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Using Simcenter fluids and thermal solutions

Solution guide – Leveraging CFD simulation across disciplines and product development cycles

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INTRODUCTION

Simcenter fluids and thermal solutions

Simcenter™ software fluids and thermal solution domain is serving engineers from computer-aided design (CAD) designers to computational fluid dynamics (CFD) analysts, from aerodynamicists to electronics thermal experts. Our mission is to tear down the boundaries of engineering siloes and enable you to leverage CFD simulation across disciplines and product development cycles. Simcenter and other Siemens' solutions mentioned are part of the Siemens Xcelerator business platform of software, hardware and services.

Find better flow solutions, faster

Discover how engineers, from designers to analysts can:

- Model the complexity with multiphysics CFD and accurate CAD handling

- Go faster with automated end-to-end and application specific CFD workflows

- Make critical design decisions earlier with CAD-embedded CFD

- Explore the possibilities with fully integrated design exploration

- Leverage flexible and scalable hardware and licensing

- Design novel materials and predict properties with computational chemistry

Model the complexity to ensure decision confidence

Using Simcenter fluids and thermal solutions allows you to model the complexity from material behavior to the fluid mechanics and thermal performance of products. We provide you with solutions to help you model the right physics, at the right time, for the right application. This includes coverage for a range of physics including flow, thermal, acoustic, motion, structures and much more.

Explore the possibilities to enabling insights

Through a systematic and intelligent exploration of the design space, you can start to gain tremendous value from the models and discover new designs, optimize for performance and improve robustness from within your CFD software environment, all in a fraction of the time it would take without these methods.

Achieving speed and agility

For your company to be competitive, you need to find a way to go faster despite products' complexity and the need to extensively explore the design space for innovative solutions. Using Simcenter fluids and thermal solutions enables you to accelerate every step of your simulation workflow and turn complexity into a competitive advantage.

Stay integrated by connecting all activities

As product development has become increasingly complex, there are more opportunities for misalignment between teams. Balancing trade-offs between performances is important but you can only achieve this when everyone is aligned. Staying integrated means having a digital thread that connects all relevant stakeholders, models and data.

There is no one-size-fits-all CFD software. Discover how you can use Simcenter fluid and thermal software solutions to model the right physics, at the right time, for the right application. Explore how you can leverage CFD and computational chemistry for an endless range of applications including external aerodynamics, multiphase and reacting flows, electronics cooling, material property predictions and many more. Whatever your fluid dynamics problem may be, using Simcenter provides you with accurate, fast, high-fidelity CFD simulations from electronics cooling to multiphysics analysis.

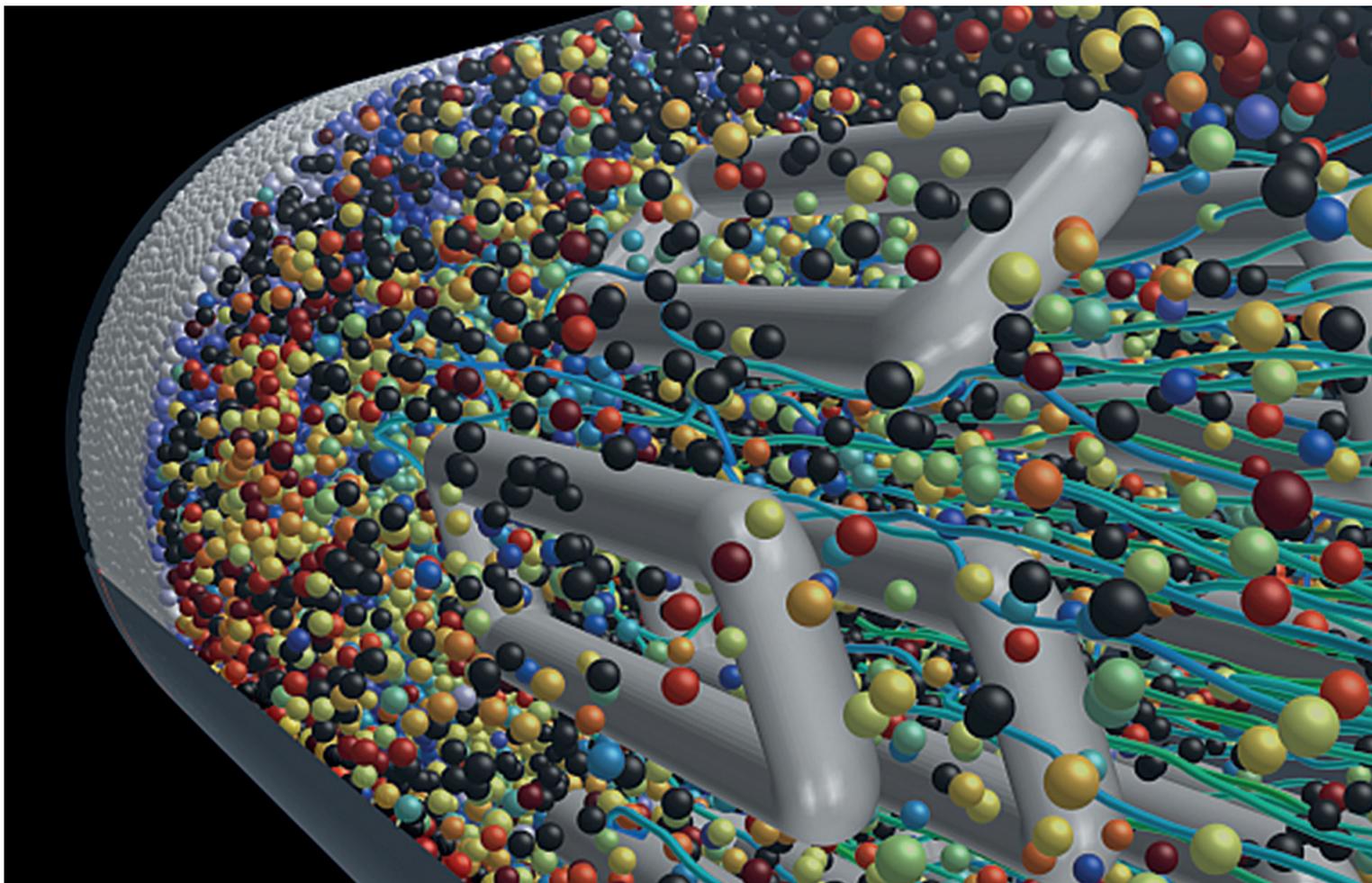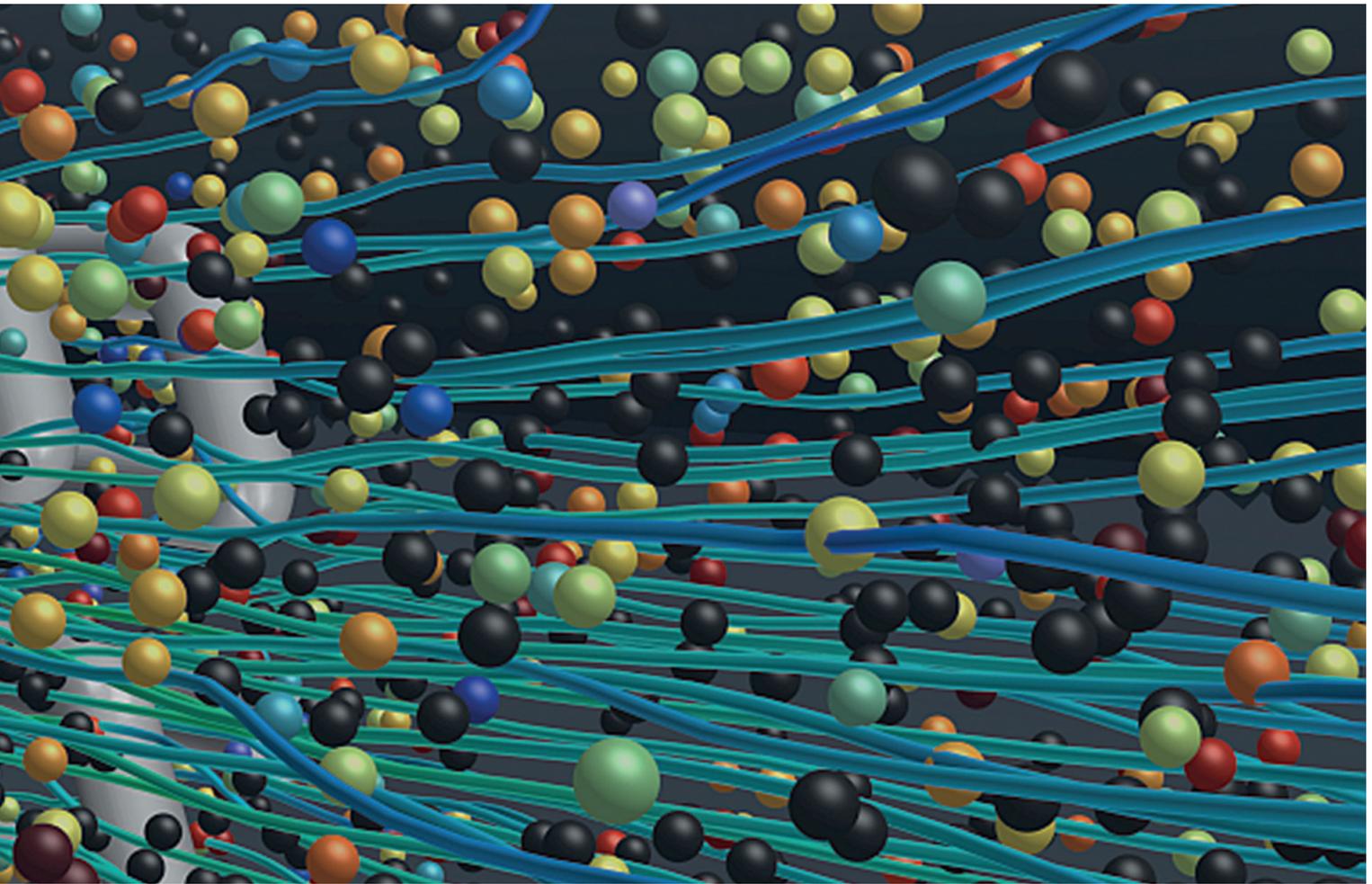# Innovate better products, faster with CFD and computational chemistry software.

