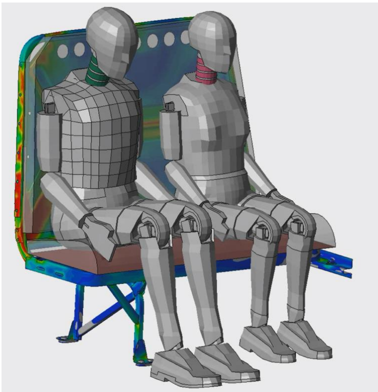
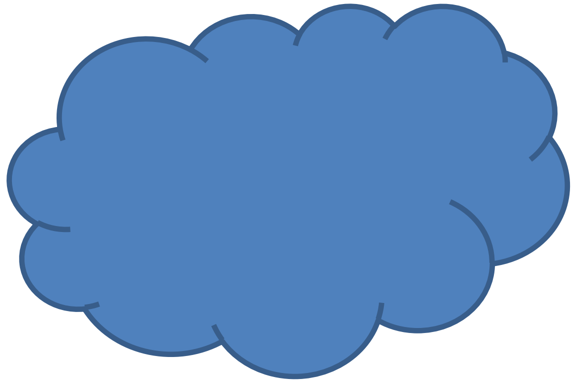
Nonlinear and Transient Dynamic FEA Consulting Projects

Most of our clients could care less whether the analysis results were obtained using an implicit or explicit numerical technique, just so long as it was quick and accurate. On our side, deep within the numerical salt mines, we do care whether it is implicit or explicit since picking the wrong numerical path can mean the difference between success or one pissed off client. In nonlinear transient analysis, the gold standard for solving the impossible is to use the explicit method but this often limits the solution time to milliseconds and rather large elements (see our LS-DYNA Class Notes). To solve nonlinear problems where the solution is in seconds or static, the implicit technique offers many advantages albeit with other challenges. Over the last several years, our simulation engineers have tackled a number of nonlinear static and transient problems using the implicit method. The choice of implicit over explicit has allowed us to solve nonlinear FEA problems that heretofore were just not practical in the sense of time and budget.

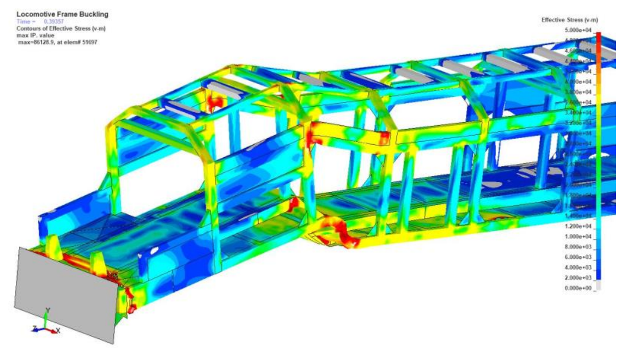
Transient Bus Seat Analysis



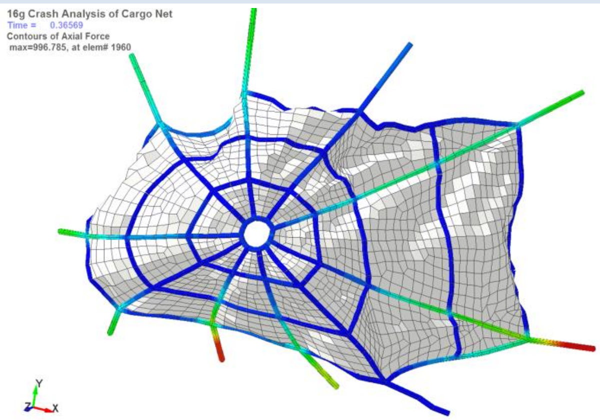
ITAR Restricted Nonlinear Composite Failure Analysis



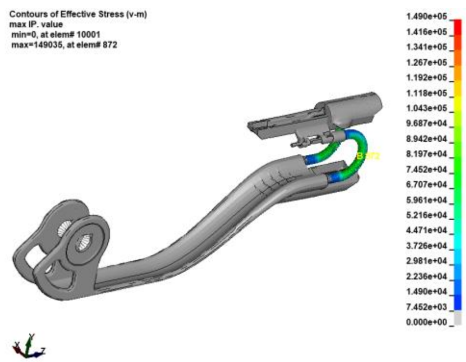
Rail Passenger Car Buckling Analyis



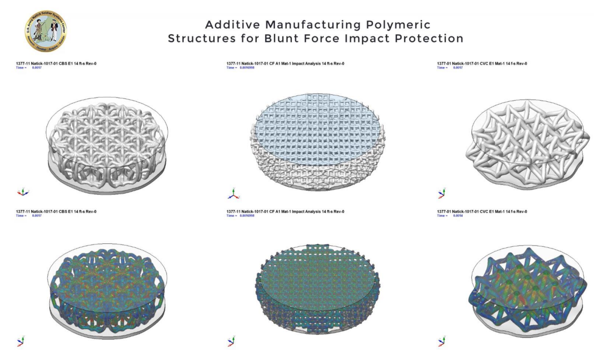
9g Cargo Net Analysis



Pre-Loaded Extension Spring Simulation



Impact Analysis of Additive Manufactured Elastomers



YouTube Video

A graphical overview of the project is available via this video: Nonlinear and Transient Dynamic FEA Consulting Services

