ALTAIR

NONLINEAR ANALYSIS BUYER'S GUIDE

INTRODUCTION

We created this guide to help managers of CAE budgets navigate the multifaceted decisions companies must make when choosing a nonlinear analysis software vendor. Additionally, we've compiled some tips and best practices for successfully managing these deployments to satisfy the needs of growing engineering teams while extracting maximum return on investment.

NONLINEAR ANALYSIS SOFTWARE ASSET MANAGEMENT - WHAT YOU NEED TO KNOW

Companies of all sizes dedicate substantial resources to nonlinear analysis in order to predict the real-world behavior of their product designs. By producing accurate simulation results, organizations seek to increase profits by optimizing their designs, reducing physical testing and redesign cycles, and getting new and improved products to market faster than the competition.

Highly complex calculations are required in order to accurately model structural nonlinearity, which necessitates specialized software tools, engineering expertise, and compute power to efficiently run these large solver jobs. Nonlinear analysis is a vital element in many product engineering processes, but the costs associated with maintaining and scaling the software, hardware, and human capital requirements make this highly important from a software asset management perspective as well.

In 2016 87% of Best-In-Class organizations used simulation, up from 75% two years earlier. Source: The Benefits of Simulation-Driven Design, Greg Cline, Aberdeen 2017

LINEAR VS. NONLINEAR ANALYSIS

Structural analysis problems can be categorized as either linear or nonlinear. Linear analysis provides an approximation of real-world behavior where a linear relationship holds between applied forces and displacements. Problems where applied forces only minimally alter the part's shape and/or material properties are ideal for the application of linear analysis and require relatively less computational resources to produce results than nonlinear calculations. Because this approach is cheaper and less complex to analyze than nonlinear, the majority of structural simulations utilize the linear analysis approach.

Nonlinear analysis is required when the part being modeled undergoes large changes in stiffness, which can affect the part's shape and material properties. If a part undergoes significant deformation, the shape can change, and if it reaches its failure limit, the material properties can be affected as well.

The best way to determine if a problem is nonlinear is to look at the load-displacement response of one or more characteristic load introduction points. When the structural response (deformation, stress and strain) is linearly proportional to the magnitude of the load (force, pressure, moment, torque, temperature etc.), then the analysis of such a structure is known as linear analysis. When the load to response relationship is not linearly proportional, then the analysis falls under nonlinear analysis.

Nonlinear Analysis Can be Broken Down into Three Main Functions

Geometric Nonlinearity
A change in geometry that significantly effects load deformation treatment. Includes phenomena such as the stiffening of a loaded clamped plate, buckling or snap-through behavior in slender components.

Material Nonlinearity
Often characterized by a gradual weakening of the structural response as an increasing force is applied. Examples include elasto-plastic, hyperelastic, crushing, and cracking.

Contact Nonlinearity
The stiffness of the structure or assembly may change when two or more parts either contact or separate from their initial contact. Examples include bolted connections, toothed gears, and sealing or closing mechanisms.

IMPLICIT VS. EXPLICIT ANALYSIS

The Implicit approach is helpful when time dependency is not an important factor. Friction, heat transfer, and the modeling of bolts or gaskets are classic cases for an implicit approach.

A solution is found at each step in a series of iterations to establish equilibrium within a certain tolerance. Implicit can be applied to solve most engineering problems, provided the growth of stress as a function of strain can be established.

The Explicit method is typically used to solve high deformation problems that must be modeled over time. Crash, blast, and drop tests are good examples of FEA problems that use the explicit approach. These problems require velocities and accelerations as well as mass and dampening to model the deformations occurring at discrete time steps throughout the dynamic simulation. Explicit time steps are generally much shorter than in implicit analysis, so they are computationally more expensive.

Most Commonly Used Types of Nonlinear Analysis

1. Large displacements
2. Contact
3. Material in yield and hardening states
4. Large Strain
5. Instability/buckling

Source: What's the State of Nonlinear Simulation?, Roopinder Tara, Engineering.com 2019

WHY DO COMPANIES INVEST IN NONLINEAR ANALYSIS?

