive engineering reports are invaluable for FAA certification and assisting the stress engineers with detailed stress calculation data to support the hardware throughout its life cycle.

HyperSizer CAE software extends the capability of MSC Nastran. The two software packages have worked seamlessly together for 15 years. Now as an MSC Software Community Partner, Collier Research Corporation is developing tighter coupling for faster run times and more efficient and robust data exchange. Recent updates include MSC Nastran-specific efficiencies such as import of OP2 binary output results files for handling thousands of load cases. See a live demo of the two software products working together at the MSC 2011 Users Conference and visit us at [www.hypersizer.com](http://www.hypersizer.com). ■

The screenshot shows the ANSYS Workbench environment. On the left, a 3D model of a mechanical part is displayed with a green mesh. The 'Global Ply' list on the right shows 18 layers. The 'Results' tab is active, displaying a 'Reference Analysis' table with 18 rows and 17 columns of numerical data.

**Global Ply List:**

- Global Ply #18, -45°
- Global Ply #17, 0°
- Global Ply #16, 0°
- Global Ply #15, -45°
- Global Ply #14, -45°
- Global Ply #13, 0°
- Global Ply #12, 0°
- Global Ply #11, 0°
- Global Ply #10, 0°
- Global Ply #9, 0°
- Global Ply #8, 0°
- Global Ply #7, 0°
- Global Ply #6, 0°
- Global Ply #5, 0°
- Global Ply #4, 0°
- Global Ply #3, 0°
- Global Ply #2, 0°
- Global Ply #1, 0°

**Reference Analysis Table:**

Reference Analysis	110	111	112	113	114	115	116	117	118
11	-41	-45	-43	-40	-45	-45	-43	-41	-45
12	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0
18	-41	-45	-43	-40	-45	-45	-43	-41	-45

**Update the FEM with new design and display optimal manufacturable sequenced laminate ply coverage (half model)**





# Simulating Reality Interview: The Student's Perspective

## The Next Generation of Engineers



Erik Pratt  
Student

**Erik Pratt:** Undergraduate from California Poly Technique University, San Luis Obispo studying Mechanical Engineering, graduating in June 2012.

**Albert Smith:** A third year graduate student at the University of California, Berkeley studying Mechanical Engineering, graduating in June 2011.

**Bryce Kelford:** 1st year graduate student at the University of California, San Diego studying Mechanical and Aerospace Engineering, graduating in June 2011.

**SR:** Where do you intend to work after graduation?

**Albert:** Aerospace Industry

**Erik:** I would like to work on the design phase of some project. I really like doing R&D projects.

**Bryce:** I have been focusing my job search in the aerospace industry, particularly with defense contractors.

**SR:** Why are you interested in engineering simulation?

**Albert:** computational (finite element) modeling is immensely necessary for analyzing structural or stress problems that involve complicated and realistic loading conditions and materials.

**Erik:** It shows an application of concepts that I have learned through the various engineering courses that I have taken.

**Bryce:** One of my specialties is Finite Element Theory.

**SR:** How do you intend to use simulation in your future career?

**Albert:** I expect it to be a major part of everyday duties as either a stress analyst or a mechanics research.

**Erik:** I would like to simulate loading in possible prototypes that I would be working on at the time.  
It would reduce the prototyping time because I would physically build them less.

**Bryce:** I intend to improve upon simulation efficiency or theory or to apply it to a novel application for research and development.

**SR:** How did you hear about MSC?

**Albert:** I first learned of the company MSC after first being introduced to what the finite element method was and then reading on the web what the most popular FE commercial codes were. This was back in 2005.

**SR:** How did you hear about the MSC "Student Edition"?

**Albert:** I had asked the computer administrator for our engineering department if MSC offered Student Editions that I could access as a student.

