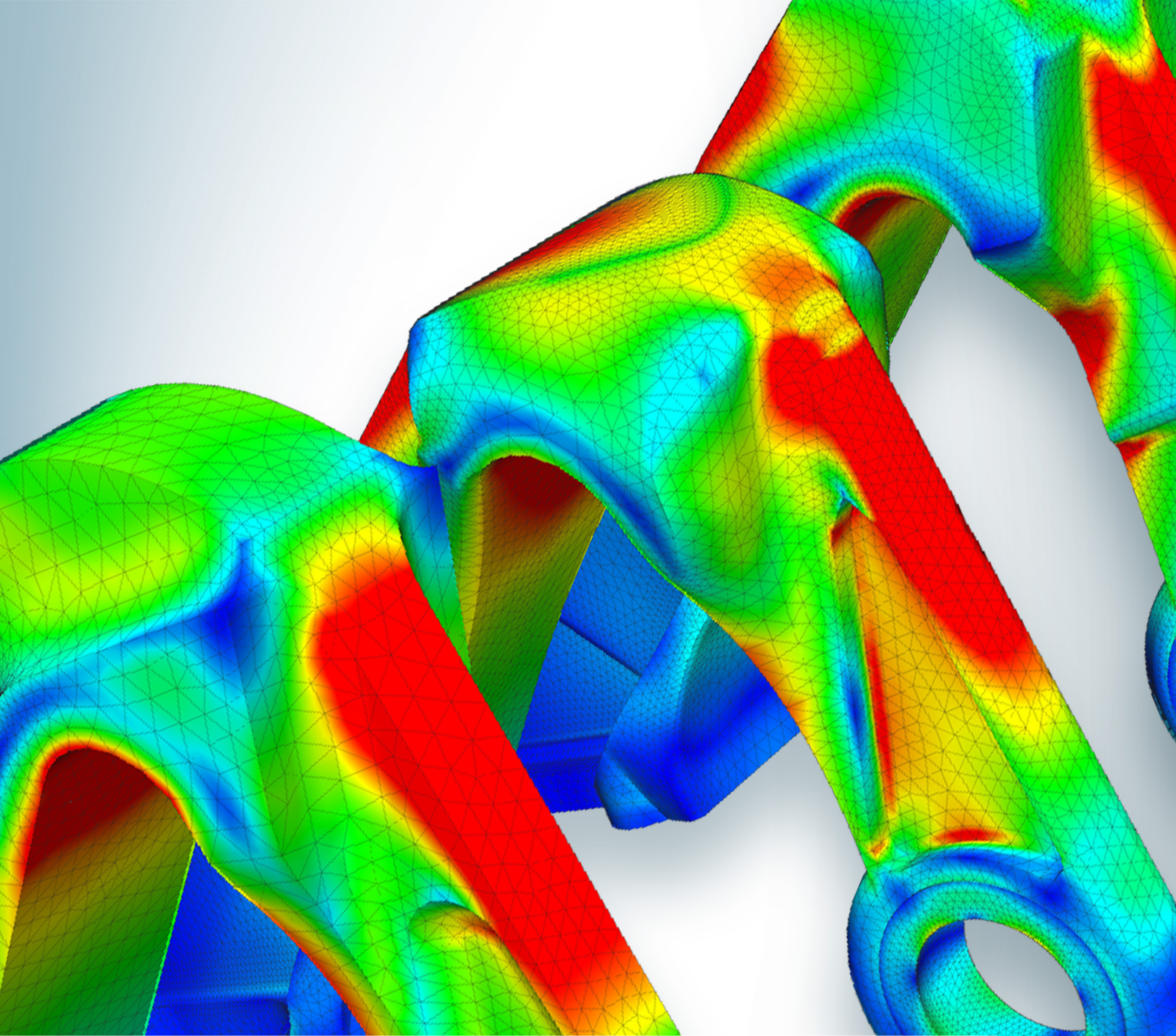
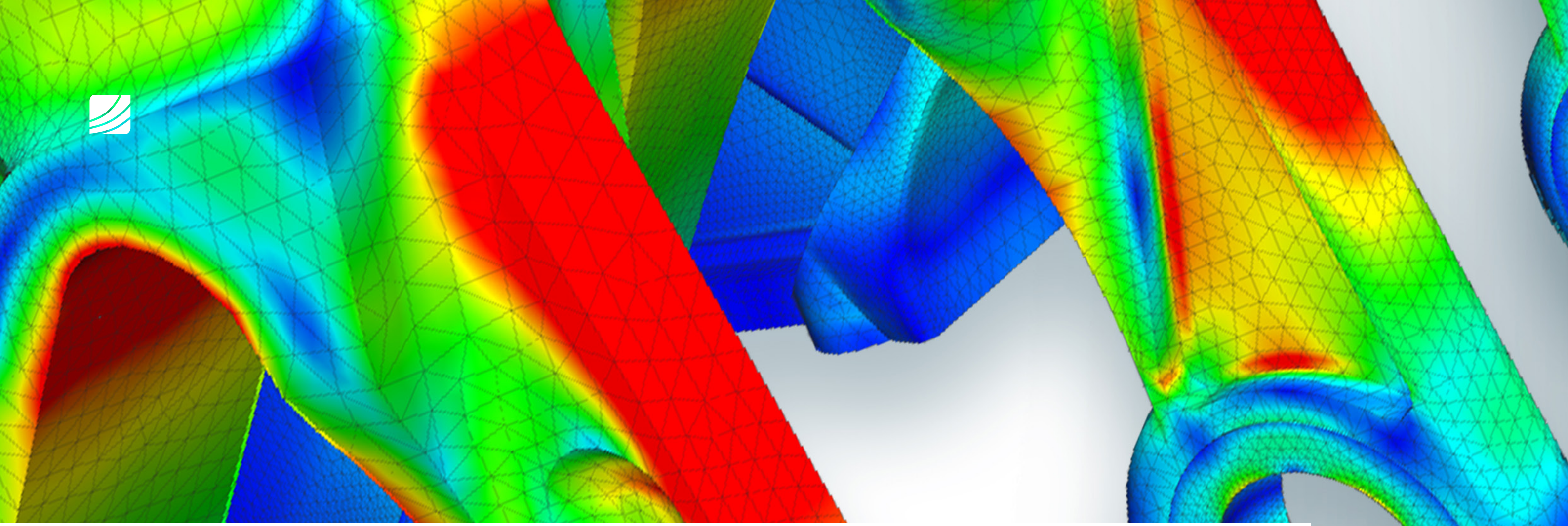


SIMSCALE

WHITEPAPERS

Structural Mechanics Simulation in the Cloud

Simulate early. Simulate more. Simulate now.