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Simcenter STAR-CCM+

Improve product performance with multiphysics CFD simulation for real-world conditions.

Simcenter STAR-CCM+™ software is a multiphysics CFD software enabling CFD engineers to model the complexity and explore the possibilities of products operating under real-world conditions.

Boost your productivity with a single fully integrated user interface
You can use Simcenter STAR-CCM+ to find everything from preprocessing via meshing through multiphysics modeling to data analysis and photorealistic visualization and virtual reality (VR) in one single unified CFD simulation software.

Leverage complex applications with integrated multiphysics and motion modeling capabilities
Designed as a multiphysics CFD software tool, using Simcenter STAR-CCM+ helps you cover physics beyond fluid flow and heat transfer. Thanks to a fully integrated solver platform, you can run even the most complex multiphysics CFD simulations.

Cut your CFD preparation times with automated meshing and preprocessing of complex geometries
Using Simcenter STAR-CCM+ will help you reduce your simulation preparation time from weeks to hours. Thanks to cutting-edge CFD software technologies like automated CAD cleanup, surface

wrapping and automated high-fidelity meshing, you will spend your time where it matters: engineering better products.

Leverage end-to-end code-free workflow automation and fully embedded design exploration
Like no other CFD software tool, Simcenter STAR-CCM+ has been built around the idea of automated simulations from start to finish to enable CFD-based design exploration.

Solution benefits
- Boost your productivity with a single fully integrated user interface
- Cope with even the most complex applications thanks to an outstanding breadth of integrated multi-physics and motion modeling capabilities
- Cut your CFD preparation times with superior automated meshing and pre-processing of complex geometries
- Leverage powerful end-to-end code-free workflow automation and fully embedded design exploration

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Simcenter STAR-CCM+ geometry handling

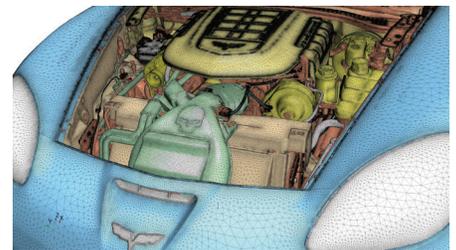Facilitate design processes by easily creating, modifying and preparing geometry

Benefits

- Integrate easily with existing design processes by importing geometry from a broad range of leading CAD and PLM software tools

- Create, modify and repair geometry using the integrated CAD modeler

- Combine CAD originating from various sources in a single simulation

- Improve efficiency with automatic geometry cleanup, search tool, surface repair and surface wrapping

- Enable powerful design exploration with an automated CAD-to-mesh process

Summary

Retaining the geometric fidelity of your product without disproportionately affecting simulation throughput is a major obstacle in performing real-world engineering simulations. As model complexity increases, engineers risk spending too much time performing manual and repetitive tasks, such as:

Trimmed volume mesh on a Corvette geometry cleaned up with surface wrapper.

- Cleaning and defeaturing dirty or incomplete computer-aided design (CAD) geometry

- Combining CAD models originating from various sources using multiple tools

- Preparing scripts to handle updating of design variants

Eliminating these potential bottlenecks is critical to allowing engineers to spend their time doing what they do best: innovating.

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Import large complex model with thousands of parts easily.

Simcenter STAR-CCM+ offers the solution
Siemens Digital Industries Software's Simcenter™ STAR-CCM+™ software helps you maximize productivity with robust automated workflows that ensure complex geometries are quickly ready to mesh. The single integrated user interface facilitates geometry handling, allowing users to:

• Efficiently handle large, complex models coming from various sources, including external CAD packages as well as an integrated 3D-CAD modeler

• Effortlessly clean up geometry with powerful tools, including automatic defeaturing in 3D CAD, manual surface repair and surface wrapping
  – The pipelined mesh operations process enables a broad range of workflows that can be created for any application
  – Automatic and manual preparation tools allow the user to work on dirty or incomplete geometry

• Seamlessly parameterize and automate design changes enabled by the single integrated user interface and repeatable CAD-to-solution processes

Capabilities

Geometry handling

CAD exchange:
• Import native and neutral formats using the Windows® or Linux® operating systems with high-quality geometry retention and fidelity

• Retain full data structure and organization from your CAD package including parts and assembly history, geometry, features, names, etc.