**SR:** Have employers asked if you know MSC Software products or CAE tools in general?

**Bryce:** Yes, I wanted to learn MSC Nastran so that I could be more valuable to my employer.

## Student Edition Experience, Use and Benefits

**SR:** Which MSC Student Editions did you download/are you using today?

**Albert:** MSC Nastran-Patran

**Bryce:** I am learning MSC Nastran-Patran first.

**Erik:** I downloaded the MSC Nastran-Patran.

**SR:** How long have you been using MSC's "Student Edition"?

**Albert:** A couple of months.

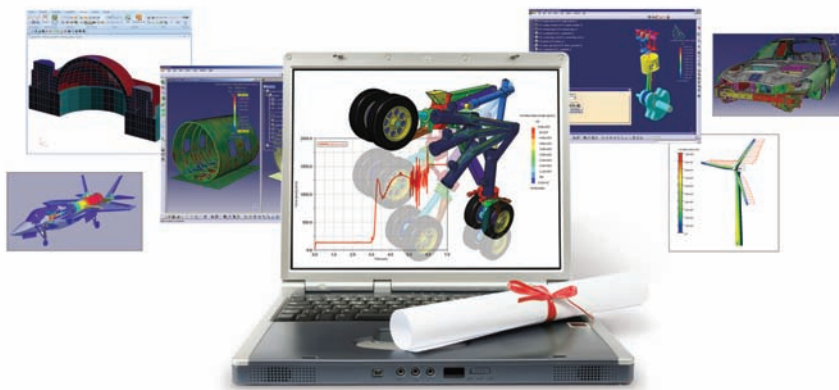
**Erik:** I have used the Student Edition for about 4 months.

**Bryce:** 2 months now.

**SR:** How (and for what) are you using the MSC Student Editions?

**Erik:** I am using the student edition of MSC Nastran-Patran to get some experience using an FEA program. I have never used one before and I have always been interested in FEA analysis. The student curriculum kit is great and easy to follow.





**SR: What are the benefits of “Student Editions” to you?**

**Albert:** The Student Edition would allow me to practice and experiment with procedures, material models, and different analysis problems during my time away from the school lab, doing things that are purely for my own interest.

**SR: Why are you interested in using MSC’s Student Editions?**

**Albert:** Incidentally, my research lab only uses MSC Nastran and Patran, so I had no choice but to try to become more skilled at it. Fortunately, MSC Nastran and Patran are widely used commercially as well.

**SR: Has our “Student Edition” enhanced your studies? If so, how?**

**Albert:** Not yet, but I know it certainly will.

**Bryce:** It has helped me see the way finite element theory is applied in practice.

**SR: Do you use other Student Editions (from other CAE companies), and if so, what is your opinion of MSC’s Student Editions versus others you’ve used?**

**Bryce:** I have used the student editions of Autodesk’s Inventor and Solidworks, which had substantially reduced capability compared to the MSC Student Edition.

**SR: Did outside advisors (e.g., professors, researchers, commercial companies, or other students) play a role in your decision process to download MSC Student Editions?**

**Erik:** After using MSC Software in my rotor dynamics class, I found out how powerful your software is. My teacher raved about Adams and was looking for other ways to implement it into other courses that she teaches.

**SR: Do you think the MSC Software Student Edition has provided or will provide you an advantage in the job market?**

**Erik:** By using this product and gaining experience using FEA I believe that I will have an advantage in the market place. Knowing the basics of a program will make it easier and take less time to master it in the work place.

**SR: Are your student colleagues using the student edition? And How?**

**Erik:** Some of my student colleagues talked about downloading MSC Nastran-Patran and using the curriculum kit.

**Bryce:** Yes, they are. They are also using it to learn MSC Nastran.

**SR: Are you collaborating with your colleagues on projects around the MSC Software Student Edition? Like what?**

**Bryce:** Not at this time. If I had known about it when I did my senior project at UC Berkeley, I definitely would have used MSC’s Student Editions.

**“What are you waiting for? It’s free! The earlier you start the more prepared you will be when you need it most.”**

**Support & Learning Aids**

**SR: Have you used any of the MSC tutorials or other learning aids, and if so how have they helped you?**

**Erik:** I have used tutorials for Adams and MSC Nastran-Patran. They were very helpful and easy to follow, which is essential for tutorials to be used as a teaching aid on how to use the program in various ways.

**SR: What other learning aids should we offer that would enhance your experience?**

**Erik:** One would be to provide full models of different objects/ structures that could then be used in Patran and with the various downloads provide objectives, (i.e. different loading conditions or provide various results (displacement, modes, etc.). Include some hints to aid the student along the way. You could call these projects and have the user struggle through the program if they are not that acquainted with the software. This can be a huge learning tool because people really do

learn from mistakes and would have to read through the software manual or help files to figure out what to do. This will make the user learn the software on a more in-depth level. Also offer advanced curriculum kits once the user has completed the one that is posted on your website. In the advance section, use real world objects/models that one might analyze in the work place.

**SR: How long did it take before you felt efficient with the software? What can we do to help you be more efficient in our software?**

**Erik:** It took me about 4 hours to be somewhat efficient using the software. This was after I completed almost all of the curriculum kit.