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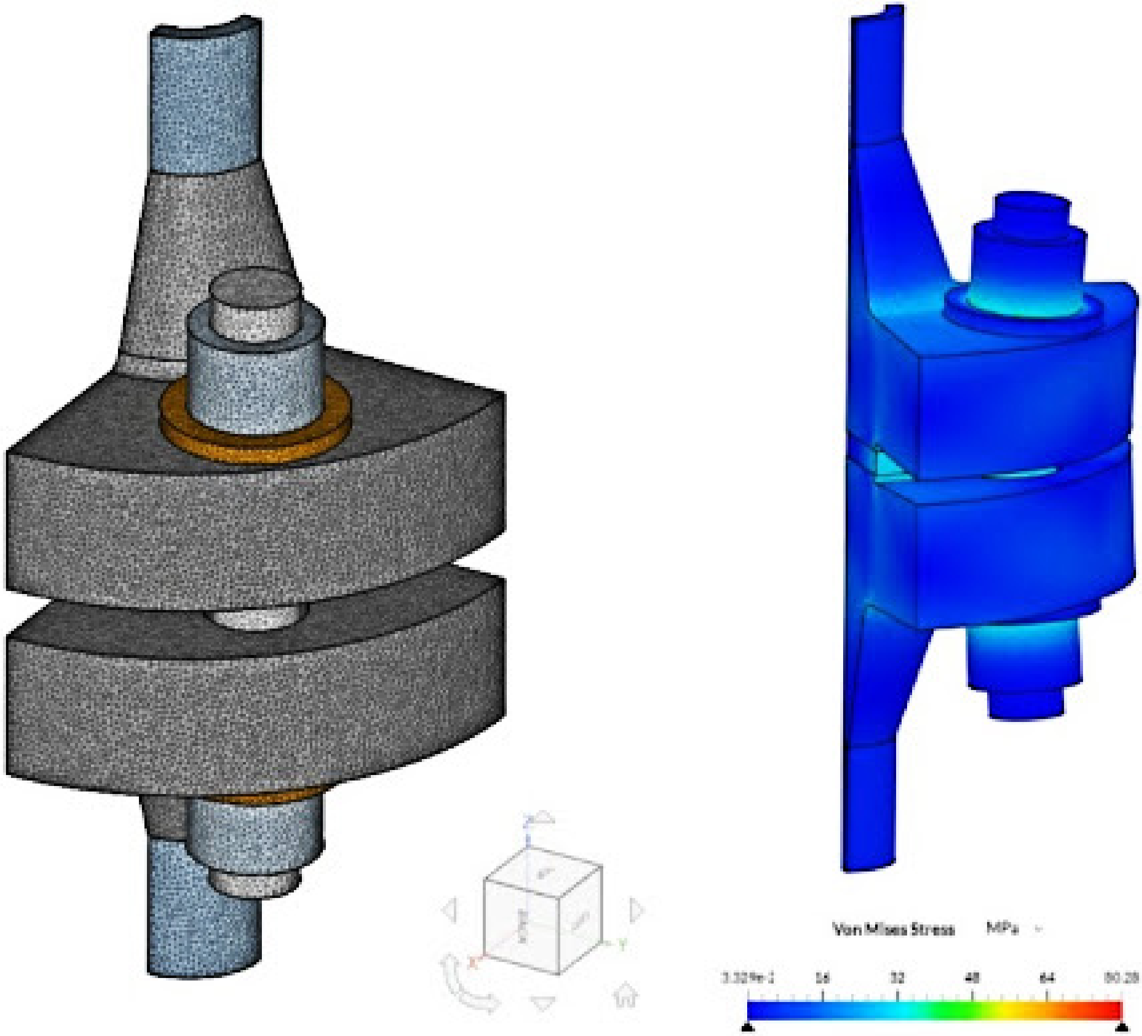
Executive Summary

Engineers designing and testing mechanical components and devices require high-fidelity engineering simulation to quickly and reliably understand their structural and thermal behavior and achieve the best designs with the least amount of iterations. In particular, Finite Element Analysis (FEA) enables engineering teams to solve realistic structural mechanics problems dealing with static, dynamic, and thermal loading conditions.

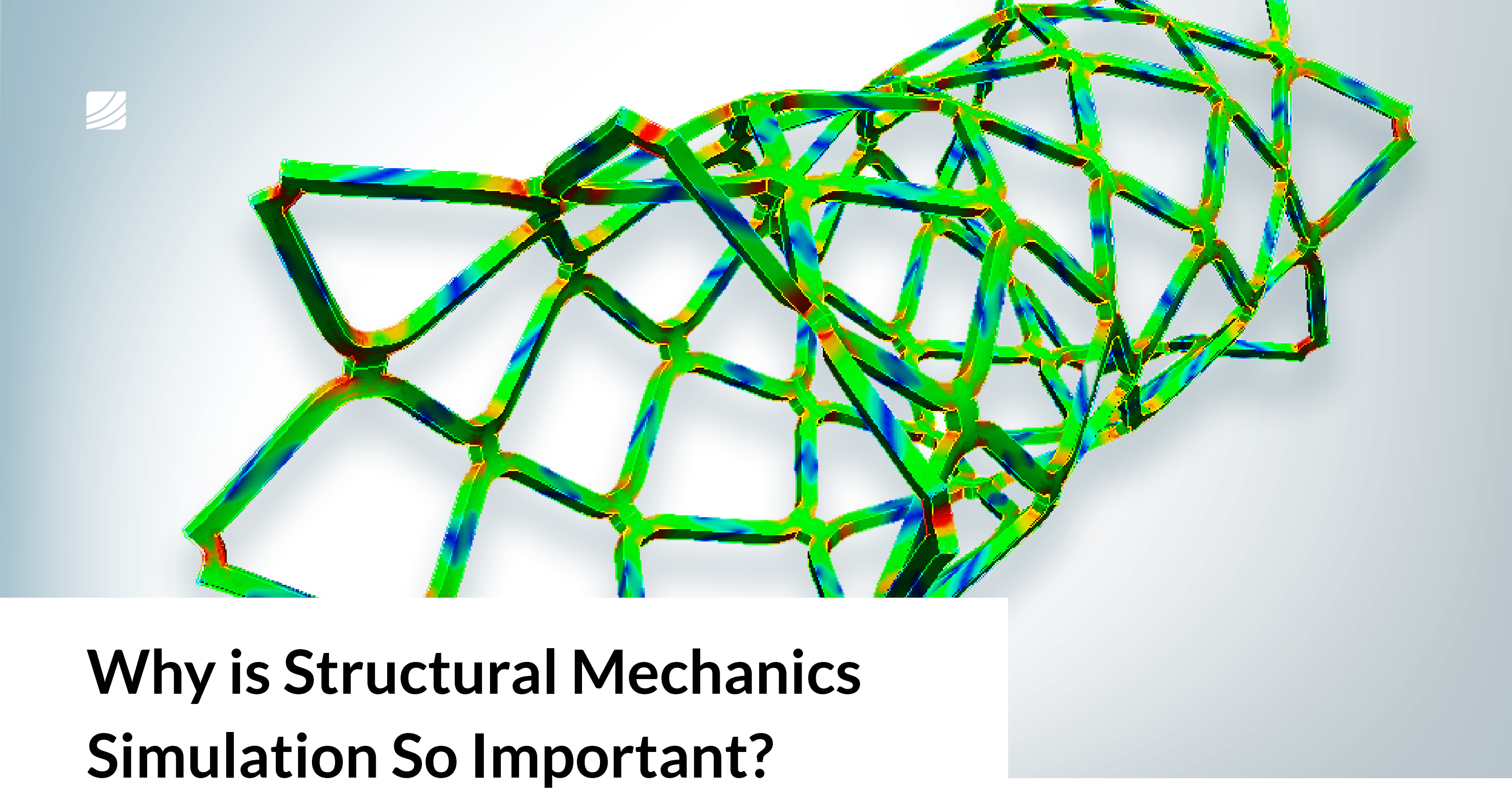
In this whitepaper, we discuss how SimScale, as a cloud-native engineering simulation platform, equips engineering teams worldwide with a wide range of functionalities and SaaS (Software-as-a-Service) accessibility to high performance computing needed to maintain a competitive edge. Thousands of SimScale users, from original equipment manufacturers (OEMs) to aerospace companies, prove that adopting digital prototyping powered by the latest

computing technology is a winning engineering and business strategy. Engineers and designers have traditionally been constrained by legacy desktop CAE (Computer Aided Engineering) simulation software. On-premise computing power does not scale up or down on-demand, nor continuously delivers newly-developed simulation and analysis capabilities.

Access to physics-based solvers in the cloud enables designers and teams to quickly assess performance, accelerate design iterations, and collaborate: this scalable approach to design is essential to fully capture real-world structural behavior early in the development stage, throughout the R&D cycle, and across the entire organization.



Bolt preload analysis: Finite element tetrahedral mesh (left) and simulated flange deformation and stress distributions (right).



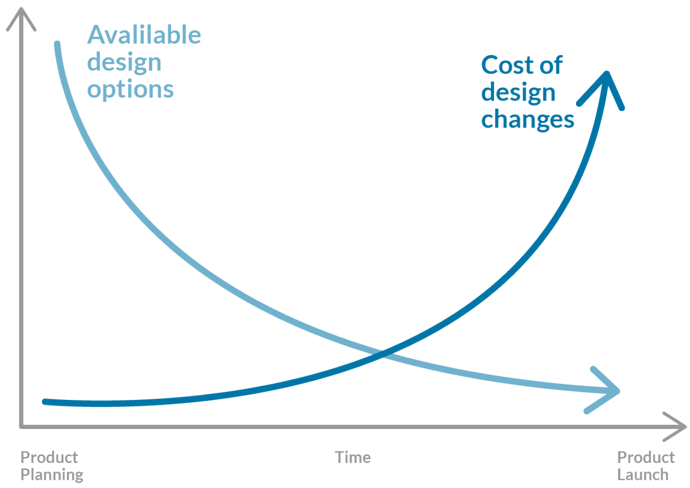
Why is Structural Mechanics Simulation So Important?