CAD clients:
• Direct transfer of geometry is possible from the CAD environment

• Design parameters can be transferred and modified bi-directionally, along with reference data and coordinate systems for design space exploration

• Multiplatform communication is easy with operation orchestration across resources and operating systems
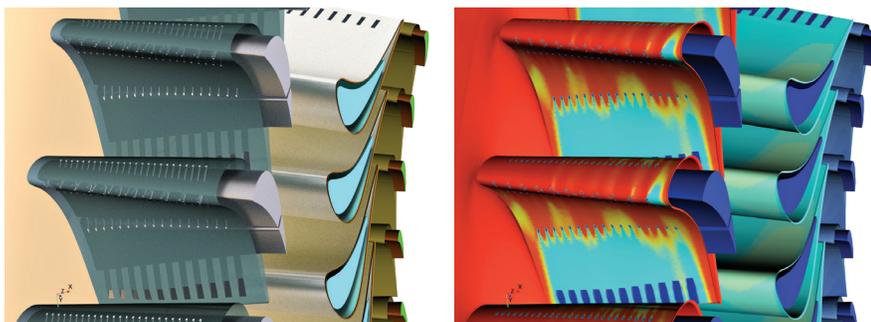

Repeatable CAD-to-solution for analysis of turbine geometry created in 3D CAD.

3D CAD:

- Save engineering time by utilizing the integrated CAD environment for CAD creation and design exploration

- Parameterize a model in a few clicks with feature-based geometry modeling and freeform technology

- Easily investigate, prepare and organize the models using the search tool, interactive sections and explode views

- Combine imported models with components created in 3D CAD

- User-controlled model defeaturing and interactive CAD repair tools

Geometry preparation

- *Surface wrapping:* fully automatic wrapping with projection to underlying CAD to provide a clean, closed surface ready for volume meshing
  – Reduce the geometry preparation time from weeks to hours with the surface wrapping of large complex geometry

- *Manual surface repair:* easy-to-use, comprehensive manual repair tool for preparation of CAD or imported tessellated geometries

- *Pipelined mesh operations*: user-defined and flexible pipeline for sophisticated combinations of operations, which allow automatic preparation of geometries, irrespective of their sources
  – Extensive set of operations for geometry preparation, including Booleans, surface wrapping and multipart imprinting

Parameterized pipe

Final optimized pipe design
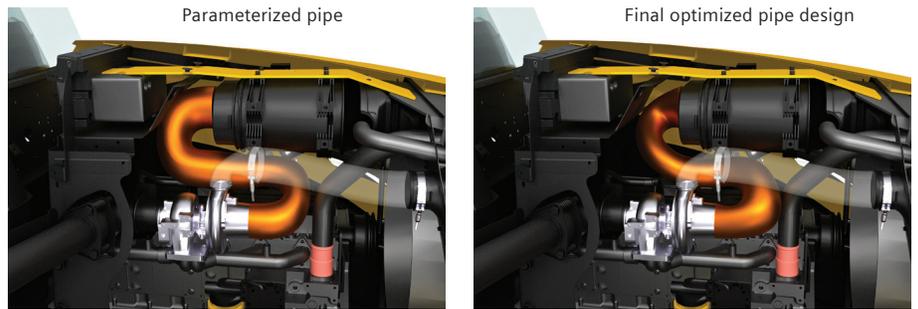
Optimized tractor pipe using parameterization for quick design study.

Combustor simulation with geometry handled using the NX CAD client.

Design exploration

Seamlessly deploy design space exploration in a single integrated user environment. With Design Manager built into Simcenter STAR-CCM+, you can:

- Effortlessly execute model updates with a robust, automated workflow

- Automatically manage dirty geometries with the surface wrapper fully within the design exploration process

- Automate exploration of geometric designs by modifying parametric CAD models in the 3D CAD module as part of your study

- Explore designs using native CAD tools via CAD clients
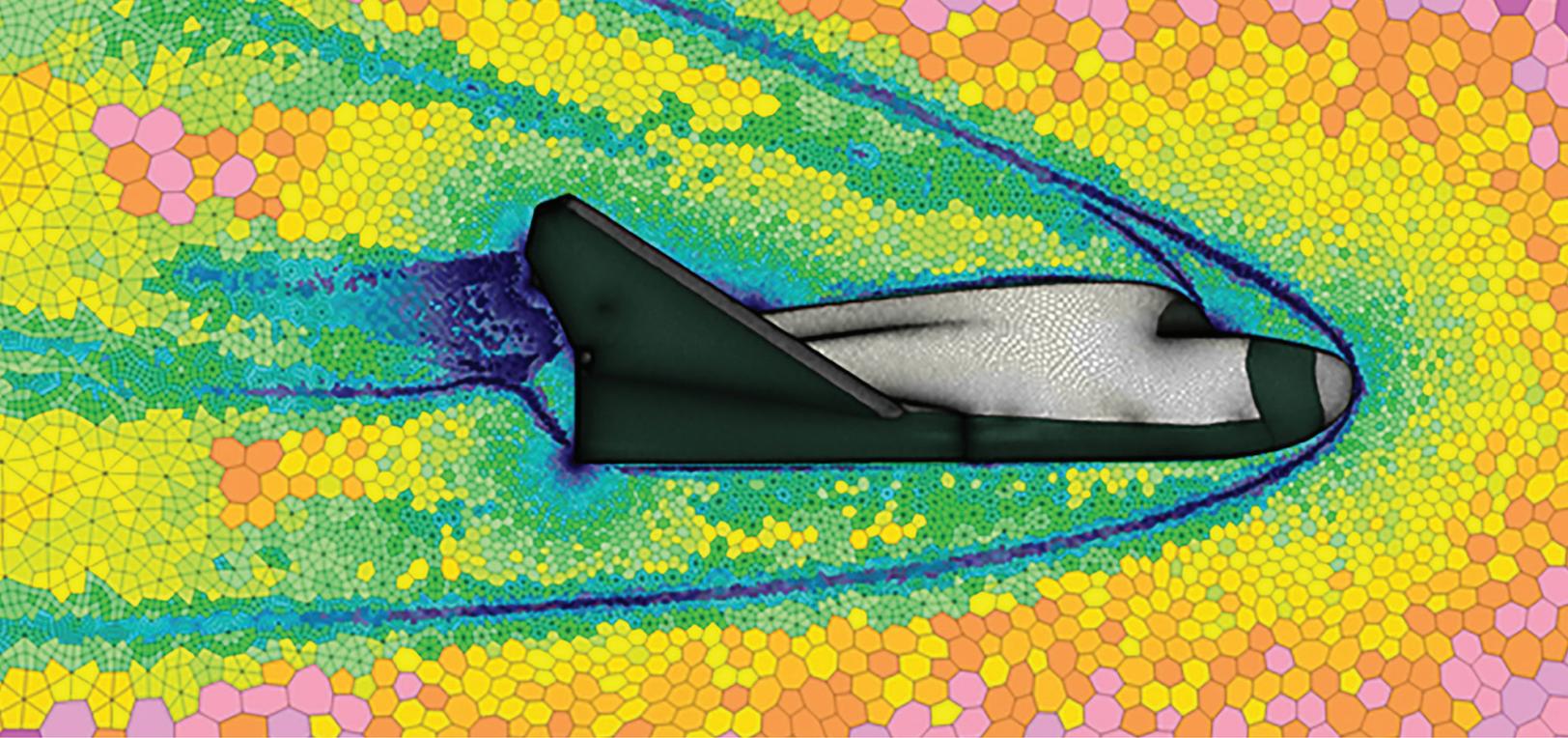
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Simcenter STAR-CCM+ meshing solutions