Nonlinear analysis is an important tool for the understanding of complex structural behavior including large displacements, material nonlinearity and advanced contacts. These analyses fit into a larger ecosystem of simulations including linear, vibrations, acoustics, thermal, fatigue, and multiphysics. Understanding the intricacies of complex nonlinear behavior is key to getting an accurate picture of how the product will behave in the real world. This enables companies to predict and prevent part failure, reduce costly physical testing and product redesign iterations, and get products to the market faster.

3 Reasons Why Companies Overpay for Nonlinear Analysis Software

1. License spend not right-sized to match actual usage
2. Not taking advantage of unique licensing approaches
3. HPC not considered as part of the software negotiation

COMMON APPLICATIONS OF NONLINEAR ANALYSIS

- Aerospace and Defense: Landing gear, Wing structures, Fuselage, Seals and hoses, Sheet metal forming
- Automotive: Powertrain, Tire, Seals and gaskets, Exhaust systems, Brakes, Suspension, Gear contact, welding, joints and connectors
- Electronics: Soldering, Welding, Drop tests, Sealing, Switches and connectors
- Heavy Equipment and Machinery: Gears, Steering yokes, Belts, Hoses, Metal forming, Hose crimping, Wire crimping, Curing, Welding, Extrusion
- Rail: Tip-over stability study, Structural components, Welding, Joints and connectors
- Shipbuilding: Structural analysis, Riveting, Bolts, Welding, Sealing

RIGHT-SIZING YOUR LICENSE SPEND FOR ACTUAL USAGE

Due to the high cost of nonlinear analysis software, it is important to appropriately manage the number of licenses your company maintains without constraining the work of the engineering teams. If you buy only for your absolute peak expected usage, much of that investment will be underutilized between times of high-volume usage.

Lease agreements enable companies to flexibly increase or decrease their license count as the needs of the business change. It also allows for exploration of alternative solutions without the worry of sunk cost associated with paid-up and maintenance license models.

SOFTWARE ASSET OPTIMIZATION TOOLS CAN HELP YOU MAKE DATA-DRIVEN DECISIONS

- Get advanced reporting and analytics on software and hardware utilization
- Pinpoint underutilized assets
- Perform “what-if” simulations to determine effects of user constraints on license availability
- Understand potential impact of increasing or decreasing license counts
- Calculate cost allocations for chargebacks

SCALING SOFTWARE DEMAND WITHIN TIGHT BUDGET CONSTRAINTS

With increasing simulation requirements of complex parts and assemblies and as engineering teams grow, the cost of adding nonlinear analysis licenses can severely constrict an organization's overall CAE budget. That's why flexible licensing schemes are an important tool for getting the most out of an engineering simulation investment. License flexibility allows you to fit your investment to the requirements of your engineers without introducing unnecessary bottlenecks when additional license access or compute power are needed.

Consider vendors that offer floating licenses which can be shared amongst various users within a group or throughout an organization. The flexibility these licenses offer compared to node-locked licenses allow you to purchase fewer total seats of software that can be accessed and shared by multiple users.

Token-based licensing models offer additional value. Rather than buying software licenses individually, you purchase a shared pool of recyclable tokens that can be used for nonlinear analysis or other CAE technologies offered by that vendor. When your job is done, the tokens return to the pool for another simulation or for other users to access. When the software spend with a vendor is diversified to cover multiple physics solvers, preprocessing tools and other engineering simulation needs, this flexibility ensures your software licenses are consistently being utilized and enables you to leverage volume discounting offered by the vendor.

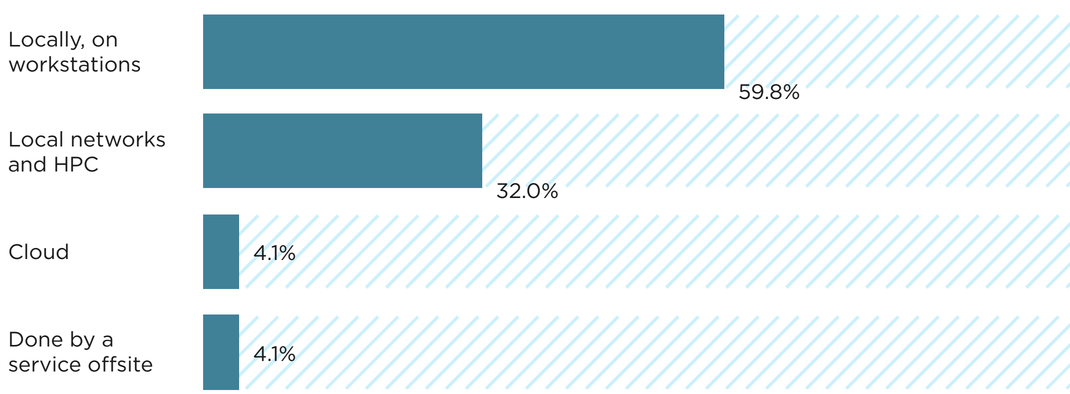
One word of caution with token-based models — avoid systems that discourage or prevent outside software from working within your CAE processes. Invariably, there will be users who need specialized technology from a variety of vendors, so seek out open-architecture solutions to allow third-party applications to work in harmony with your standardized tools.