Stress analysis of a cardiovascular stent.

The numerical simulation of structures, machines, and devices brings enormous value to companies in order to reduce costly and time-consuming physical prototyping processes, resulting in significant savings. In many cases, measurements for design verification are either impossible to make or very expensive and can add strong perturbation to the variable in question, leading to skewed results. Some products operate in environments and under conditions that are impossible and/or extremely difficult and expensive to recreate for testing purposes, but can be modeled inside simulation tools at less cost and risk. For example, medical applications that require extensive and invasive human testing such as the nonlinear stress analysis of cardiovascular stents can now be easily simulated.

As FEA can be computationally expensive and time-consuming, leveraging the practically unlimited power offered by the cloud grants organizations speed, scale, and accuracy. With a web browser-based user interface easily accessed from anywhere, at any time, engineering teams of all sizes can start adopting engineering simulation earlier in their design and development processes and do more with simulation.

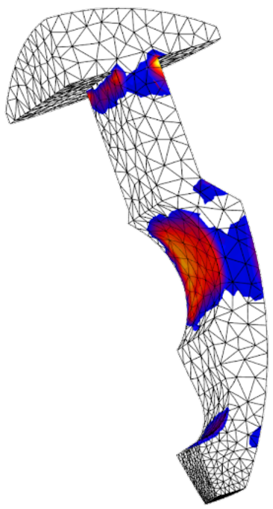
Structural simulation with SimScale means that in one platform and using the same model, engineers can use different structural analysis types to holistically simulate and analyze their projects. Structural, thermal, and thermomechanical behavior can be investigated in order to find critical stress regions and unpredictable deformations stemming from the complexity of real life scenarios.

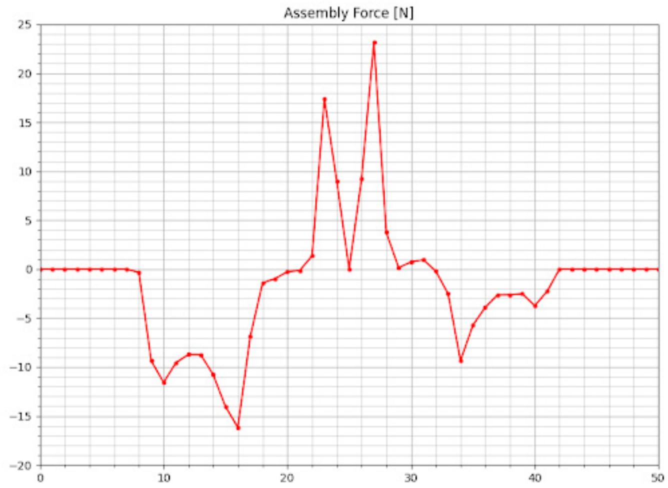


Simulate at the Early Design Stages

The traditional product development process involves building a physical prototype and taking it to the lab for testing. The testing will likely reveal several design flaws that require a redesign. This traditional cycle can stretch the development schedule indefinitely. By adopting digital prototyping, users can eliminate the unnecessary loops from the design optimization process at an early stage, cutting both time and costs of development as a result.

With CAE, it is still possible to have an iterative design process, but the days, weeks or months of physical testing are replaced with hours or sometimes even minutes of digital prototyping, often achieving more reliable results and ultimately more durable products.

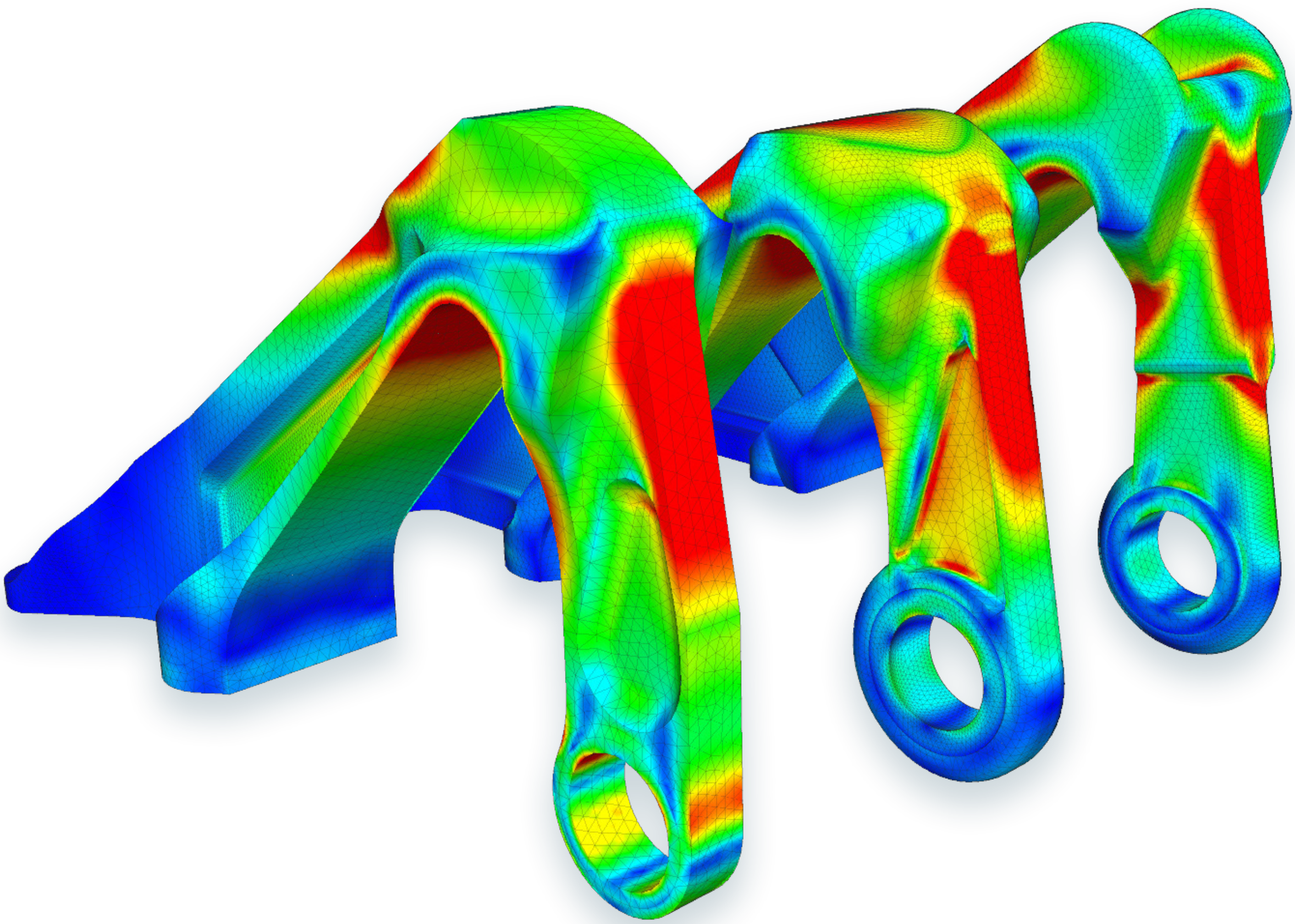




Push pin mechanical simulation: Plasticized regions (left), insertion and extraction force history (right).

What Can Be Simulated

SimScale enables engineers to perform simulations of structures, including linear static and nonlinear quasi-static analyses, and to assess structural integrity and stress distributions, and predict deformations.Users can simulate plastic behavior in nonlinear analyses but also include thermomechanical behavior into the analyses. Additionally, all types of nonlinearities can also be taken into account, including geometric, contact problems, and material. Applications include heavy machinery, industrial equipment, automotive and aircraft components, pipes, and bridge design.