Reduce time-to-market through an automated CAD-to-mesh process

Benefits
- Achieve robust design exploration and faster time-to-market using an adaptable, automated pipeline of CAD-to-mesh operations

- Reach engineering decisions faster with high-quality meshes for any dirty CAD assemblies with surface wrapping and comprehensive volume meshers

- Increase simulation throughput with parallel volume meshing and local meshing

- Provide fast and accurate handling of complex moving geometries using robust overset and morphing capabilities

- Reduce engineering time with advanced model-driven adaptive mesh refinement techniques

Summary
There is a continual drive to incorporate greater realism in engineering simulations to better understand product behavior earlier in the design cycle. To achieve this, geometric complexity is increasing so more engineering disciplines must be accounted for in the analysis. Both requirements have a direct impact on, and are facilitated by, effective generation of the computational mesh. To quickly build high-quality, run-ready meshes, you must address how to:
- Mesh geometries that have tens of thousands of complex parts

- Deliver scalable, robust and effective meshing algorithms that offer reduced meshing times, increasing productivity, ease of use and solution accuracy

- Address the meshing requirements unique to specific applications

- Easily incorporate design changes in the meshing process through an automated meshing pipeline

- Deliver robust advanced model-driven adaptive mesh refinement (AMR) techniques with employable user-defined criteria and with also automatic dedicated models for specific applications:
  – Free-surface driven AMR
  – Overset-driven AMR
  – Reacting flow AMR

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Offering comprehensive solutions

Simcenter™ STAR-CCM+™ software, which is a part of the Siemens Xcelerator business platform of software, hardware and services, offers comprehensive meshing solutions to address engineering analysis challenges. It allows you to prepare and generate meshes for the most complex geometries and offers the ultimate balance between user control and automation easily and efficiently. Simcenter STAR-CCM+ provides:

- *Productivity:* Reduced engineering and meshing time with an easy-to-use pipelined workflow delivered from a single, integrated user interface

- *Accuracy:* Geometric fidelity and maximum accuracy per central processing unit (CPU) time for complex applications using robust and scalable meshing algorithms

- *Mesh motion and adaptation:* Optimal cell count and solution accuracy using industry-leading, model specific AMR along with robust overset and morphing tools for handling complex moving bodies
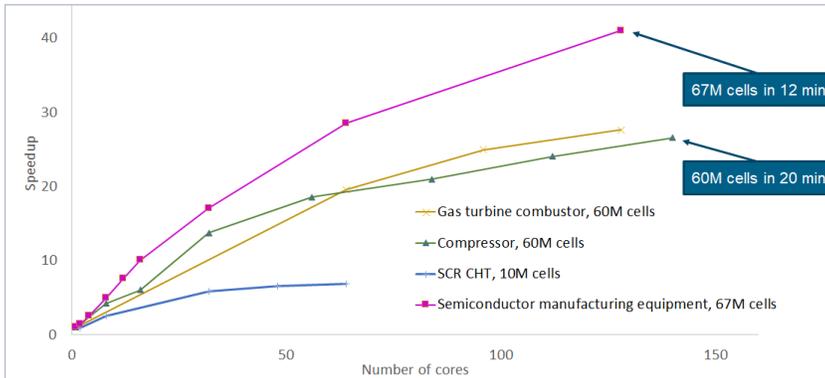
Productivity

Using Simcenter STAR-CCM+ enables a flexible approach to mesh generation with a user-definable pipeline of operations:

- Robust and automatic process from initial geometry preparation to volume mesh generation

- Capabilities accessed through an easy-to-use, single-integrated user interface

- Facilitates automatic parameter studies and intelligent design exploration

- Efficient and scalable parallel volume meshing algorithms that can help harness the full power of high-performance computing (HPC) resources and expedite
  the overall mesh generation process for any application

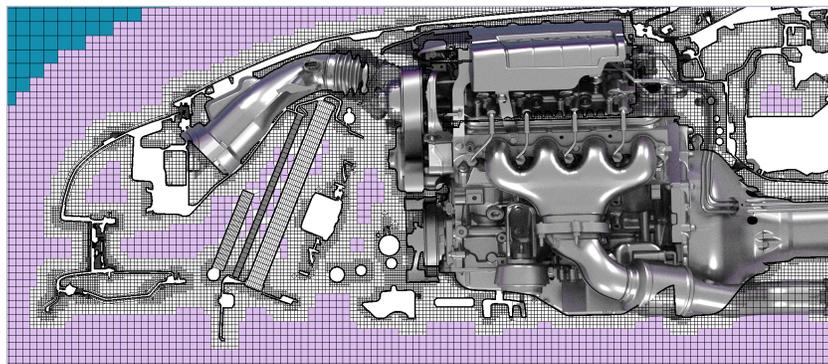- Built-in diagnostic tools to assess mesh quality

Accuracy

Achieve highly accurate simulations using Simcenter STAR-CCM+ via several powerful meshers, enabling you to create the optimal mesh for your simulation:

- *Surface wrapper:* Robust surface preparation tool that can handle poor quality and complex computer-aided design (CAD) geometries, generating a closed, manifold and nonintersecting surface

- *Polyhedral mesher:* Unstructured, general-purpose mesher for complex geometries, ensuring mesh conformality between multiple parts offering enhanced conjugate heat transfer (CHT) simulation accuracy

- *Trimmed cell mesher:* Predominantly hexahedral mesh for general purpose and efficient, fast meshing

- *Tetrahedral mesher:* Unstructured mesher primarily used for computational solid mechanics (CSM) and computational rheology, ensuring mesh conformality between different parts

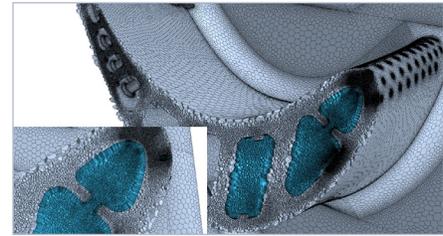Speed-up of the parallel polyhedral mesher for various applications.

Chart legend:
- Gas turbine combustor, 60M cells
- Compressor, 60M cells
- SCR CHT, 10M cells
- Semiconductor manufacturing equipment, 67M cells

Chart annotations: 67M cells in 12 min; 60M cells in 20 min

Axes: Speedup (y-axis), Number of cores (x-axis)

Plane section showing trimmer volume mesh around under-hood parts in a passenger vehicle.

Robust volume mesh for turbine blade cooling study (left) and accurate conjugate heat transfer simulation results (right).

Combination of polyhedral, trimmer and thin meshers for solid and fluid regions in a vehicle thermal management study.

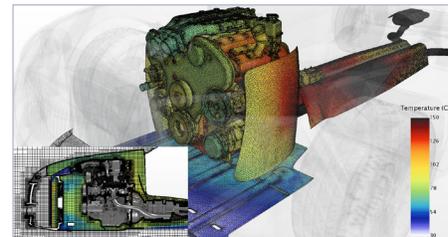High-quality hexahedral mesh for a rotor-stator passage.