Nonlinear, Transient Dynamic Bus Seat Analysis

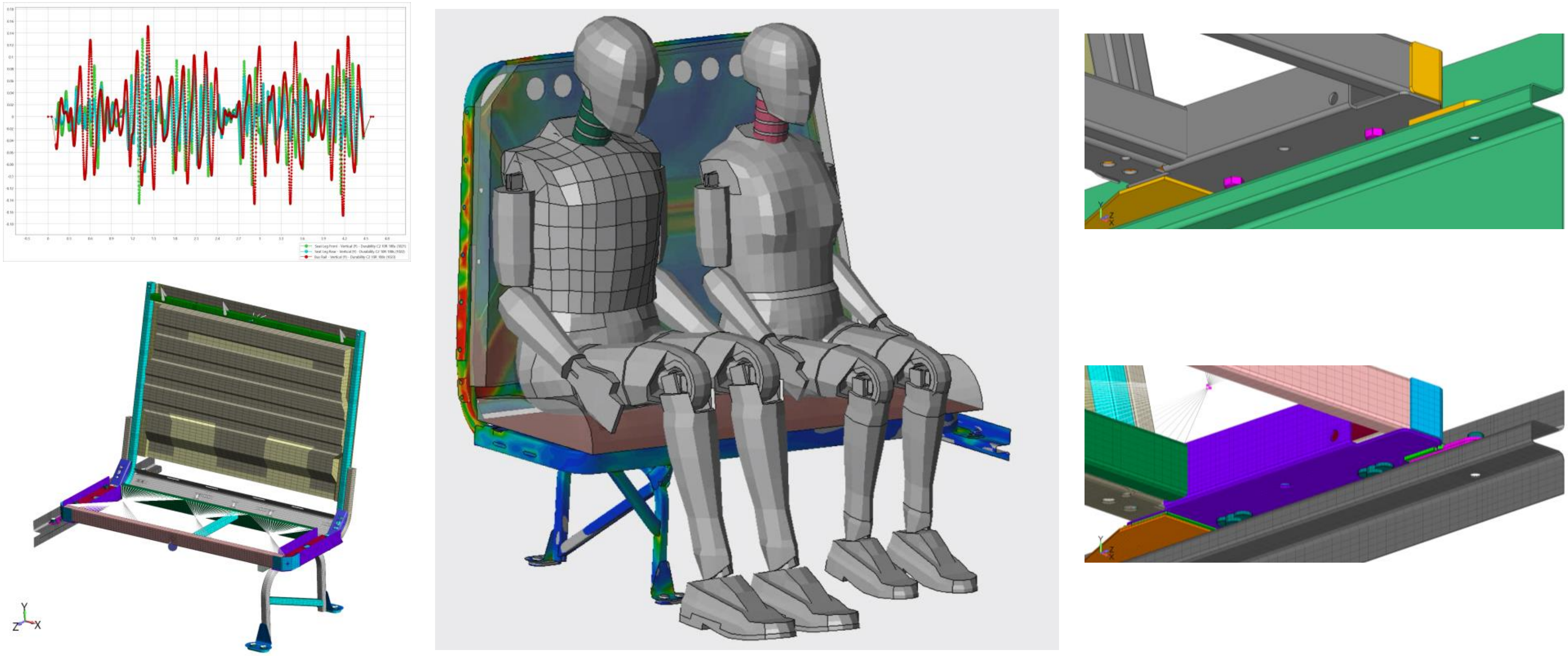
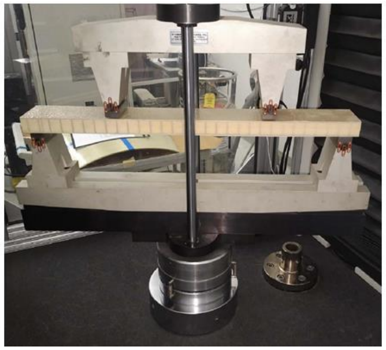


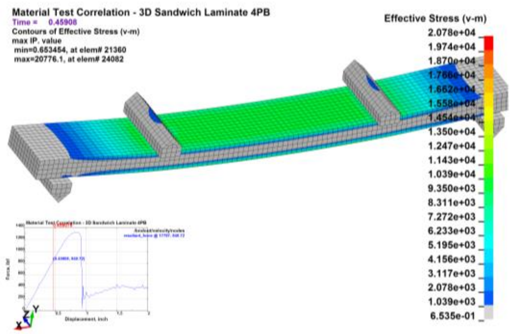
Figure 1: Nonlinear, transient implicit analysis of bus seat with 5 second experimental loading curves

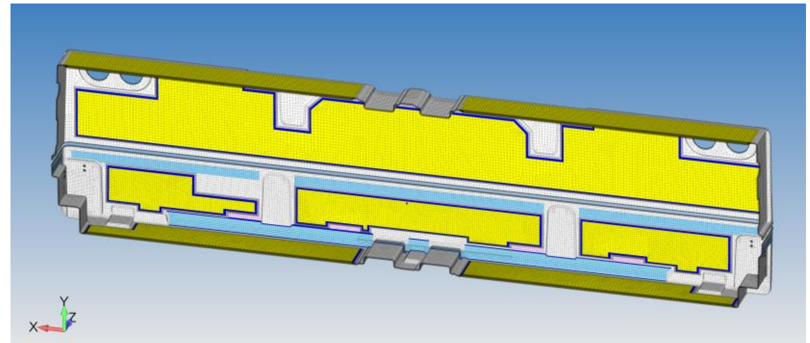
This project was our most challenging nonlinear transient implicit analysis in our history. Thanks to our client we were able to present this work at a conference (see 032_Jensen, A. - Transient Dynamic Implicit Analysis for Durability Testing of Bus Seats.pdf). Experimental test track data was harvested as accelerations and then converted to displacement load data. These loading curves were then used to drive the FEA model over time periods from five to ten seconds. The model employed contact between components, bolt preload and material yielding throughout the transient loading event. If we had tried to run this model using the explicit method, each analysis would have taken weeks whereas the implicit method generated a complete run in more or less six hours on 32 CPU-Cores.

Composite Analysis from Validation, PSD Analysis to Pressurization Failure Analysis

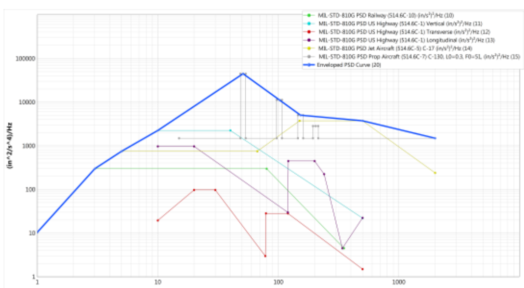
4-Pt Bend Testing | **4-Pt Bend FEA Progressive Failure Validation** | **FEA Composite Model of Large Aviation Transportation Container**