BOOSTING SOLVER PERFORMANCE WITH HPC

The concept of right-sizing for regular usage also applies to solver job computing. Nonlinear analyses are often compute-heavy simulations, and high-performance computing (HPC) helps to speed up analysis times and enable more robust design of experiment and optimization studies. But many small businesses still see HPC as prohibitively expensive in terms of both capital expense and IT resources. In actuality, HPC is not just reserved for OEMs anymore. Options like on-premises starter nodes and virtual compute clusters require little setup and administrative work at a price point that won't break the bank.

Cost predictability and flexibility are imperatives for any IT team. Rather than incur the upfront costs and ongoing maintenance of purchasing HPC infrastructure outright, some vendors now offer yearly and multi-year appliance lease options. Companies that already leverage HPC sometimes exhibit irregular or unpredictable cadences of job submissions, which can have a choking effect on job scheduling efficiency, budget, and IT resources. If your company only requires extra compute power infrequently, scalable, pay-as-you-go virtual HPC appliance options will be more cost-effective than buying and managing additional dedicated compute clusters. You may find savings by investigating vendors that offer both simulation software and HPC solutions. It also ensures that your appliance will be properly configured to optimally schedule and deploy CAE jobs.

Where do nonlinear users perform their solver jobs?



Source: What's the State of Nonlinear Simulation?, Roopinder Tara, Engineering.com 2019

RESEARCHING AND SELECTING A NONLINEAR ANALYSIS SOLVER

Questions for the Engineering Team

- What departments utilize nonlinear analysis software?
- Do all departments use the same vendor? Are these deals negotiated individually or through a central corporate deal?
- Does each department have their own dedicated licenses or are they shared between multiple teams?
- How many total nonlinear users are in the company?
- How many are full-time users vs. part-time users?
- What is the perception of nonlinear analysis license availability? Are users feeling that a lack of licenses is reducing their efficiency?
- Are nonlinear analysis jobs run on individual workstations, local HPC networks, or on the cloud?
- How many CPU cores does the typical nonlinear job require? What is the peak CPU core requirement for the largest jobs?

Questions for the IT Team

- How often do nonlinear license checkout failures occur due to lack of licenses?
- Do jobs typically run during work hours or overnight?
- Could compute resources be more effectively utilized by queuing jobs to run in off-hours?
- What is the percentage of utilization of nonlinear analysis licenses? Which divisions have the highest and lowest utilization per user?
- What is the percentage of utilization of HPC resources used by nonlinear analysis jobs?
- What is yearly the cost for maintaining current on-site HPC resources?
- Do engineering teams have the ability to burst jobs to the cloud for additional short-term solver requirements?

Questions for Future Planning

- Do I expect the use of nonlinear analysis to grow in the next 3 years among existing CAE users?
- How many additional nonlinear analysis users do I expect the company to hire in the next 3 years?
- How much do I expect the software budget to grow in that same 3-year span?

GENERATING CONSENSUS AND FOSTERING ADOPTION WITH TECHNICAL TEAMS

TIPS FOR GETTING ENGINEERING TEAMS ON BOARD WITH A NEW SOFTWARE AND NAVIGATING VENDOR INERTIA

Because of the model complexity and expertise needed to effectively perform nonlinear analysis, users often have years of experience running particular software applications and carry strong allegiances to these tools. Additionally, there may be specialized features and custom workflows that make it difficult for engineering teams to get on board with using a less expensive alternative.

In order to execute any changes to an existing nonlinear analysis software deployment, there are a few key tips to ensure a successful value-driven transition without sacrificing productivity.

Where do nonlinear users perform their solver jobs?