- *Prism layer mesher:* Used with core volume mesh to create prismatic cells next to wall surfaces to accurately capture the boundary layer

- *Advancing layer mesher:* Generates high quality prismatic cells around the surfaces of regions or parts and fills the remaining void with polyhedral cells

- *Dedicated meshing tools:* Robust dedicated meshers that can generate prismatic elements to tackle thin and geometries that require a swept mesh

- *Turbomachinery mesh:* Fast and robust structured multi-block hexahedral mesher that can generate high quality, flow-aligned meshes for axial blades with support of variable shroud and hub tip gaps. Supports concurrent execution that enables mesh generation for large cases in a matter of minutes
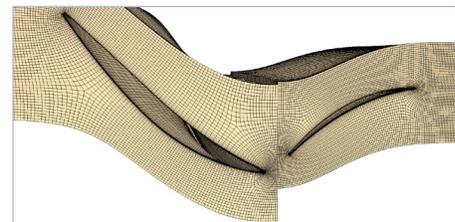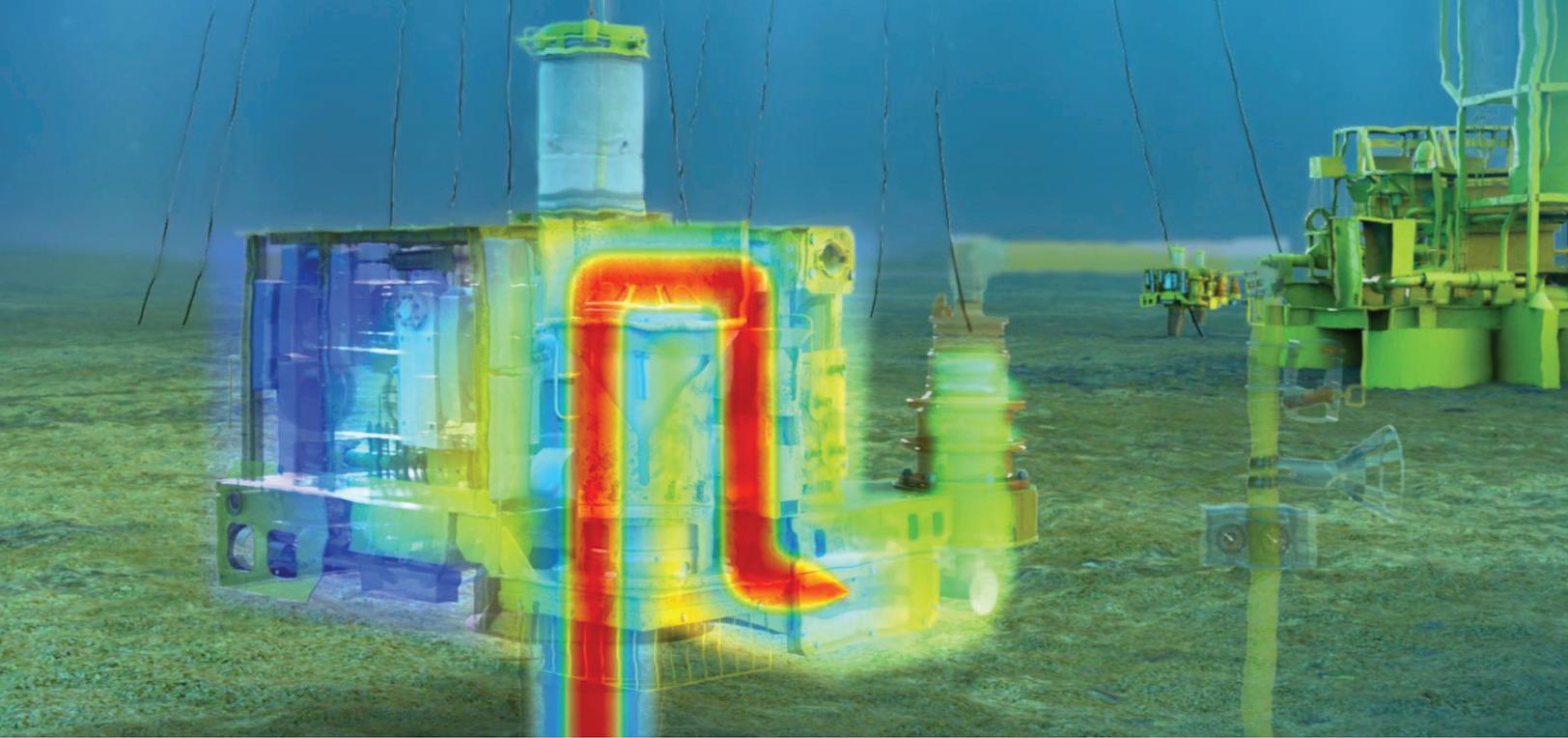
Mesh motion and adaptation

- *Morphing:* Robustly account for displacement and deformation of moving boundaries in a transient analysis

- *Overset meshing:* Avoid cumbersome remeshing with dynamic overlapping of meshes in applications with complex moving bodies

- *AMR:* Easy-to-use mesh adaptation methods based on user-defined criteria and/or model-specific criteria for free-surface and reacting flows along with overset mesh-driven criteria

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Simcenter STAR-CCM+ multiphysics solutions

Enabling the prediction of real-world performance earlier in the design process

Benefits

- Enables users to predict real-world performance earlier in the design cycle

- Reduces time-to-market and costly failures

- Improves realism and accuracy by providing a wide range of physics in a seamless, single integrated user interface

Summary

Multiphysics engineering simulation can accurately capture all the relevant physics that influence the performance of increasingly sophisticated products. Simcenter™ STAR-CCM+™ software enables users to minimize the level of approximation and assumption by providing a comprehensive, accurate and efficient array of multiphysics solutions, providing confidence the predicted performance of designs will match the realworld product.

Multiphysics simulations you can trust
Simcenter STAR-CCM+ delivers accurate and efficient multidisciplinary technologies in a single integrated user interface (UI). This enables the study of sophisticated industrial problems with complex physical phenomena in a fully coupled manner. Users benefit from increased accuracy and the ability to discover better designs faster. Comprehensive multiphysics include fluid dynamics, solid mechanics, multiphase and particle flow, acoustics, heat transfer, reacting flow, electromagnetics, electrochemistry and rheology.

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Fluid dynamics

Simcenter STAR-CCM+ offers powerful flow solvers that are easy to set up and are robust, accurate and deliver excellent scalability. This allows users to quickly transition from single point simulations to exploring the entire design space. It enables you to:

- Cover a full range of applications from subsonic to hypersonic with robust and easy-to-use coupled and segregated flow/energy solvers

- Get to solutions quickly using the most efficient solver for the application, with steady and unsteady implicit and explicit formulations, including Pressure-Implicit with Splitting of Operators (PISO)

- Account for turbulence on any scale with a wide range of turbulence models, from Reynolds-Averaged Navier Stokes (RANS) to detached/large eddy simulation (DES/LES)

- Represent unresolved devices and components and their effect on the flow-field with porous media. Includes the ability to account for heat transfer with unresolved solid components. Fan and heat exchanger models allow such components to be accurately characterized

Heat transfer

Simcenter STAR-CCM+ can be used to rapidly solve conjugate heat transfer (CHT) problems by solving on a separate timescale in fluid and solid regions within a single simulation:

- Includes all modes of heat transfer, including the effects of radiation between surfaces and participating fluids

- Saves meshing and computational time by replacing thin solid components with zero-thickness shells

Applications include vehicle thermal management, headlamps, electronics cooling, gas turbine cooling and combustion.