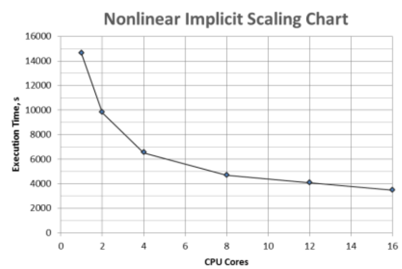






PSD Analyis | **Implicit Scaling Efficiency** | **Composite Progressive Ply Failure Analysis**





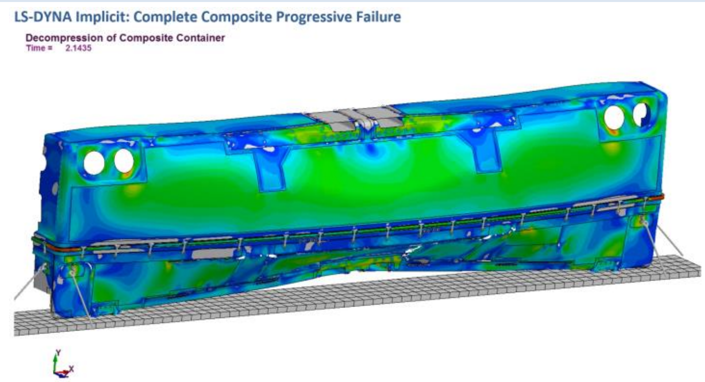
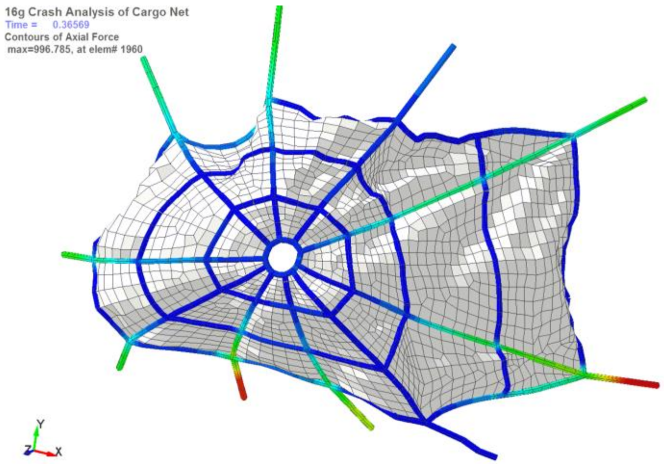


Figure 2: Composite analysis of large aviation transportation analysis from material validation to final delivery

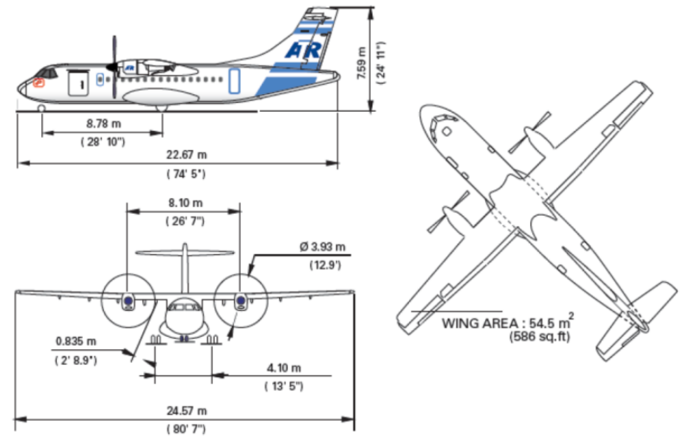
This composite analysis work was a landmark project for our FEA consulting services. We started with material property validation to FEA verification of transportation loading (static lift, PSD, vibration and pressurization) to full-on drop testing using the same FEA LS-DYNA model. The final structure was validated at the US Army's test facility and was recognized as the first composite article of this type that passed with no revisions. A research paper: Broad-Spectrum Stress and Vibration Analysis of Large Composite Container was published by Predictive on this work in 2016.

9g Cargo Net Load Analysis for Air Freighter Conversion

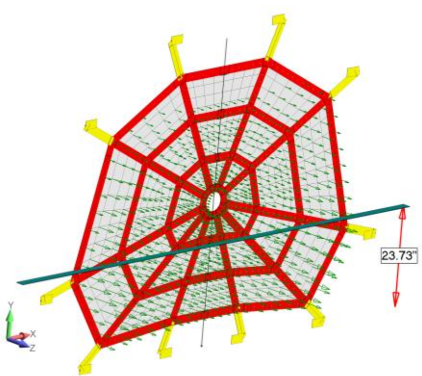
Deployment of Cargo Net under Max Cargo Load



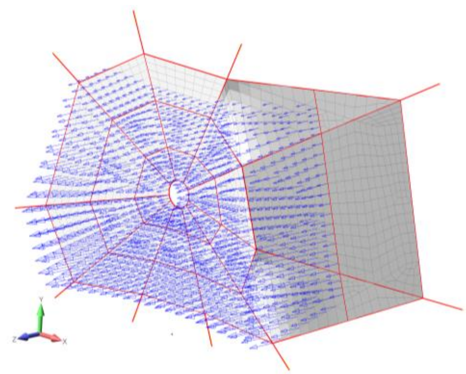
Air Freighter Conversion



Several Types of Cargo Nets were Evaluated



Cargo Loads were Applied via Pressures



Fully Loaded Dogleg Cargo Net

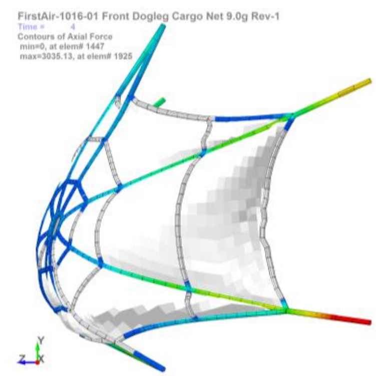


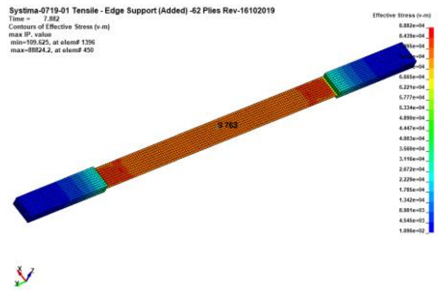
Figure 3: 9g nonlinear, transient implicit analysis of 9g cargo net deployment under maximum load

A nonlinear transient implicit analysis was done to determine the anchor loading during 9g cargo net deployment. Four nets were idealized and simulated under 9g deployment: i) Main Cargo Net; ii) Separator Net, iii) Aft Cargo Net and iv) Front Dogleg Cargo Net. Our client used the anchor loads calculated from the analysis work to design the frame attachment structures. Being able to run the models in implicit provided a bit more flexibility and speed (5x faster) but was not really necessary since we also verified the models against an explicit run.