**SR: Have you attended any of our Webinars? Are they helpful? What topics would you like to see covered?**

**Bryce:** I have not, yet. I did not look into the webinars because I thought they might be expensive, but realize now they are free to attend.

**SR: Do you know of SimCompanion support, MSC’s support portal? Have you used it?**

**Erik:** I do know of SimCompanion Support. I used it to try and find help with my MSC Nastran-Patran installation.

**Words of Wisdom**

**SR: What words of wisdom do you have for other students who have not yet downloaded MSC’s Student Editions?**

**Albert:** Since MSC is widely used commercially and academically, it would be prudent to at least give it a try.

**Erik:** You should definitely download the student version. It is free and learning tools are available so you have nothing to lose. It provides exposure to programs that you might use in industry and offers an application to engineering concepts that you have learned or are currently learning.

**Bryce:** What are you waiting for? It’s free! The earlier you start, the more prepared you will be when you need it most. Plus, FEA pictures look really good in presentations.





## CORNELL UNIVERSITY

# Pathfinder for Future Missions

## Simulating Extreme Thermal Conditions in Violet Satellite Spacecraft

### The Role of Violet Satellite

The Violet Satellite, under development at Cornell University, is the first operational agile nanosatellite. It utilizes eight Control Moment Gyroscopes (CMG) to experimentally validate high-agility attitude control and novel CMG steering laws. Guest Investigators will be able to use Violet's multiple CMG architectures for experimental validation of CMG steering technologies. Violet also offers the optional capability to perform science observations as a pathfinder for future missions.

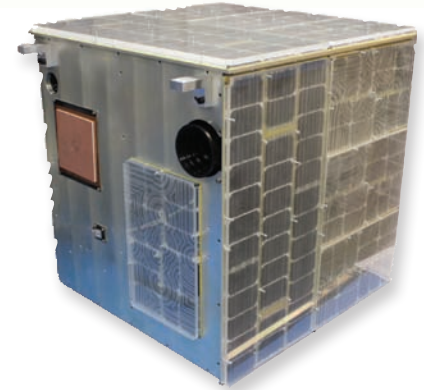
### Research and Development Initiatives

There exists a clear need among the public and commercial sectors for public-domain research and development in pursuit of increased spacecraft agility. This need can

be further seen by the development of the Air Force Research Laboratory's Miniature Momentum Control System, which aims to provide in-orbit experiments of next generation steering laws for future small, agile spacecraft. Increased agility has immediate relevance for achievement of tactical goals, while also carrying with it benefits that translate to greater value for end-users of spacecraft that carry payloads for earth-imaging, radar, space situational awareness (SSA), and other high-value missions. Violet is the first agile nanosatellite. Furthermore, its small scale enables extraordinary agility, at least  $20^\circ/\text{sec}$  and  $20^\circ/\text{sec}^2$  rate and acceleration. Violet serves as a pathfinder for operational missions that exploit the physics of small-scale spacecraft to enable new mission capabilities.

### Violet's Guest Investigator Program

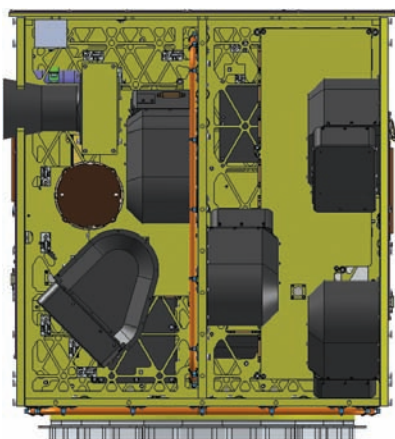
Those within the spacecraft attitude control community interested in this research include organizations from the Department of Defense (DoD), academia, and industry. To make the largest impact, any research effort should appeal to as many members as possible of this community. Violet's Guest Investigator Program fills this role, providing a common platform whereby a diverse set of interested parties can perform a variety of experiments, all connected by a common thread—the goal of increasing understanding of CMG array



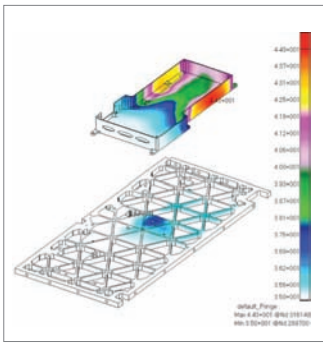
dynamics and novel steering technologies by utilizing them in their intended environment. The open and unclassified nature of this project is unique because it brings together a broad community to both collaborate on this project and make connections leading to additional efforts to advance the field. Although non-disclosure agreements (NDAs) regarding proprietary technology are honored when requested, this project has many fewer restrictions on information flow than a typical government or industry-sponsored undertaking of a similar nature. Furthermore, there is zero cost to Guest Investigators to participate in the program as long as they conform to Violet's interface requirements.