Conjugate heat transfer of a cooled turbine blade.

Hybrid multiphase

Real-world multiphase problems span every industry and application. They cover more than one regime, including mixtures of one phase containing bubbles or droplets of another, free surfaces between immiscible fluids, mixed regimes in which no phase dominates, and thin fluid films and sprays of droplets with dimensions too small to resolve. Traditional multiphase models can cover only one of these regimes, forcing the user to make

assumptions and accept the associated error, or to face not carrying out a simulation due to computational cost.
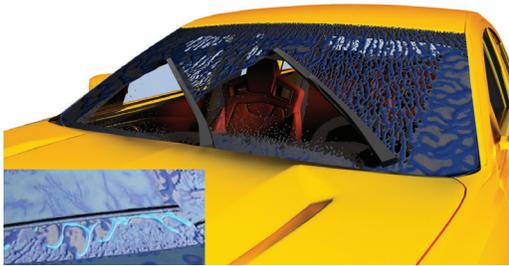
Vehicle water management using hybrid multiphase switching between fluid film and VOF.

Simcenter STAR-CCM+ offers an unrivaled set of hybrid and multiple regime multiphase capabilities to automatically transition between different regimes based on local flow conditions and modeling budget in a single simulation. This unique approach ensures the most efficient and appropriate modeling strategy is used without compromising physical accuracy.

- Hybrid multiphase is built around a family of multiphase models that collectively can cover any regime, including but not limited to the volume of fluid (VOF) model for free surfaces, fluid film for thin unresolved films on walls and Lagrangian Multiphase (LMP) for discrete droplets

- Alongside these models, Simcenter STAR-CCM+ provides a set of phase interaction models to allow them to work collectively in a hybrid fashion, intelligently switching between models based on local needs to capitalize on each model's strengths and avoid its weaknesses. These models provide a large array of physics, including boiling, droplet-wall impingement and surface tension

Applications include: marine hydrodynamics, tank sloshing, vehicle water management, aircraft icing, e-motor cooling, selective catalytic reduction (SCR) and fuel cells.

As an alternative to the hybrid multimodel approach, Simcenter STAR-CCM+ also provides the multiple regime model, extending the comprehensive Eulerian Multiphase (EMP) model that enables the user to solve real-world problems that are not limited to a single regime. This allows sharp free surfaces and mixed regimes to coexist alongside traditional continuous/dispersed regimes.

Applications include bubble columns, fluidized beds and mixing vessels.

Particle flows

Multiphase applications are not restricted to gas and liquid flows but can also involve the processing of solid granular materials. Simcenter STAR-CCM+ provides a comprehensive set of solutions including the discrete element method (DEM), which allows users to accurately model solid particle flows in which particle collisions and shape are important.
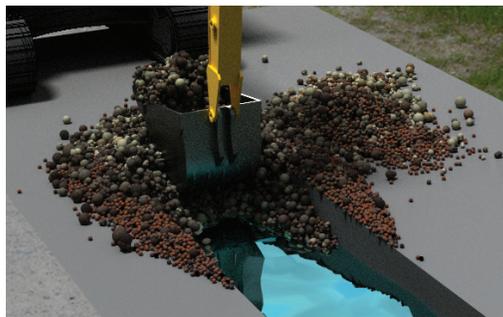
An excavator digging rocks/soil modeled using DEM particles in a flooded trench (VOF).

You can efficiently model any particle shape with spherical, coarse grain, composite, clumped, cylindrical, capsule and polyhedral particles. It allows the user to model complex systems in a single software package, coupling fluid flow and motion with the dynamic fluid-body-interaction (DFBI) for six degrees of freedom (6DOF) solver, avoiding complex multi-code coupling.

Applications include fluidized bed reactors, blast furnaces, tablet coating, construction equipment, agricultural machines and bulk material handling equipment.

Electromagnetics

Environmental considerations are driving an increase in electrification and alternative propulsion methods. A key aspect of multi-physics simulations in the design of such new technologies is electromagnetism.

E-machine cooling simulation.

Simcenter STAR-CCM+ offers a set of low frequency electromagnetics solvers that can easily be coupled with flow and thermal analyses for the thermal management of electric machines.

Simcenter STAR-CCM+ enables the user to solve in either a time or single-frequency domain to produce results quickly on large industrial meshes with a highly scalable finite element (FE) iterative solver.

Applications include electric machines, magnetohydrodynamics, plasma arcs and induction heating.

Electrochemistry

Simcenter STAR-CCM+ electromagnetic capabilities are complemented by electrochemistry models that allow the user to predict and understand real-world behavior in complex electrochemically driven processes coupled with the flow, thermal and electromagnetic fields:

- Electrochemical and bulk ion reactions allow the user to resolve ion distributions and the resultant voltages in devices
- Complex plasma phenomenon can be modeled with the coupled plasma electron model
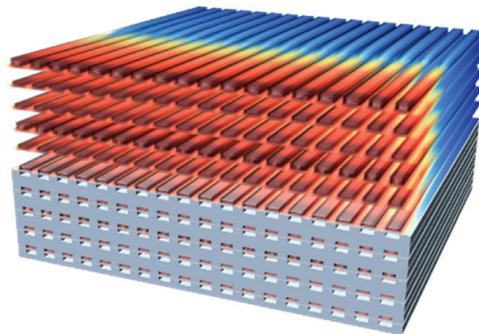
Water management in a SOFC fuel cell.

Applications include proton exchange membrane (PEM) fuel cells, circuit breakers and other plasma applications and electroplating.

Solid mechanics

Solve fluid-structure interaction (FSI) and fluid-thermal-stress problems quickly in Simcenter STAR-CCM+ with an expansive nonlinear FE-based solid mechanics capability.

• Reduce time to solution with the direct parallel solver, and increase thermal problem size with the iterative solver for solid energy

• Handle a wide range of material types, including elastic, hyper-elastic and elastic-plastic materials

• Include the effects of loads and constraints on surfaces, lines or points

Applications include heat exchangers, fuel rods, stents, marine propellers and hydrofoils.

FSI simulation of a car rear wing.

Reacting flows

Tightened emissions controls are driving a move to alternative fuels and novel combustion methods. To be successful, much greater control of (and insight into) the reacting flow-field is required. Simulation tools must give detailed and accurate results quickly. Simcenter STAR-CCM+ provides a comprehensive suite of reaction and emission models to give insight into real-world behavior in reacting flows. A wide range of methods are provided to balance compute time and accuracy.

You can determine the yield of processes by accurately predicting species concentrations with complex chemistry.