Von Mises stress distribution in a bearing bracket of an airplane engine.

SimScale is deployed as a SaaS engineering simulation platform offering a single user interface that supports the following analyses:

Static - Linear and nonlinear analysis of displacements, stresses, and strains in one or multiple solid bodies

- Aluminum pipe bending (large deformations)
- Snap fit permanent deformation (plasticity)
- Rubber seal installation (hyperelasticity)
- Shaft and rotor interference fit (nonlinear frictional contacts)

Dynamic - Transient calculation of displacements as well as stresses and strains in one or multiple solid bodies

- Shock
- Drop test

Harmonic - Simulation of the steady-state structural response of solids applied to periodical (sinusoidal) loads

- Shaker table testing - sine swept
- PCB vibration
- Bracket and fixation assessment

Frequency Analysis - Calculation of natural frequencies of oscillation of a structure and the corresponding oscillation mode shapes

- Modal surveying
- Prestressed eigenmode analysis (bolt prestress)
- Support and fixtures due diligence

Heat Transfer - Calculation of the temperature distribution and heat flux in solids under conduction, convection and radiation)

- Transient power cycling
- Thermal packaging

Thermomechanical - Calculation of the structural and thermal behavior of one or multiple bodies

- Thermal shock
- Thermal interference fitting
- Thermomechanical fatigue

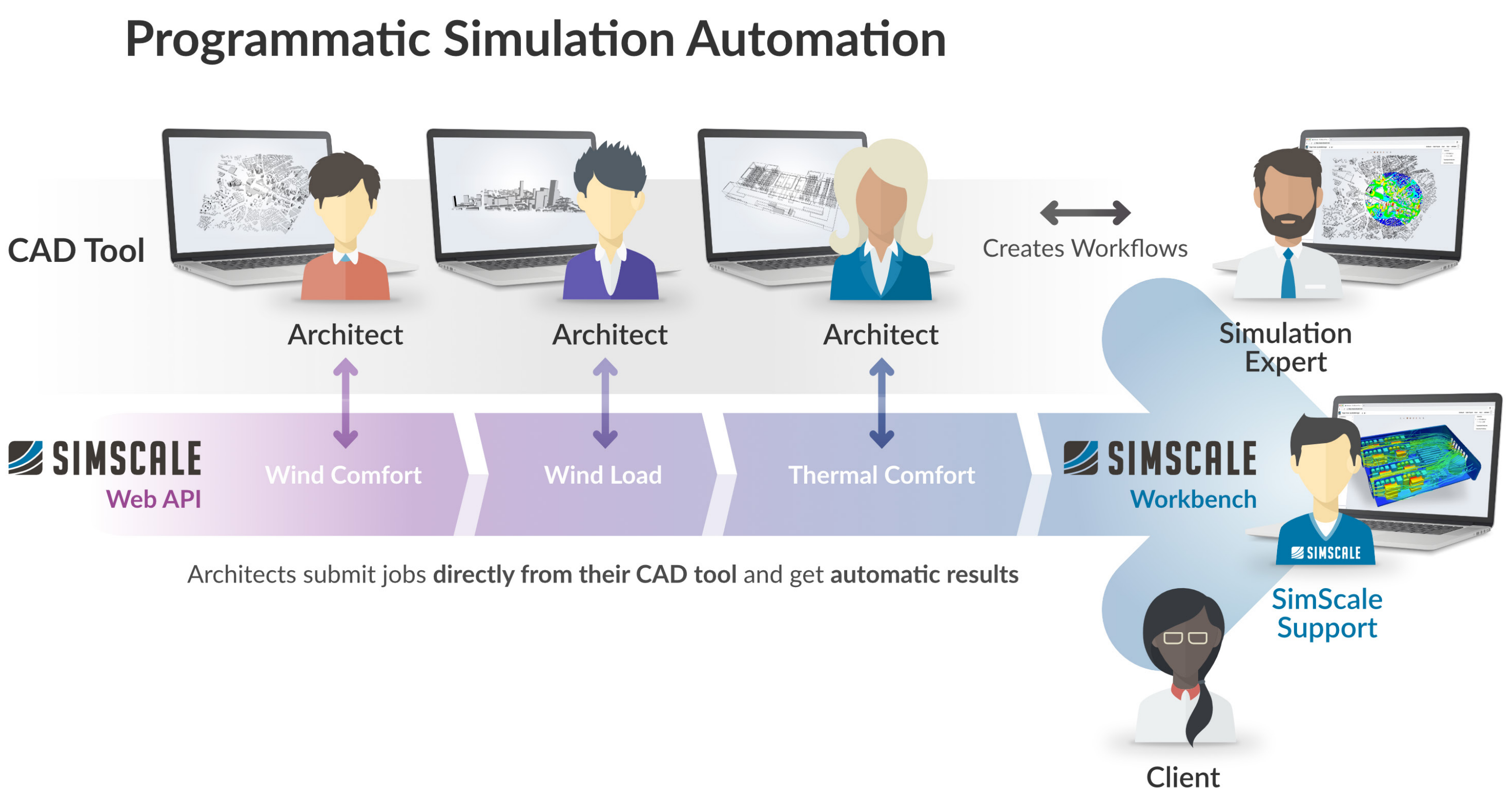
Explore the Design Space Fully Before Converging on a Final Product

Multiple iterations of a design have to be run in order for the best and final product to emerge. Using traditional CAE tools, this can be an expensive and tedious process as simulations are executed sequentially, rather than in parallel. SimScale has made this possible by developing an engineering simulation platform that grants engineers access to the practically infinite computational power offered by the cloud. With SimScale users run hundreds of design iterations in parallel from their web browser while maintaining the desired accuracy and avoiding any IT bottlenecks. SimScale leverages high-performance cloud computing to solve complex physics accurately, automate meshing, optimize CAD import and offers interoperability with common engineering design tools. Structural simulation using SimScale means that in one platform, engineers can investigate the structural integrity of multiple real life scenarios.

In order to exploit full product behavior for different scenarios, SimScale offers a variety of FEA modules to model and investigate structures that are subject to static, dynamic, or even thermal conditions.

Eigenmode analysis of an ADAS Roof Mount Design by OxTS.