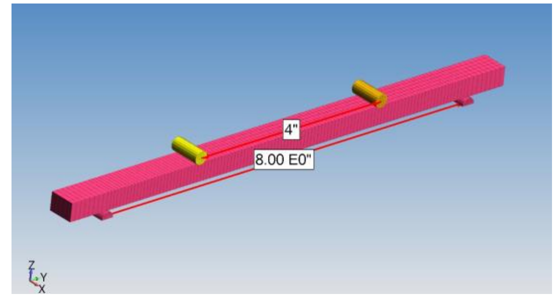
Nonlinear, Transient Carbon Composite Aviation Analysis (ITAR)

You Get the Idea

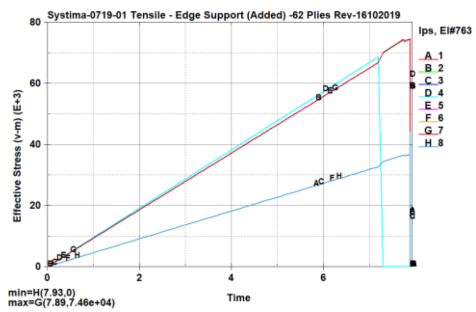
Composite Tensile Test Analysis



Composite Property Development Against Testing



Progressive Ply Failure under Tension



Progressive Ply Failure under 4-Pt Bend Testing

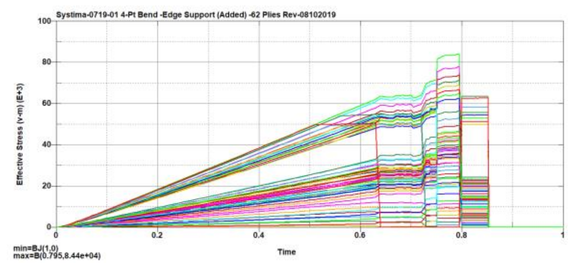


Figure 4: Nonlinear, transient analysis of carbon composite aviation structure with material property validation

At Predictive Engineering, we are generalists with simulation skill sets from submarines, medical instruments, FFG(X) ships to aviation and space. As part of this portfolio work, we occasionally get involved with ITAR work. This project started with the development of the composite material models via validation of FEA models of tensile and 4-Pt bend test coupons. With this foundation, the composite aerospace structure was analyzed under transient dynamic loading using the implicit method. Why implicit? The loading regime was in the order of 50 of milliseconds and it wasn't necessary to capture frequencies above 500 Hz, hence, we could use an implicit time step of 0.2 millisecond and have a solution with 250 steps and a quick solve time. The results compared favorable against the experimental tests.

Impact Analysis of Additive Manufactured Polymeric Structures

Impact Analysis of Polymeric Structures

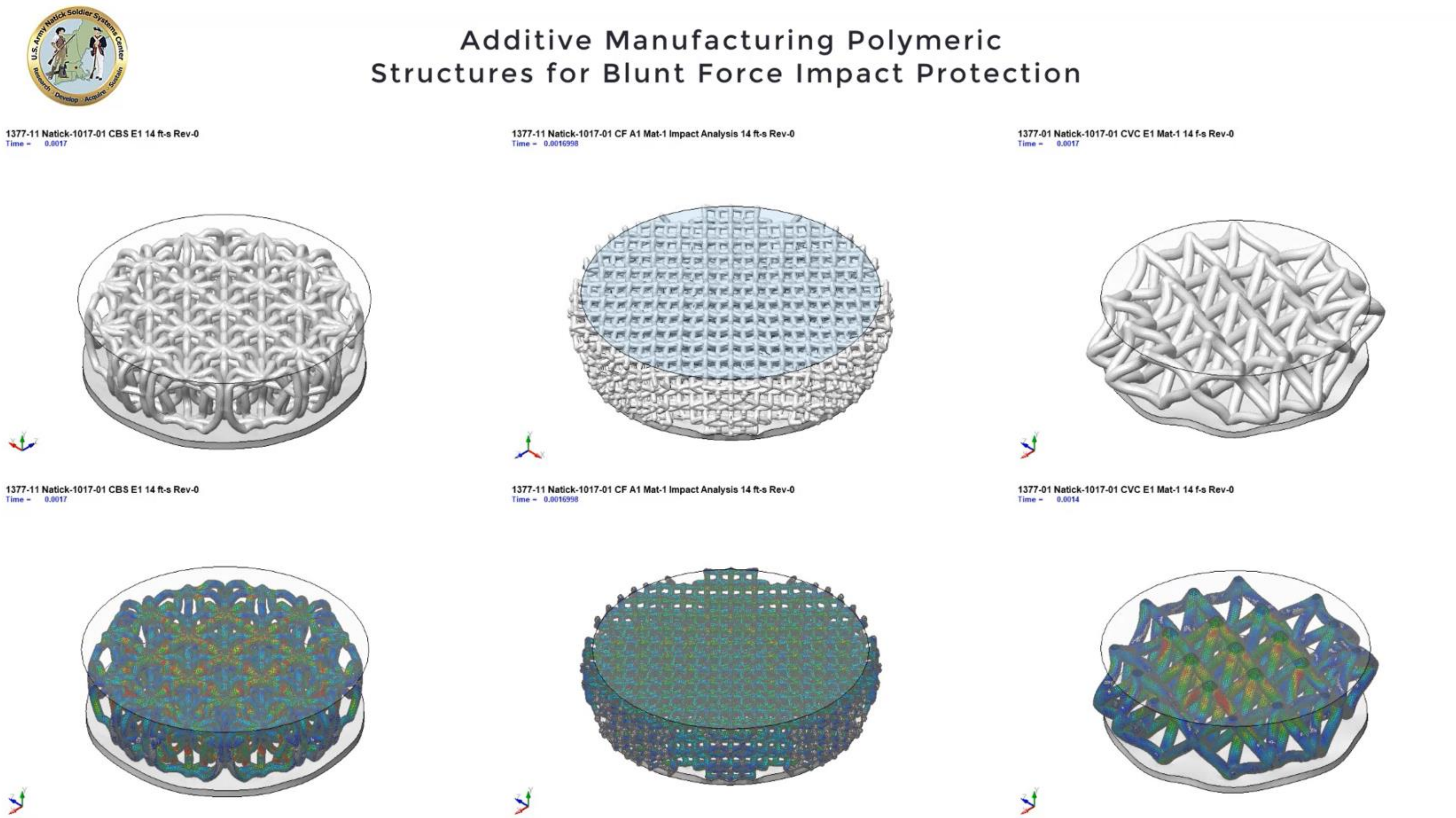
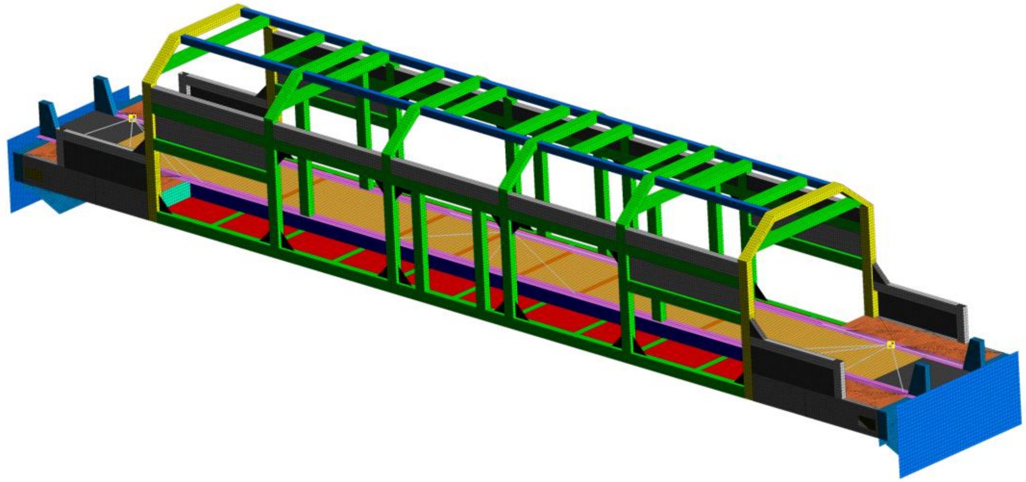