• Determine flame location and dynamics with flamelet models

• Predict emissions of nitrogen oxide (NOx), soot, carbon monoxide (CO) and other pollutants with specialized emission models

• Simulate reactions between fluids with multiphase reactions for VOF, Lagrangian and DEM models
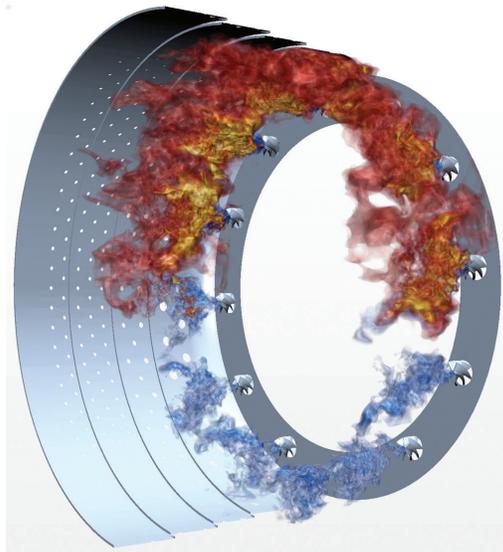

Aero gas turbine ignition.

Applications include gas turbines, internal combustion engines, after-treatment systems, polymerization reactors, chemical vapor deposition and coal furnaces.

Acoustics

Wherever there is flow, there is the potential for unwanted noise, which is increasingly recognized as a form of pollution to be minimized. To accurately predict the sources of noise and propagation to the environment or

users of equipment, Simcenter STAR-CCM+ provides an extensive library of aeroacoustics models:

- Quickly identify sources of noise in a RANS simulation with steady-state models and estimate mesh cutoff frequencies for mesh refinement

- Accurately model sources of noise with computational aeroacoustics using DES or LES, including prediction of convective turbulence and methods for propagating noise in the near field
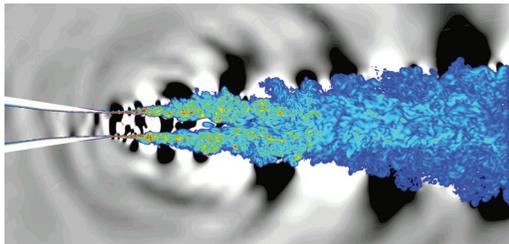
Sound waves propagating from a nozzle.

- Model the propagation of aero-acoustic noise sources to the far field using in-built Ffowcs Williams-Hawkings time domain methods

- Improve accuracy and reduce spurious noise with the hybrid acoustic perturbation equation (APE) solver

- For subsequent acoustic/vibroacoustic propagation analysis in Simcenter 3D, Simcenter STAR-CCM+ can also export computational fluid dynamics (CFD) data representing sound sources

Applications include heating, ventilation and air conditioning (HVAC), external aerodynamics, engine powertrain, aircraft noise and fan cooling.

Rheology

In industries such as chemical processing and food production, engineering extends beyond devices to the fluids themselves, which are designed to exhibit highly viscous, non-Newtonian behavior. Simcenter STAR-CCM+ enables the study of such complex rheological materials by providing a finite element rheology solver.

- Accurately model complex viscoelastic materials using one of four standard viscoelastic constitutive equations (Oldroyd-B, Giesekus-Leonov, Phan Thien-Tanner and extended Pom-Pom)

- Model thixotropic fluids with the Rolie-Poly model, and other non-Newtonian fluids with the generalized Newtonian models

Applications include mixing of non-Newtonian materials such as foodstuffs or paint and extruding parts such as door seals and material processing.
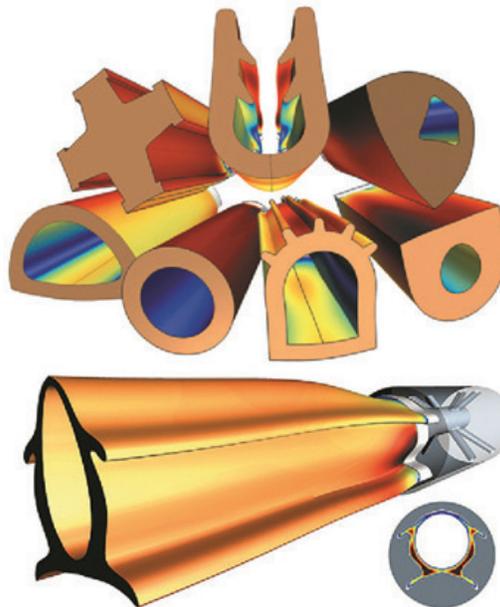
Extruded parts.
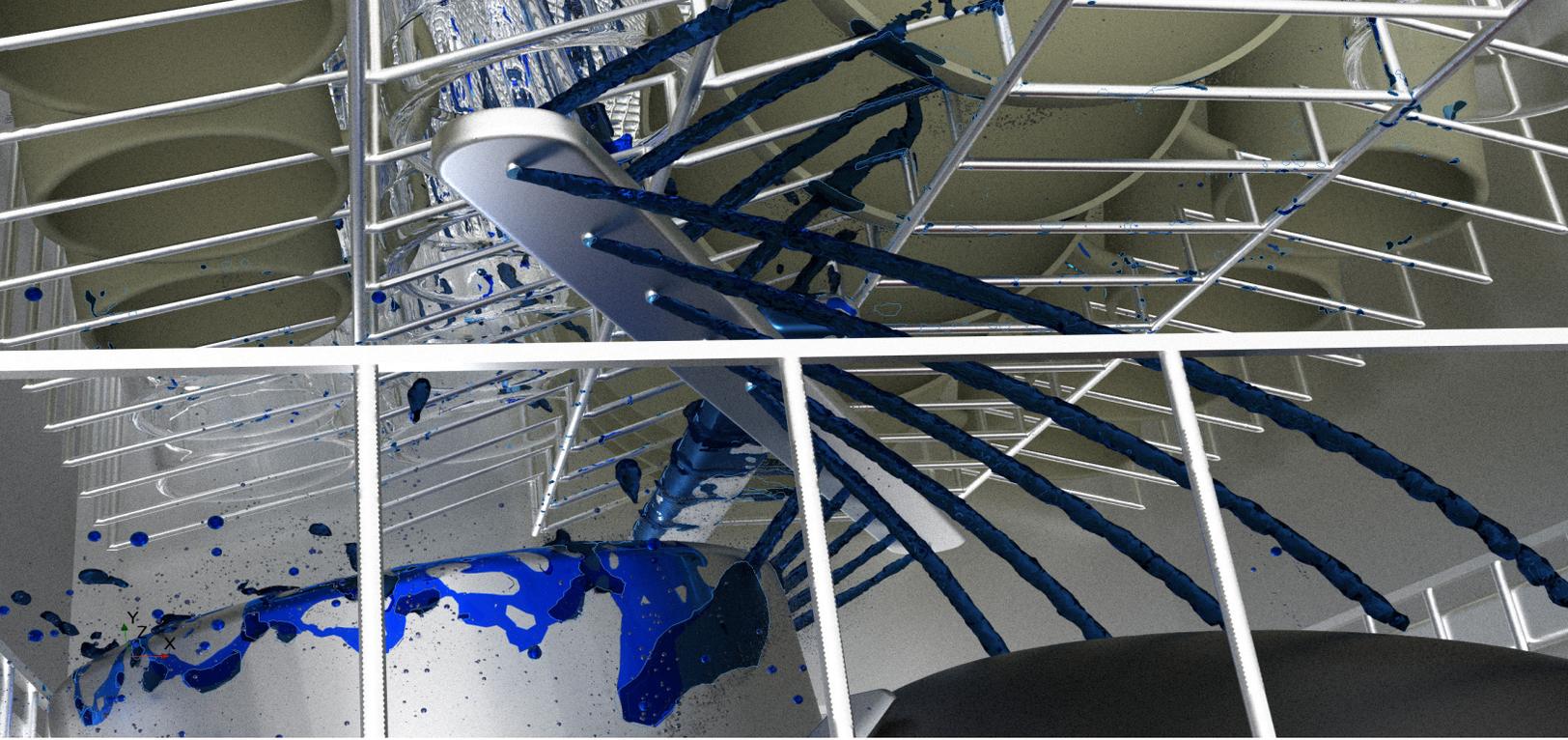
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Simcenter STAR-CCM+ multiphase CFD simulation