48% of respondents cite "not enough training or education" as the number 1 barrier to use of nonlinear analysis software. Source: What's the State of Nonlinear Simulation?, Roopinder Tara, Engineering.com 2019

Focus on Validation

The accuracy of a new tool is of vital importance to engineering teams considering the introduction of a new software. Benchmarks are the best way to evaluate whether a software can deliver results within an acceptable range of the incumbent tool.

In most instances, especially when benchmarking multiple vendor's software, it's best to use a common, standardized model that represents an approximation of the work analysis teams do on a day to day basis. Using the same model with each vendor makes it easier to compare the accuracy of each solution and using a somewhat simplified model allows you to focus on the core competencies of each software rather than getting bogged down by the intricacies of setting up highly specialized simulations.

Set clear accuracy thresholds and work closely with the vendors during the benchmarking stage. You'll help instill confidence among users that the software can perform to the level they require and get a window into how each vendor approaches project support.

Take an Incremental Approach to Tool Conversion

There is often a tendency when benchmarking a new tool to investigate and attempt to replicate results from the company's most complex nonlinear analysis jobs. These jobs often rely on intricately developed customizations as well as highly specialized features. The new vendor may have different workflows, user interfaces, and calculation methods that make one to one comparison difficult in these cases.

Critically, these highly complex use-cases are also often run infrequently and by a small subset of the overall nonlinear user-base. A more efficient approach is to examine the most commonly used applications of nonlinear analysis and test the new tool's viability in these regularly-applied usage scenarios. A tiered deployment allows an initial set of users to transition tools without disrupting the workflows required of highly specialized applications. As the relationship with the new vendor grows, additional functionality and customization can be added to justify broader adoption.

Accessible and Comprehensive Training

A trained and informed user-base is perhaps the most important key to a successful introduction of new software. Without internal champions and external expertise, it will be difficult for users to accept a change in process and motivate them to learn a new software.

The most successful training programs involve a mix of instructor-led classes and on-demand e-learning resources. Check with any prospective vendors about their live and online training resources, their ability to train users at locations around the world, and the availability to provide classes and self-paced resources in each team's local language.

Research and Vet the Vendor's Technical Support

With any nonlinear analysis software deployment, ongoing vendor support is key to establishing a productive simulation process. Research each vendor both directly and through third-party review sites to understand their industry reputation, typical response time, and support request submission processes. Do they support users in each location's local language?

Are all requests submitted online, or do they have a phone hotline as well? Would there be a dedicated Application Engineer for my account? All of these questions are helpful when considering the level of support a vendor is able to provide to users in need of guidance and technical expertise.

Encourage Vendor Collaboration & Process Synergy with Engineering Consulting Services

A great way to build confidence in a new tool and work out the kinks of integrating that software into an existing design and analysis process is through a services engagement. Many software companies have their own engineering services groups whose employees are expert in that software and trained to use it in a myriad of simulation environments. Running a project using the vendor's consulting group can help to build confidence in the viability of a tool as well and impart knowledge about process integration and best practices so future projects can be run in-house.

WORKING WITH ALTAIR

Altair® OptiStruct® is a modern solver technology that delivers the functionality that customers of traditional nonlinear implicit codes expect, including simulation of large displacements, material nonlinearity, and advanced contacts. Already the industry standard for optimization of topology, composites, mechanisms, and additive manufacturing, OptiStruct has evolved over the past three decades into a comprehensive linear and nonlinear analysis solution.

Altair's flexible, value-based licensing model allows metered usage of Altair's entire catalogue of CAE software including OptiStruct and a broad suite of other physics solvers. And as your computing requirements increase, Altair offers high-performance computing optimized for CAE, from cost-efficient turnkey starter nodes up to powerful enterprise-level solutions.

Want to learn more about nonlinear analysis with Altair OptiStruct?
Visit **altair.com/optistruct**

> "Recognized as the pioneer and leading technology for structural optimization, OptiStruct has evolved over the past 25 years into a modern, single-solver solution for both linear and nonlinear analysis and optimization."

Altair is a global technology company providing software and cloud solutions in the areas of simulation, high-performance computing (HPC), and artificial intelligence (AI). Altair enables organizations across broad industry segments to compete more effectively in a connected world while creating a more sustainable future.

To learn more, please visit www.altair.com