Figure 5: Implicit nonlinear transient FEA consulting project work with additive manufactured structures

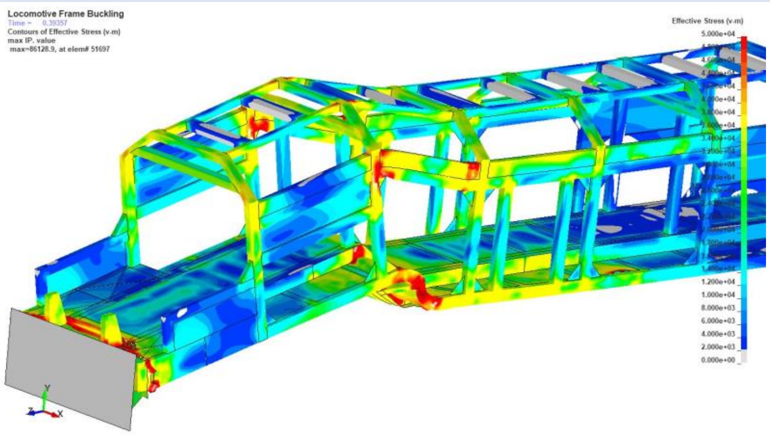
This project was driven by the desire to create more efficient energy absorbing structures for military helmet liners. The idea is to custom design the energy absorbing response by unique lattice structures that could only be created by additive manufacturing. The lattice dimensions were in the order of millimeters and were meshed using tetrahedrals. With such small elements, the only efficient analysis technique was implicit. The US Army chose us for this project due to our prior published work on nonlinear FEA modeling.

Nonlinear Buckling of Railroad Transit Cars - ASME RT-2-2014

Railroad Transit Car Analysis – Jacking and Buckling Failure Loading



Implicit Nonlinear Buckling Analysis



Force vs Deflection Buckling Response

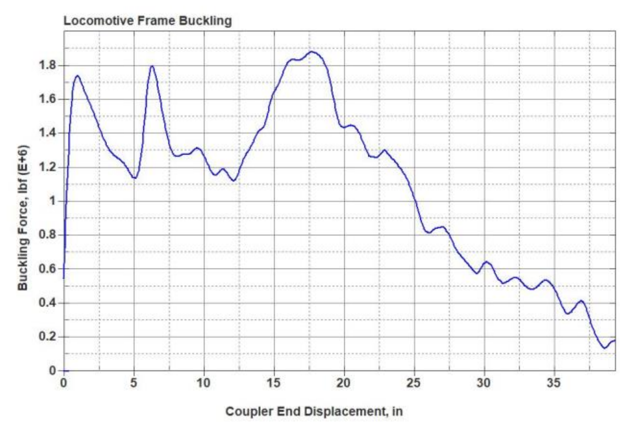
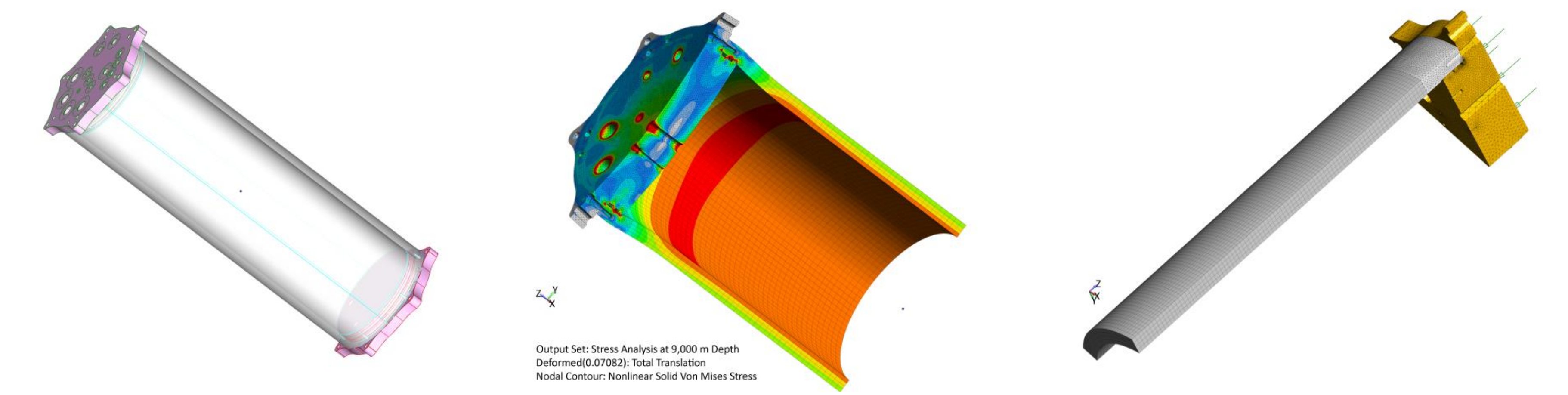