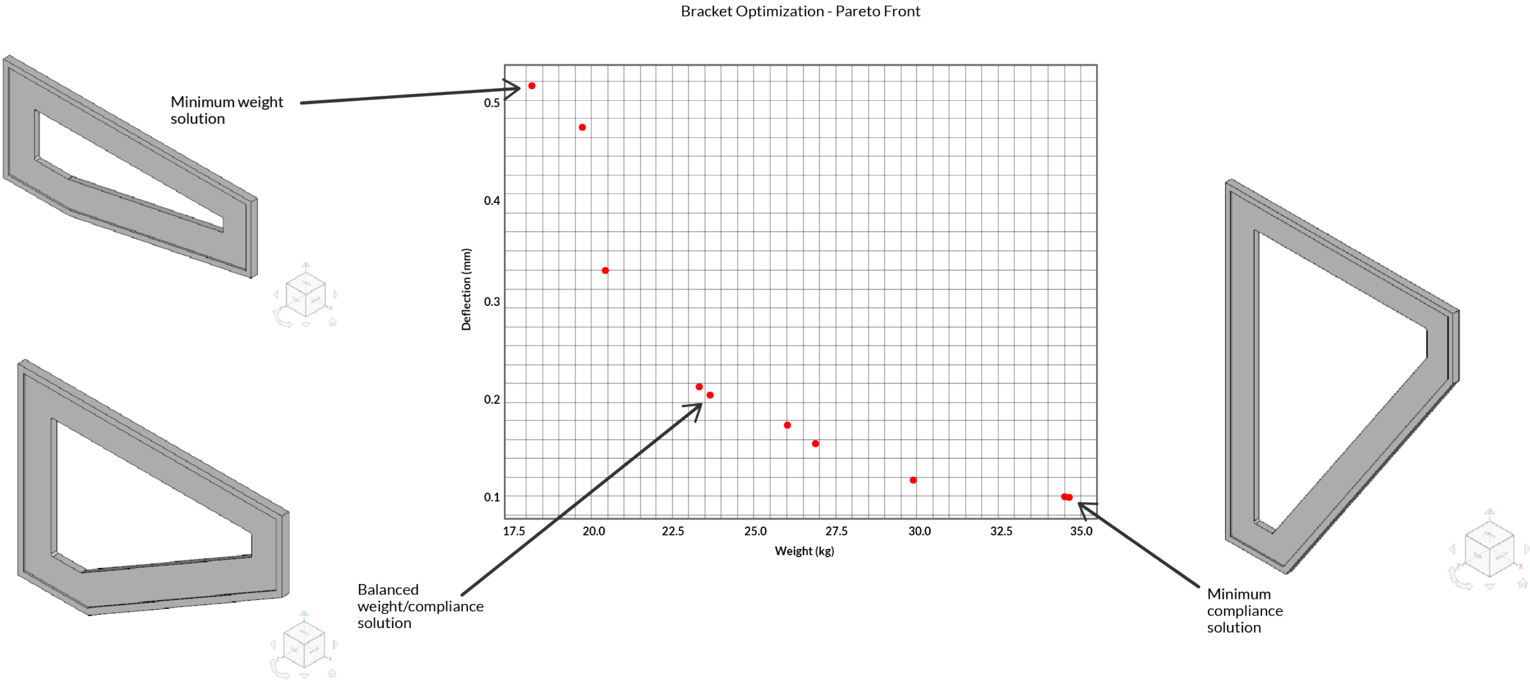
Additionally, SimScale's API integration facilitates full scalability of simulation capabilities. Instead of working on a very limited number of structural designs and kicking off simulations in a manual, sequential process , engineers now have the power to evaluate dozens of designs simultaneously from a single platform and investigate hundreds of iterations in parallel without reducing local computational power.
A better way to implement a design workflow is to automate the process as much as possible using an integrated software solution fit for this purpose and aligned to give the desired outcome. A more automated, rather than manual approach, is described in the image below. The SimScale API can be used to drive the entire design process—linking with, and driving, multiple design tools. In this case, the preferred CAD tool could be automated to output multiple design iterations, all of which are simulated in parallel, on the cloud, withSimScale.



Programmatic engineering simulation: SimScale allows the set up of a data-driven simulation environment where different users, based on skill set and design goals, can run a dedicated simulation starting from a CAD model.

Beyond building workflows for specific applications, design automation and optimization with an arbitrarily scalable simulation backend are now possible, leading to a true iterative and generative design capability. Other compelling use cases are 'digital twin' solutions, where SimScale API is a perfect fit for gathering data from devices in the field, feeding those into simulations, and deriving actionable insights, for example, for predictive maintenance.

In the following use case, a multi-objective structural optimization is performed, aiming to minimize cost and compliance, which are conflicting objectives, subject to a constraint on allowable stress. Geometry dimensions are used as parameters to define the search space, and the NSGA-II algorithm is run to find the pareto front of optimal solutions. The SimScale API allowed fast evaluation of the structural performance using automated FEA simulation, run in parallel for the multiple candidate solutions in each iteration, on the cloud without hardware limitations.



Results of a multi-objective optimization run, showing pareto front.

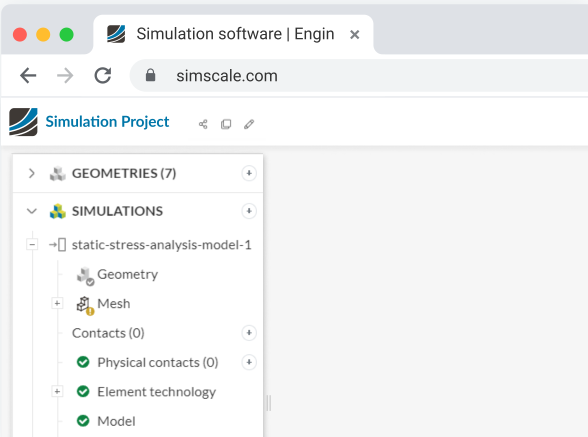
Collaborate With Your Design Team and Partners

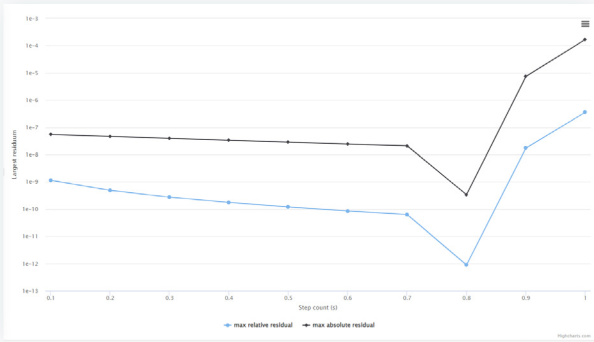
Engineering teams across many disciplines frequently experience tight project timelines and deadlines, meaning multiple designers/engineers will be running or using simulations on a given project. Additionally, international companies with teams working in various countries and timezones struggle to communicate and work together as efficiently as possible in a remote-working setup. Conventional simulation workflows are time-consuming and cumbersome with each simulation step requiring immense manual effort including moving large amounts of data. Using SimScale, project time and cost is reduced by eliminating complex deployments and IT footprint with a cloud-native platform. Users avoid the queuing of costly computing resources during peak demand and are able to visualize and control computing consumption across different teams collaboratively. Additionally, training efforts can be minimized with a simple user interface, intelligent automation, and real-time support.

Multiple users can work simultaneously from any location, eliminating the need to copy projects and start over from scratch. Simulations are kept within one project, instead of having multiple projects for the same application. Moreover, team members can share knowledge and expertise more quickly, and even in remote work set-ups, as different members can access the same project in real-time. All of this, controlled through a dashboard that displays computing usage overview, enables engineering teams to accomplish tasks like never before. This ensures the production of high-performance structures with a shorter time-to-market and lower costs for physical testing.

Multiple users can collaborate on same simulation project in real-time thanks to the cloud-native collaboration features.

Why Simulate in the Cloud?



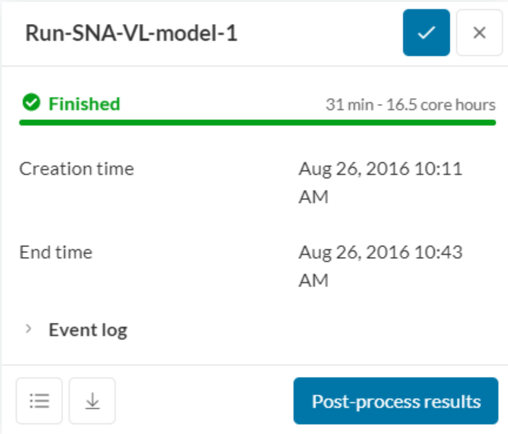


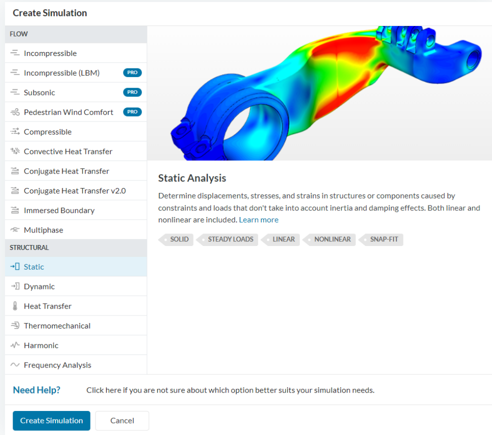
Accessibility

SimScale makes engineering simulation economically and technically accessible through an easy-to-use, browser-based solution that can be accessed from anywhere, at any time. Users benefit from live technical support and a simple usage-based pricing model that minimizes IT and licensing costs. The SimScale platform easily integrates with existing workflows and design processes. As an end-to-end simulation stack users can bring a CAD model to SimScale and leave with robust design decisions.

Accuracy

SimScale uses proprietary solver technology specifically designed for mechanical and structural applications that has been validated extensively against industry standards. Engineers can harness advanced solvers that account for thermal and structural behavior for fast and accurate assessment of deformation, stresses, and other design critical output quantities. Our solver delivers accurate results across a variety of problem domains and scales. Moreover, thanks to the huge computational power offered by the cloud, the accuracy of the simulations can be increased by performing more detailed analysis.