### Modeling and Analysis of the Structure

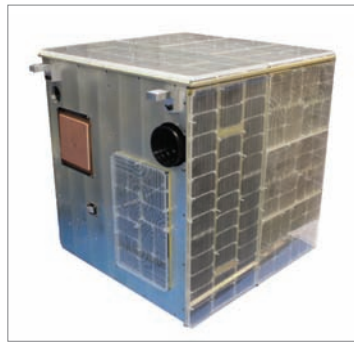
In order to make sure the spacecraft will survive the harsh conditions of space, a model of the overall structure was imported into MSC Patran to determine the temperature distribution during the worst case cold and worst case hot scenarios. Individual component models were also imported into Patran to determine the temperature distribution during the hottest situation, which is where the component is powered on high, and the mounting panel is at the highest temperature as determined by other overall structure analysis. The ease of importing parasolids created in other 3D modeling software into Patran



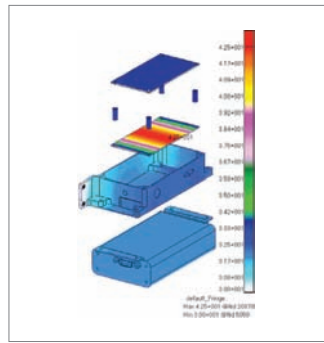
Back View



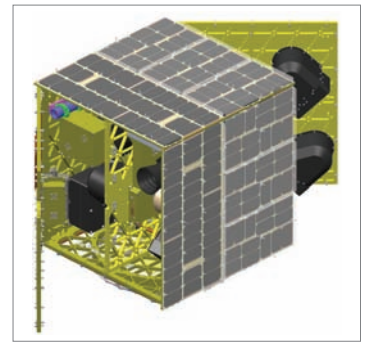
CDH Assembly



Cropped Satellite



GPS & TC Assembly



Hinged Wall

“The analysis data provided by Patran allows Violet to accurately predict and design for extreme component and environmental temperatures.”

helped keep the analysis up to date as designs changed. All assemblies could be imported in full detail which then could be evaluated to either show where project changes were needed or validate the design’s requirements. With successful use of Patran, it has been shown that the Violet spacecraft will survive.

## Meeting the Standards Demanded by Industry

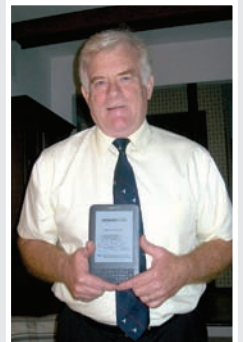
Violet’s use of Patran assists the team in meeting the professional standards demanded by the aerospace industry. The analysis data provided by Patran allows Violet to accurately predict and design for extreme component and environmental temperatures. This has given Violet a leading edge against other universities in the Air Force Research Laboratory’s Nanosat Program, and now the Violet Satellite is on track to be launched in the near future. ■

This article was authored by  
Joshua Abeshaus, Cornell University

## And The Winner Is...

Once again, papers were submitted, emails were hopeful, and phones anxiously waited to ring for their owners. Names were cast like seeds on a fertile field. The seeds casted were many, but only one would bear fruit.

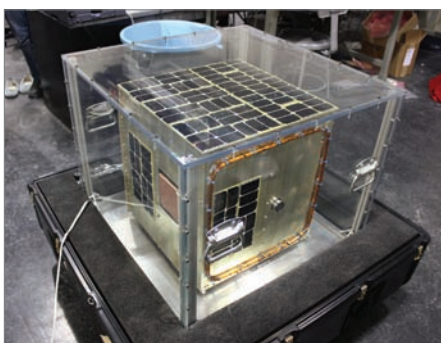
**James O’Malley** was the lucky name whose seed bore fruit! James O’Malley has a rich history with MSC Software, he has been using our software since 1989. In fact, when we dropped off the kindle to our winner, he had some MSC Software literature on his coffee table “*Finite Elements in Mechanical and Structural Design*” The MacNeal-Schwendler Corp.