Figure 6: Elastic Stability of Railroad Transit Cars – ASME RT-2-2014

This FEA consulting project was done for an off-shore transit car manufacturer. The idea was to demonstration that one FEA model could be used to analysis static loads (implicit) according to ASME RT-2-2014 and also for crash loading (explicit).

Nonlinear Service and Collapse Pressure Loading: Deep-Sea Camera Housing

Titanium Camera Housing | **Detailed FEA Stress Model (Half-Symmetry)** | **Refined Cyclic-Symmetric Nonlinear Model**



Loading Sequence to Collapse

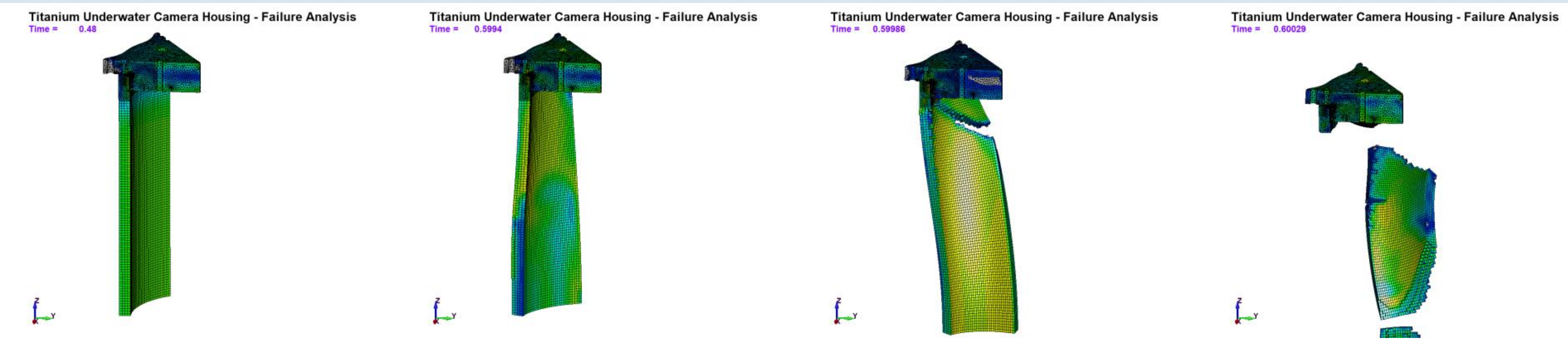


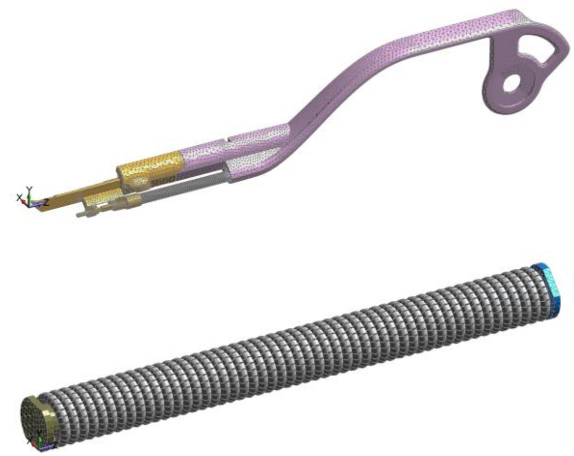
Figure 7: Underwater Deep-Sea Camera Housing Analysis from Service Loading to Ultimate Collapse

Our client came to us after one of their camera housings had failed during hydrostatic testing. We had worked with this company for many years performing various types of FEA services on marine winches, tow vehicles and other ship mounted structures. This project was unique since our analysis work showed that the housing should not have failed during service. To explore the robustness of the design, we loaded the housing to collapse. Results demonstrated that the failure had to be due to a metallurgical defect. Upon further inspection, it was discovered that machining had created an overly sharp notch and slightly "burned" the material creating a crack initiation site that led to the failure of the housing. A slight modification was made to the machining procedure and all subsequent housings passed the hydrostatic test.

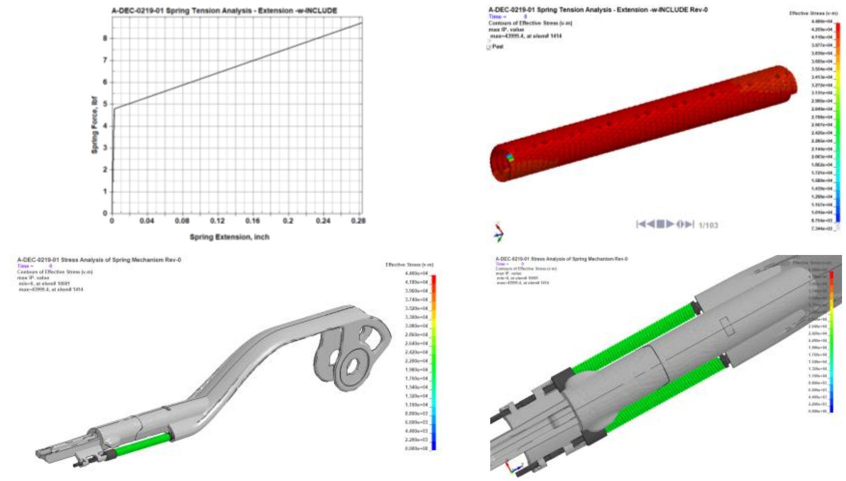
And now a word from our sponsor:

Dynamic Analysis of Extension Spring for Dental Equipment

Half-Symmetry FEA Model and Spring Model (Beam Elements)



Extension Spring with Initial Tensile Stress and FEA Model



Spring Extension Thru Range of Movement

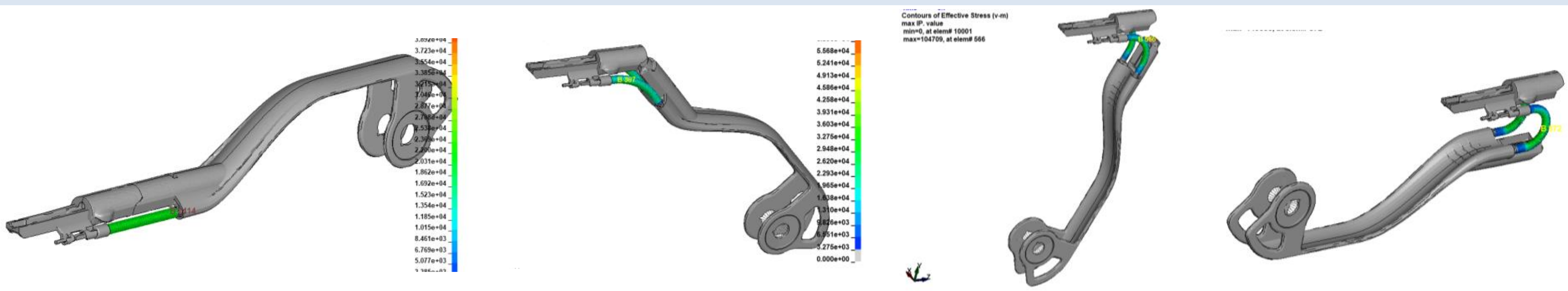
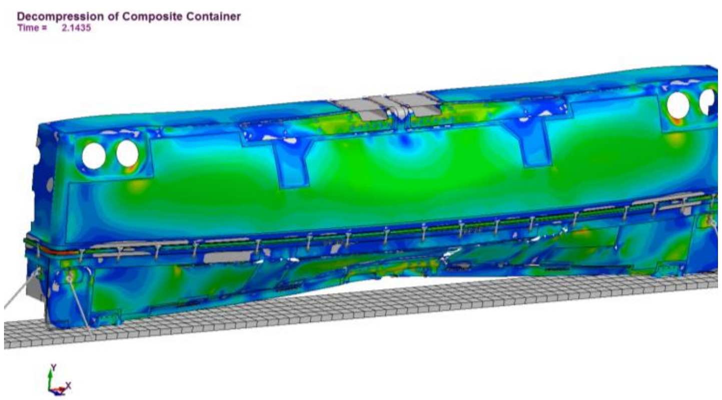


Figure 8: Extension Spring Fatigue Analysis from Preload to Full-Extension (Implicit, Nonlinear FEA Simulation)

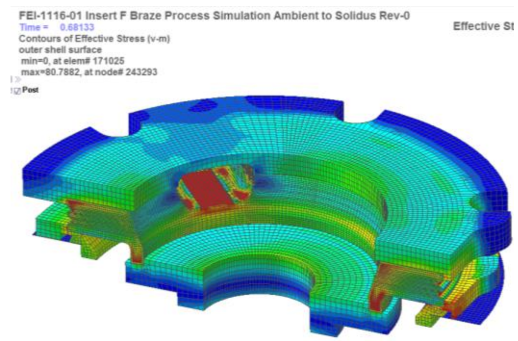
Spring design is a very classic mechanical engineering task and usually one can get obtain a reasonable solution following handbook rules. In this case, our client came to us after repeated fatigue failures of their high-tensile strength extension spring. Their design required the use of an extension spring (a spring that is cold rolled to create an initial preload state that requires a certain force to initial extension). The analysis technique required us to preload the spring (beam elements) and then use this stress state as an initial stress for the subsequent device movement. Analysis results showed that fatigue damage was real and that their only design solution was to lower the extension spring preload.

General Examples of Implicit Nonlinear and Transient Dynamic FEA Projects

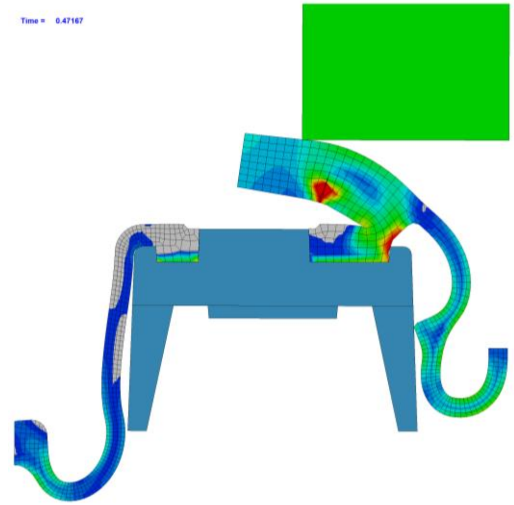
Depressurization Analysis of Composite Container



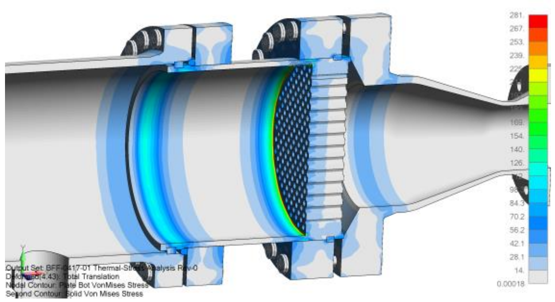
Transient Thermal Braze Analysis



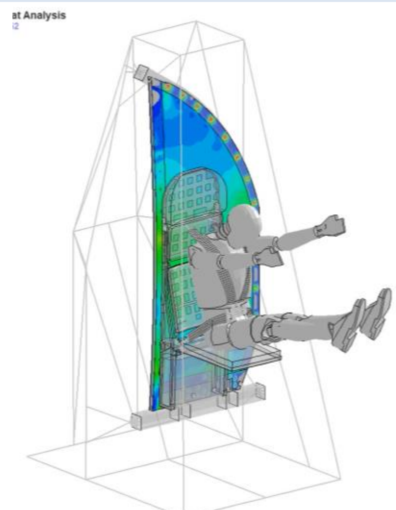
Axisymmetric Rubber Seal and O-Rings



Plastic Collapse ASME Section VII, Div 2



Aerospace (static preload)