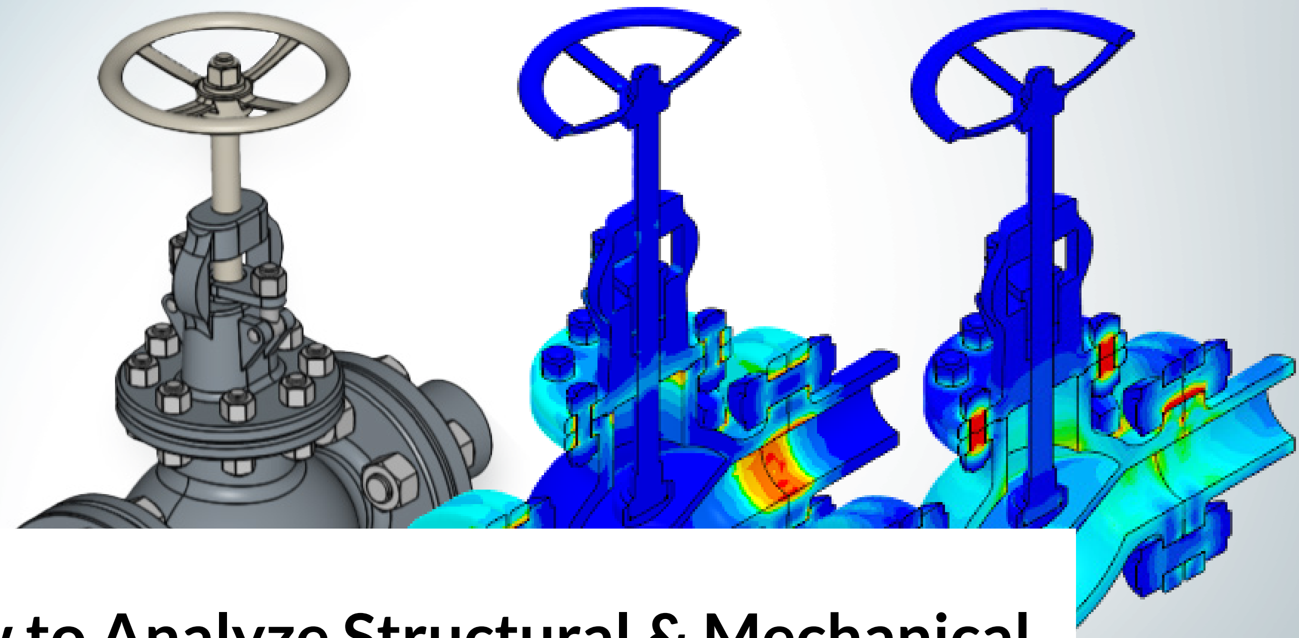


Efficiency

SimScale offers a fast simulation solution by harnessing practically unlimited HPC power of the cloud. Recent improvements in proprietary solvers have enabled an order of magnitude increase in speed of simulations while boosting the accuracy and confidence in the results. The ability to run multiple design iterations in parallel means that simulating an entire project from CAD preparation to post-processing can be performed with fast turnaround times.

Versatility

With SimScale, engineers can solve structural and thermal problems of industrial components, valves, medical devices, turbomachinery, pressure vessels, and much more. The scale of simulation projects can range from the analysis of coronary stents all the way to silo superstructures using solid elements without having to worry about disk space, calculation, or post-processing speed. Engineers can benefit from a vast number of existing public projects, spanning multiple industries and applications, to serve as a starting point for their own studies.



How to Analyze Structural & Mechanical Effects Using Simulation in the Cloud

As a cloud-native engineering simulation platform, SimScale facilitates a high degree of collaboration between team members and automates the most common steps of a simulation workflow, from CAD import and meshing to results analysis.

Import & Edit Your CAD Models with Ease

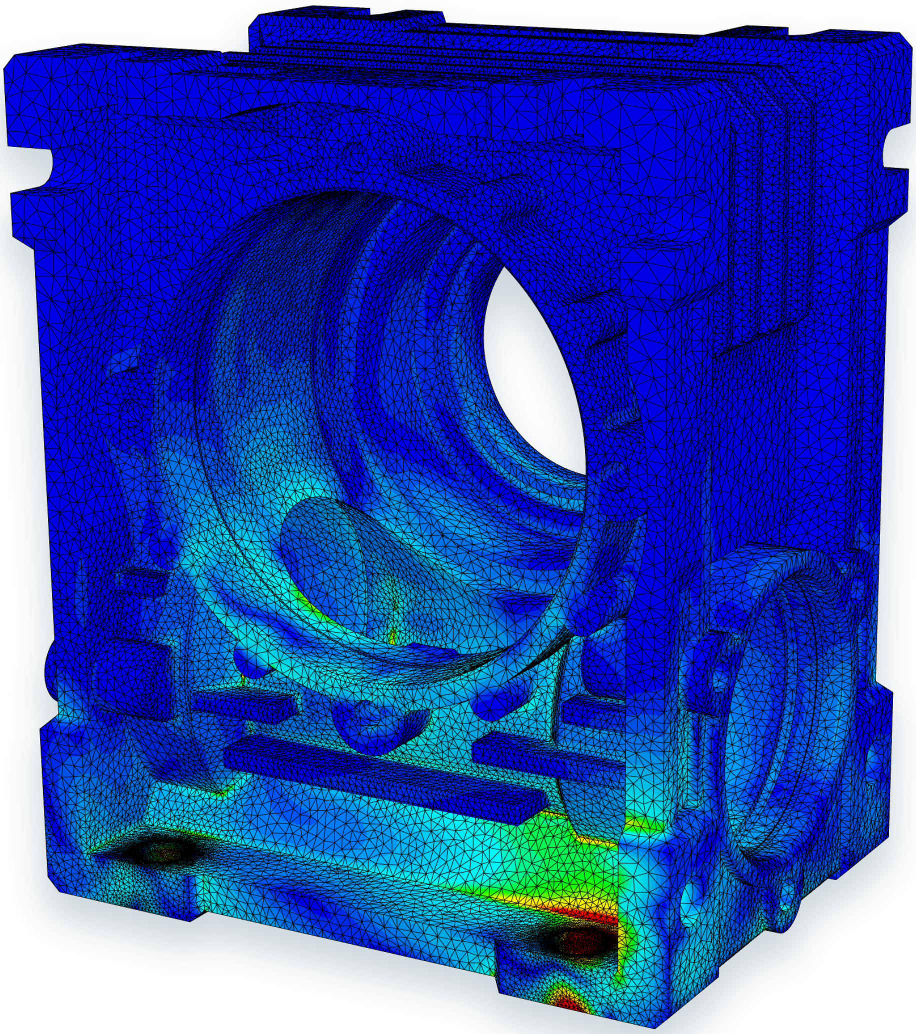
Preparing, uploading, and adapting your CAD model for analysis is the first step in setting up a simulation. SimScale supports the most common geometry formats for importing CAD including Solidworks, Inventor, STEP, IGES, STL, and Parasolid. Third-party CAD connector apps are available for Onshape and other tools, allowing for a more seamless integration. After CAD upload, some additional preparation might be required depending on how the file has been created. SimScale offers a dedicated environment to interact with your model called *CAD mode* that helps users prepare the model within SimScale without having to switch to external CAD software. Users typically need to create the fluid volume. *CAD mode* supports operations like scaling, extrude, body and face delete, surface splitting, etc. with new features being added continuously.

The *CAD mode* feature available in the SimScale platform offers a set of purpose-built CAD editing and simplification tools. Unlike traditional CAD systems, *CAD mode* focuses on a core set of simple, intuitive, but also versatile, tools that are ideal for making CAD models simulation-ready.

Quickly Mesh & Solve Complex Designs

Mesh generation is a labor-intensive and tedious aspect of traditional FEA software. SimScale's platform is based on a special meshing technique that ensures the mesh interfaces are both conformal between all parts and robust enough to apply to many types of CAD models the first time around.