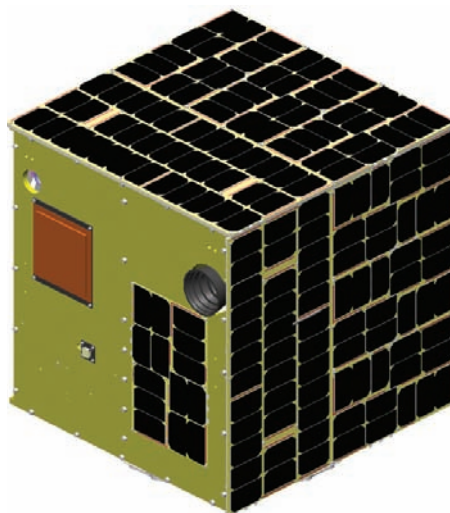
As an industry leader and innovator, MSC Software wanted to offer more to our customers at industry related tradeshows. We all have walked away from tradeshows with pens, notepads, etc. We wanted to offer more, what did we give away? Hope! This year, MSC Software held a raffle for a kindle. Entries were submitted at select tradeshows in which MSC Software was present. Several names were submitted, but the name that emerged was James O’Malley! Congratulations to James and thank you to all who submitted an entry.

This New Year will present new opportunities. Look for more giveaways at future MSC Events.

To view our events calendar, visit:  
[events.mscsoftware.com](http://events.mscsoftware.com)



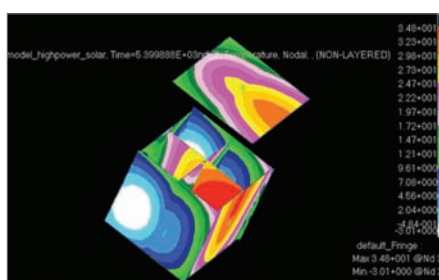
Ship 121



Solar Panel Isometric



Team Photo



Worst Case Heating



## UNIVERSITY OF SOUTHERN CALIFORNIA

# Incubator for Modeling & Simulation

## Mid-Size Businesses Get Access to Modeling & Simulation Tools & Support

**M**SC Software and the University of Southern California have created a unique incubator to help manufacturing companies realize the benefits of simulation. Large integrators need supply chains that have the ability to collectively generate components that can operate effectively under complex environmental loading conditions. The challenge is that most small and medium businesses don't have access to high performance computing networks, modeling and simulation software, nor the expertise to run these systems.

For several years the Council on Competitiveness and the University of Southern California (USC) worked with DARPA to understand the challenges a small to medium enterprise (SME) manufacturing firm faces in a high performance computing (HPC) modeling and simulation cooperative (HPCMSC). USC's Viterbi School of Engineering is the host for ISI, DARPA's center of

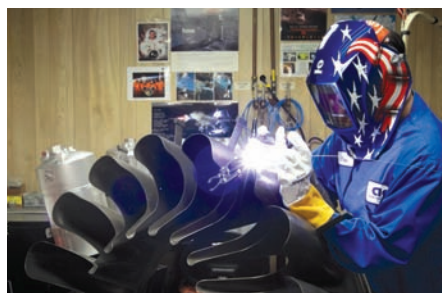
excellence in information technology. ISI worked with DARPA to evaluate the ability of cloud computing to reduce an SME's startup costs. USC's western research application center WESRAC was selected to conduct a DARPA/AFRL case study. WESRAC chose ACE Clearwater, a machining, welding and metal forming company. ACE Clearwater had no previous experience with HPCMSC.

WESRAC used USC graduate students to assist the firm in understanding the benefits of HPCMSC. MSC Software provided modeling and simulation software for the desktop and HPC machines in the WESRAC laboratory. After a single summer semester the students presented the results to AFRL, the Council on Competitiveness, ACE Clearwater and MSC Software. The audience was impressed with the HPCMSC accomplishments demonstrated by a team of students, with only class room experience, and inexperienced practitioners. Ace was impressed enough to purchase SimXpert from MSC Software and sponsor a USC design clinic to do assist them in integrate HPCMSC into their enterprise.