Medical Instrument Analysis for Endoscopic Surgery

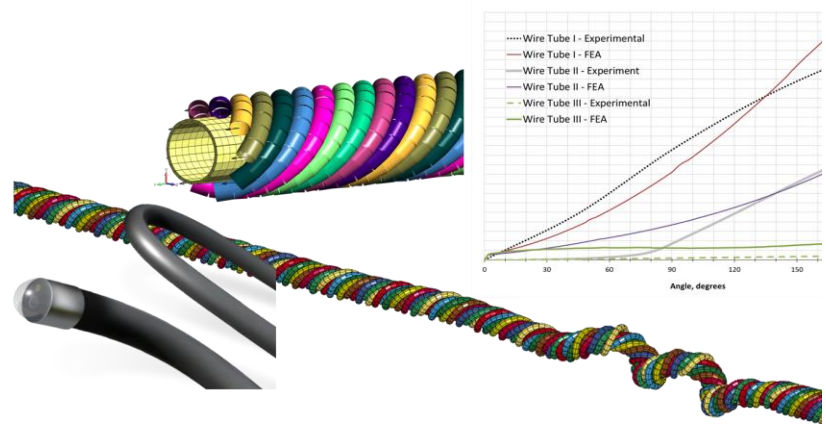


Figure 9: Just a Sampling of our FEA Engineering Services

Who we are

We are experienced simulation engineers that have successfully analyzed and validated hundreds and hundreds of finite element analysis (FEA) projects. With more than two decades experience we know how to optimize your design to eke out every last bit of performance and to ensure that it will meet your service requirements whether in Aerospace, Marine, Energy, Automotive, Medical or in Consumer Products.

Our Experience

When tackling a tough simulation problem, whether CFD or a nonlinear analysis with LS-DYNA, there is very little that beats experience. We feel that our experience provides a competitive edge to our clients to obtain the absolute best design. As for project costs, it is not unusual for our FEA or CFD consulting services to save our clients money given more efficient use of materials or by limiting testing to one prototype.

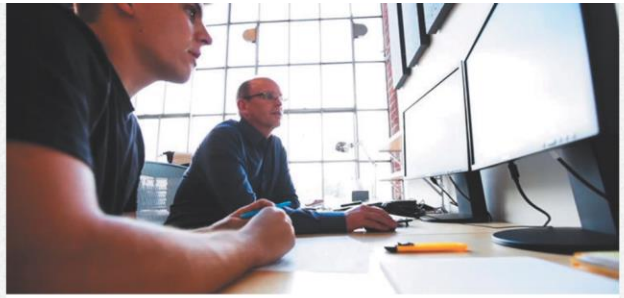
We Can Work for You

We'll let our Case Studies speak for themselves. Please see PredictiveEngineering.com/Consulting about how we have helped clients develop better structures and systems, from submarines to 3,000 HP transmissions to medical instruments to ASME Section VIII design-by-analysis pressure vessels.

Finite Element Analysis
Predictive Engineering

2512 SE 25th Ave, Suite 205
Portland, OR 97202

503-206-5571
info@PredictiveEngineering.com
www.PredictiveEngineering.com



Our History

Since 1995, Predictive Engineering has continually expanded its client base. Our clients include many large organizations and industry leaders such as SpaceX, Nike, General Electric, Navistar, FLIR Systems, Sierra Nevada Corp, Georgia-Pacific, Intel, Messier-Dowty and more.

Over the years, Predictive Engineering has successfully completed more than 800 projects, and has set itself apart on its strong FEA, CFD and LS-DYNA consulting services.

Our Mission

Our mission is to be honest brokers of information in our consulting services and the software we represent. We strive to exceed client expectations for accuracy, timeliness and knowledge transfer. Our process is both cost-effective and collaborative, ensuring all clients are reference clients.

View our portfolio of consulting projects

Next to our customers, our work is our biggest advocate. Please view our portfolio at
PredictiveEngineering.com/Consulting

Our FEA, LS-DYNA, FEMAP and NX Nastran expert George Laird

George Laird, PhD, PE, is Principal Mechanical Engineer for Predictive Engineering and Applied CAx. Author of over 40 publications on wear, fracture mechanics and finite element analysis. Dr. Laird has 20+ years of industrial LS-DYNA / FEMAP / CFD experience, with his doctorate in engineering mechanics (fracture and fatigue).

Our FEMAP, API and NX Nastran expert Adrian Jensen

Adrian Jensen, PE, is Senior Staff Engineer at Predictive Engineering and Senior Application Engineer for Applied CAx. With 10+ years of experience, Adrian specializes in all things FEMAP. His curriculum vitae includes stress, vibration, flow and heat transfer analysis for a variety of applications such as mining equipment, submersibles, electronics, gearboxes/ transmissions, wind turbines, large facility HVAC, offshore structures and ASME pressure vessels.

Our Thermal Analysis and CFD expert Clay Hearn

Clay Hearn, PhD, is Staff Mechanical Engineer and STAR-CCM+ lead. With over 15 years experience, Clay has worked on a wide variety of projects including thermal management design, vibration analysis of advanced power conversion products, free piston linear compressors, fuel cell hybrid electric vehicles, composite flywheel energy storage, and magnetic bearings.

Our Staff Mechanical Engineer Brian Kolb

Brian Kolb EIT, is Staff Mechanical Engineer. With a Master's in mechanical engineering focusing on failure analysis, material science, and FEA, Brian also has 5+ years consulting experience in project management, instrumentation, product testing, mechanical testing, failure analysis, non-destructive inspection, and fabrication.