Our proprietary technology is harnessed specifically for mechanical and structural applications and lends itself to meshing complex geometries. In one engineering simulation tool, you can mesh and solve your models with an easy-to-use and intuitive workflow.



Structural integrity simulation of a worm gearbox. Mesh and von Mises stress are shown.

Visualize Design Insights

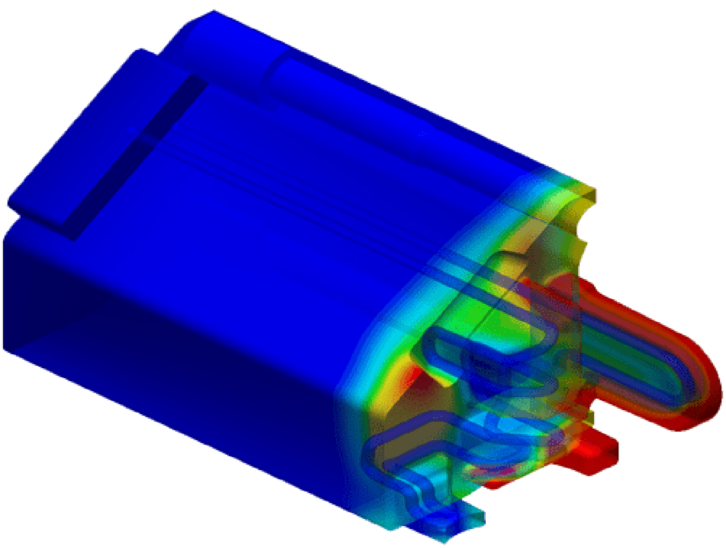
Engineers and designers need to identify performance issues early in the design process before they manifest in real-world situations and fail to meet customer expectations. FEA, for example, empowers engineers to visualize important behaviors and physical quantities and rapidly gain insight into product performance.

SimScale offers a platform to quickly investigate design changes in its own intuitive post-processor, empowering users with a better understanding of mechanical, thermal, and thermomechanical phenomena. Physical variables including displacements, strain and stress types, reaction forces and moments, or even heat flux can be calculated and visualized.

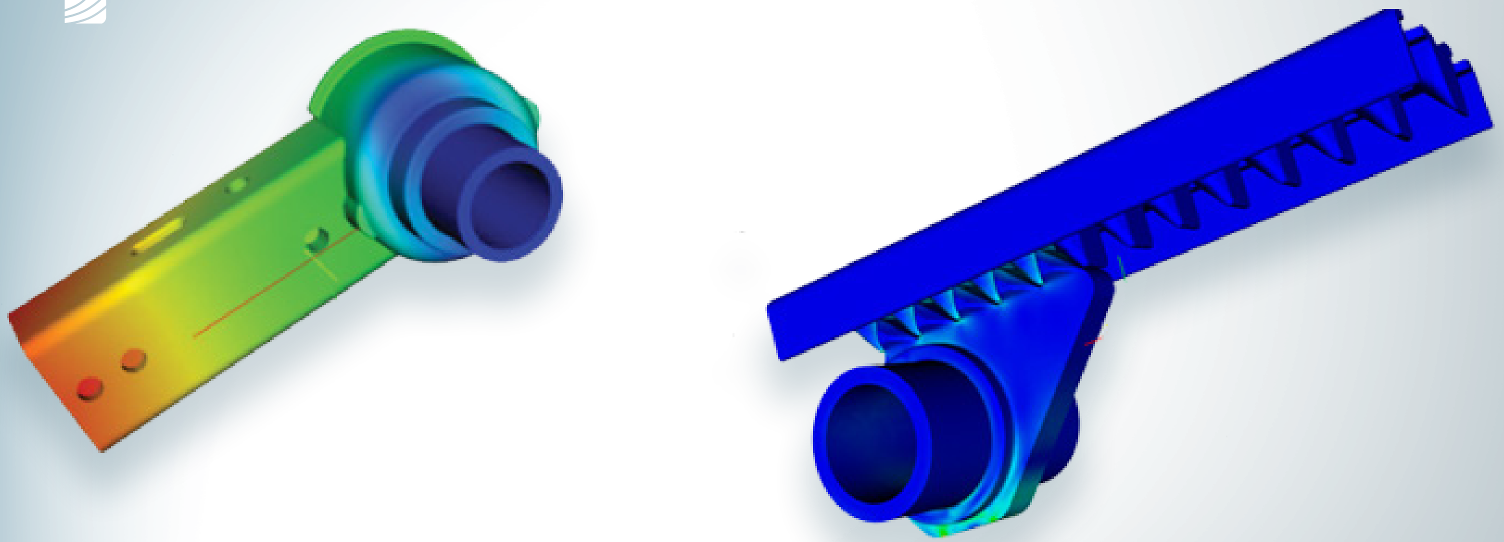
Additionally, engineers can post-process further quantities including the force history of entire components, stress and temperature distributions, deformation, and much more using the advanced post-processing features in SimScale.

Result control allows users to define extra simulation result outputs such as:

- **Edge calculation:** Calculates statistical data of a chosen parameter on an edge. For example, the average displacement on an edge in the x-direction.
- **Area calculation:** This gathers statistical data of a surface in the model. For example, the minimum and maximum values of velocity in the y-direction.
- **Volume calculation:** Statistical data for a volume. For example, the sum of forces and strains in the z-direction or all directions.
- **Point data:** Users can define points that will be measurement points for the simulation.



Transient heat transfer simulation of a cooling channel from PRISMADD Japan.



Case Studies

FEA of an ISOfix Connector (left) and a length adjustment rack (right) of a child's car seat.

Malaika: Static Analysis to Optimize the Design of a Child Car Seat

Our customer Malaika performed an FEA simulation for testing car seat components. To meet such an extreme design challenge, the engineers at Malaika implemented rigorous product testing and design verification procedures at both the component-level and system-level. The SimScale platform has been a requisite part of this process and a series of component simulations have been done to validate the structural integrity of the primary ISOfix connection to the main chassis and the adjustment rack. As a supplement to physical testing, structural simulations were conducted with SimScale based on worst case scenarios to a force of 3600 N.

Having successfully launched their car seat product, the Malaika team plan to continue using structural simulations with SimScale to frequently test the designs and reduce the number of required physical prototypes. As a complement to physical testing, the SimScale platform completes the design cycle.

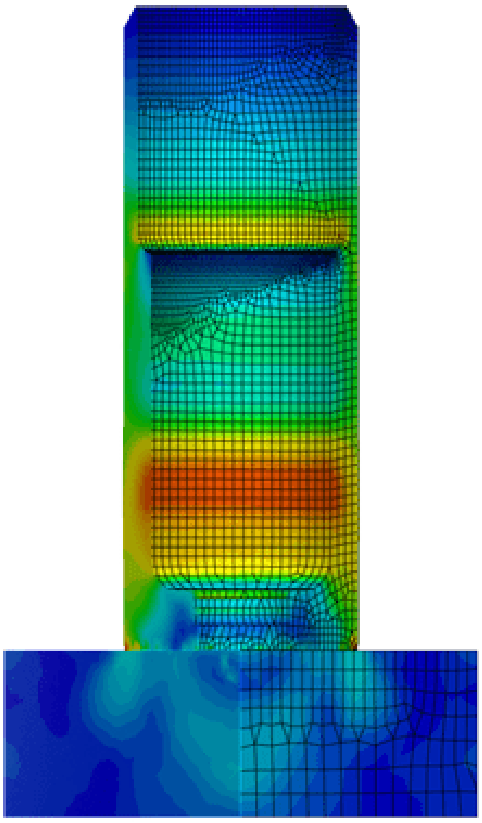
Read The Full Story

Explotechnik: Reduce Physical Prototypes with Nonlinear Analysis

Some of the solutions offered by Explotechnik AG require a high velocity piston to generate a shockwave. The piston is designed to slow down by hitting against a hardened steel surface. Before using CAE and SimScale, Explotechnik struggled getting their non-linear material properties at specified temperatures. This caused the piston to experience plastic deformation in their long-term experiments. The team at Explotechnik ran different design iterations featuring different piston geometries and materials, to see which influences the changes had to the piston (stress – strain, plastic strain, etc).