WESRAC generates a media piece profiling the history of ACE and their vision for the future use of HPCMSC. Work is underway at the WESRAC to make Hollywood modeling techniques compatible with the MSC solver. Design clinics have three primary goals: determine the optimal configuration for doing modeling, simulation and media production on a multi-processor desktop, solve an actual production problem, and generate a media piece that demonstrates how the firm uses Hollywood modelers such as Zbrush and a manufacturing simulation program such as SimXpert to create a Renaissance HPCMSC capability. Future WESRAC design clinics will focus on: cloud based HPCMSC, Mathematica enhanced cloud simulation and Hollywood open source rendering. WESRAC is dedicated to expanding the capabilities of Renaissance Manufacturing by working side-by-side with ACE Clearwater and other SMEs. ■

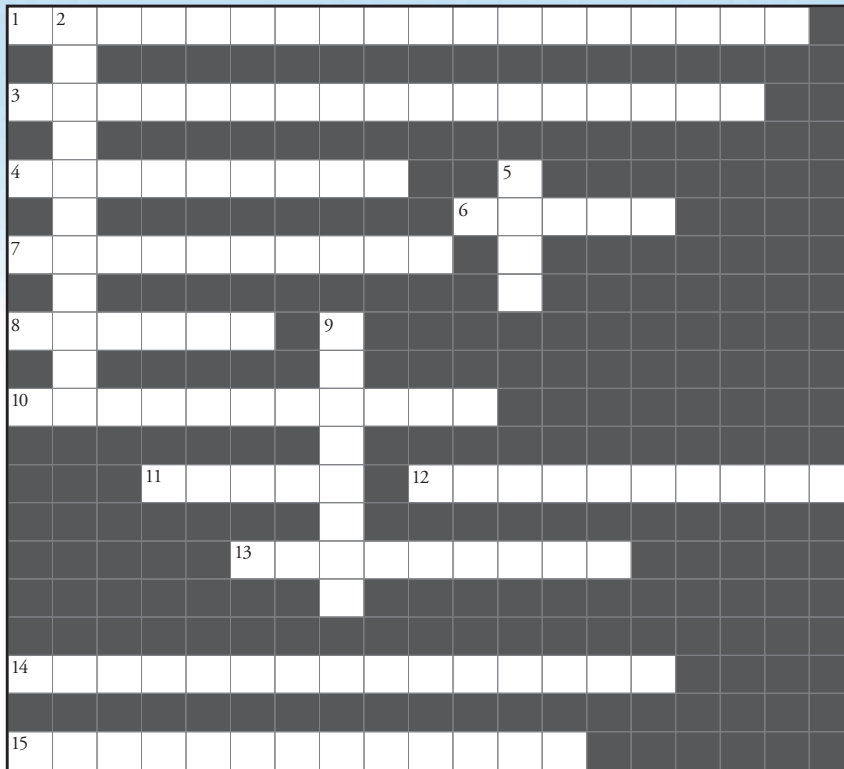
For more Information, please visit:  
<http://www.mscsoftware.com/ace>

**ACE**  
 Clearwater Enterprises



As Executive Director of the Western Research Application Center (WESRAC), Ken Dozier manages academic, federal and commercial programs. The Western Trade Adjustment Assistance Center (WTAAC) the Engineering Technology Transfer Center and the High Performance Supply Chain Center have affiliate offices in the four western states. The WESRAC gained national recognition when it received the Justin Morrill Award for Innovation from the Technology Transfer Society.

This article was authored by  
 Ken Dozier



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## ACROSS

1. An act, process, or methodology of making something (as a design, system, or decision) as fully perfect, functional, or effective as possible
3. Florentine artist, one of the great masters of the High Renaissance, celebrated as a painter, sculptor, architect, engineer, and scientist.
4. The component of a composite material that resists compressive stress and provides bulk to the composite material.
6. Was granted a U.S. patent for a "system of transmitting electrical energy"
7. Is the branch of classical mechanics that describes the motion of bodies (objects) and systems (groups of objects) without consideration of the forces that cause the motion.
8. The description of a motion in space of a point along a line
10. The discipline, art, skill and profession of acquiring and applying scientific, mathematical, economic, social, and practical knowledge, in order to design and build structures, machines, devices, systems, materials and processes.
11. A next generation CFD software system from Next Limit Technologies that uses a proprietary, particle-based, meshless approach which can easily handle traditionally complex problems.
12. 1900 \_\_\_\_\_ transmission extends across and between major cities.
13. The primary branch of engineering behind the design, construction and science of aircraft and spacecraft
14. Is regarded by some as the father of electrical engineering or electricity and magnetism

## DOWN

2. A condition in an internal combustion engine characterized by a knocking sound and caused by the fuel-air mixture having been ignited too soon because of an abnormal condition.
5. Created a water organ, a fire engine, a coin-operated device, and the earliest known steam-powered engine.
9. A term often used to denote the fixed, usually rather small, programs and/or data structures that internally control various electronic devices. Coined by Ascher Opler.

For Answers, go to:  
[simulatemore.mscsoftware.com](http://simulatemore.mscsoftware.com)

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