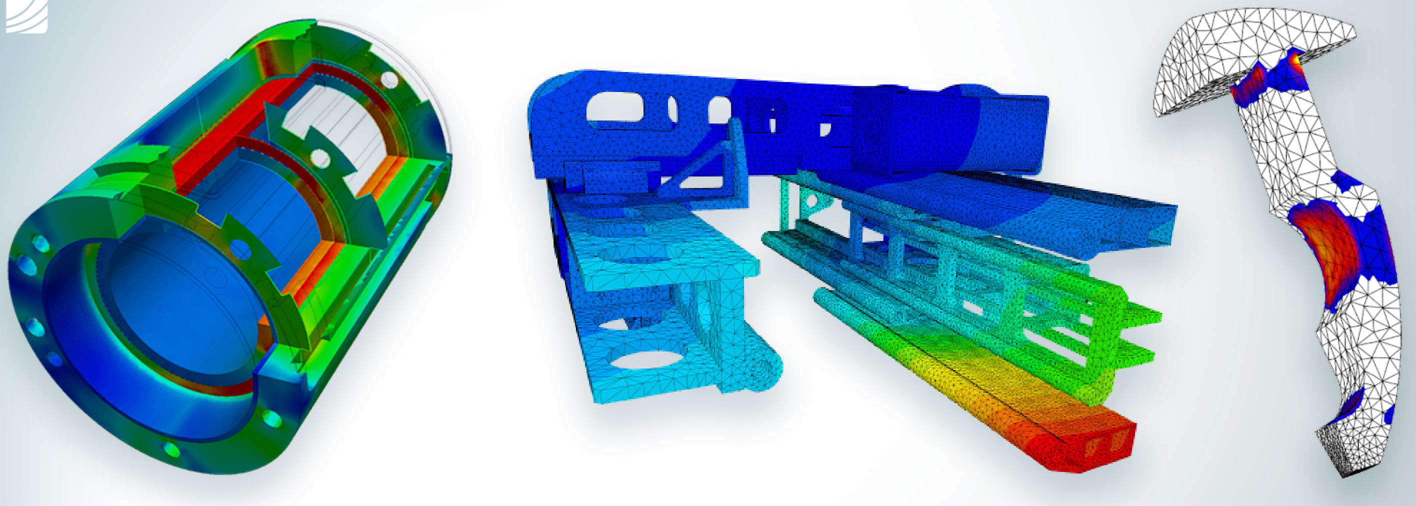
The team ran a dynamic simulation using the Lagrange contact method and tetrahedral meshes with allowed quad. For the analysis, a nonlinear hyper-elastic material was used and performed both with and without friction.

In total, the team ran about 10 simulations, on average using 200 core hours and lasting 200 min with 64 processors. The results collected from SimScale were then validated through a real-life experiment, which enabled them to move on to the production phase of their new piston design. In total, Expotechnik was able to save 1-2 weeks of experimentation, as well as reduce the use of physical prototypes and other tangible resources.



Von Mises stress analysis of a piston.

Read The Full Story



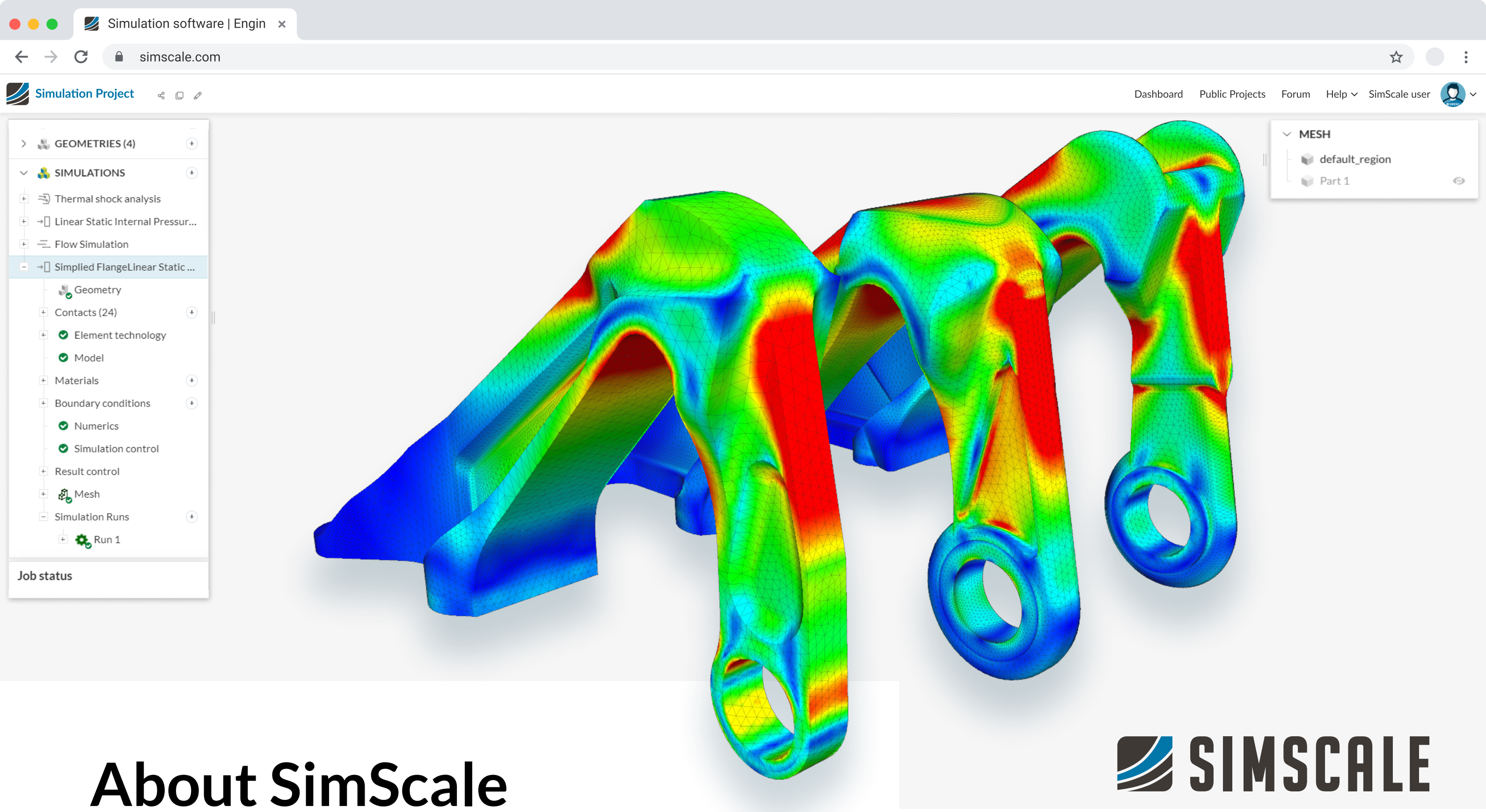
Conclusion

From left to right: Laboratory equipment thermal design (heat flux field inside the FlexyCUBE), robotic gripper strength analysis (displacement shown), and nonlinear static analysis of a plastic push pin (permanent deformation regions shown).

Global engineering organizations recognize the benefits of running simulation natively in the cloud and are rapidly adopting the SimScale platform as part of their product design and digital transformation strategies. R&D leaders and engineering managers rely on the accessibility of cloud-native engineering simulation and trust SimScale to provide their teams with immediate access and support.

Optimize your greatest designs with SimScale.

Request a Demo



About SimScale

SimScale provides SaaS engineering simulation in the cloud giving engineers and designers immediate access to digital prototyping early in the design stage, throughout the entire R&D and product development cycles, and across the entire enterprise. The SimScale platform enables engineering teams to innovate faster by making high-fidelity engineering simulation truly accessible from everywhere, and at any scale. Being a cloud-native engineering simulation platform, SimScale seamlessly integrates everything required for an end-to-end simulation workflow, from design to engineering, making broad and early use of simulation for the first time technically and economically accessible for any organization. Simulation in SimScale is performed through a single, collaborative platform that delivers the accuracy required for late-stage design validation with the ease-of-use needed for early-stage design simulation.