Accurately model complex industrial multiphase applications with confidence

Benefits
- Model complex industrial multiphase systems without extensive geometry simplification
- Simulate multiphase applications with a high degree of fidelity
- Get accurate results using optimal multiphase modeling techniques based on available resources

Summary
In the highly competitive race toward a sustainable future, environmental concerns must be factored into new product design. To maximize performance, the scope of your simulations must extend to the digital twin at the system level. As a result, applications are more likely to be multiphase in nature. For example, a pump may be a single-phase application, but its system might not be.

In addition to being multiphase, larger problems likely contain multiple flow regimes such as mixtures, free surfaces, sprays or fluid films. This is a challenge for classical multiphase models, which were designed for a single flow regime and no longer meet the computational fluid dynamics (CFD) simulation needs for many applications. Without a new approach, we are constrained to simulating part of the problem or accepting an inaccurate approach that operates beyond its range of applicability. How do we close this gap?
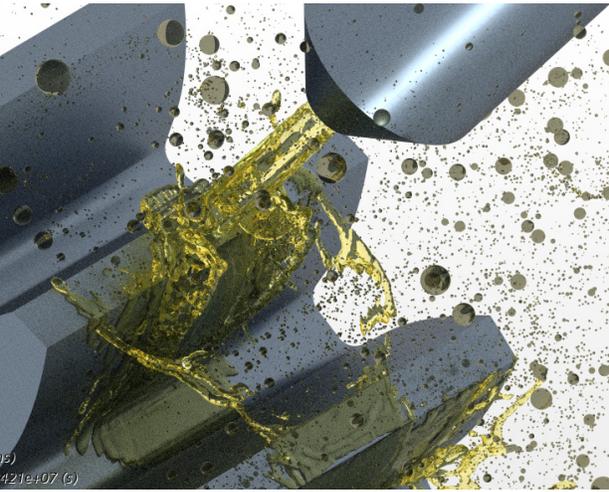
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Figure 1. VOF to LMP resolved multiphase simulation of an oil jet hitting a rotating gear.

Simcenter STAR-CCM+ offers the solutions

With its innovative, industry leading, hybrid and multiple regime multiphase technologies, Simcenter™ STAR-CCM+™ software enables you to go faster by providing new insight into your design. You can model the complexity of an entire system without simplification, which unlocks your potential to improve performance. Simcenter STAR-CCM+ is a part of the Siemens Xcelerator business platform of software, hardware and services.

Simcenter STAR-CCM+ provides:

- A comprehensive ecosystem of multiphase models that can be used in a hybrid manner. This allows the solution to adapt locally, on the fly, to any regime

- Multiple regime modeling capabilities, which enable mixtures and free surfaces to coexist

- Complementary technologies to accelerate your solution, including adaptive mesh refinement (AMR) and adaptive time stepping

The multiphase models

The ecosystem of multiphase models in Simcenter STAR-CCM+ caters to every regime in industrial multiphase flows:

- *Volume of fluid (VOF):* Captures free surfaces and highly resolved details such as individual droplets and bubbles. Applications include marine vessel simulations and automotive applications such as water management and powertrain lubrication

- *Mixture multiphase (MMP):* Models mixtures with a smaller difference in velocity (slip) between phases. Applications include multiphase pumps and powertrain lubrication

- *Eulerian multiphase (EMP):* Models mixtures that allow the phases to behave more independently with significant levels of slip. This is suited for oil and gas, nuclear and chemical/process applications

- *Dispersed multiphase (DMP):* Models dispersed phases with low-volume fractions. Useful for applications such as aircraft icing

- *Fluid film:* Models liquid wall films that develop where droplets impinge on 2D surfaces (the thickness is not resolved). Applications include spray painting, coating, aircraft icing and vehicle water management

- *Lagrangian multiphase (LMP):* Models dilute discrete phases such as sprays of droplets or particle flows. This is most suitable for ballistic droplets in sprays that cannot be represented as a mixture

- *Discrete element method (DEM):* Models particle flows that place importance on particle shape and particle-particle contact. Applications include excavation, drilling, agriculture and food and materials handling
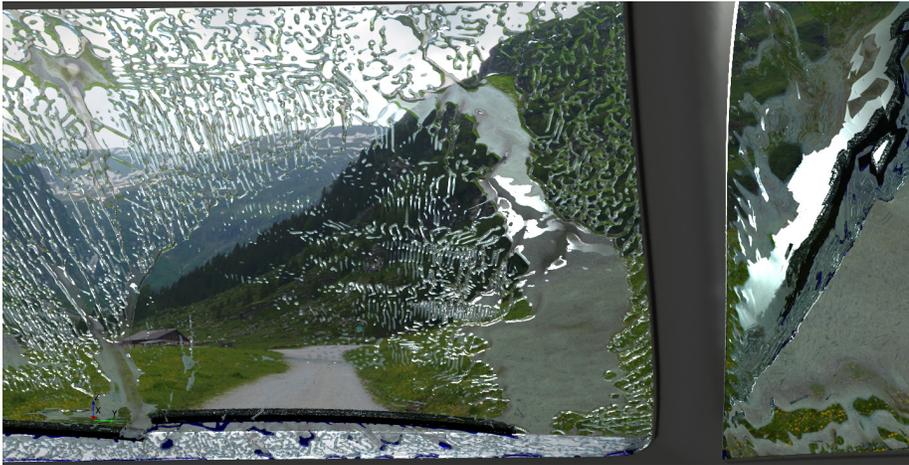
Figure 2. Vehicle water management (LMP-VOF-film).

- *Smoothed-Particle Hydrodynamics (SPH):* Models liquid flows with complex geometry and motion. This is suitable for applications involving highly dynamic free surface flows such as drivetrain lubrication, sloshing and liquid run-off applications

Each of these models meet a need. However, they reach their full potential when used together.

Hybrid multiphase – multiple model approach
In Simcenter STAR-CCM+, Siemens has pioneered an innovative hybrid approach that allows multiple multiphase models to seamlessly work together. This enables each model to be used in the flow regime it is designed for without being pushed beyond its applicability range.

A common hybrid multiphase strategy is to extend the VOF model by using it alongside the fluid film and LMP models for smaller scale multiphase features. Resolving these features with VOF is computationally expensive, but the hybrid multiphase strategy can prevent errors.

In this approach, small droplets are modeled using LMP and thin films are modeled using fluid film. VOF only needs to capture the large-scale flow features. This allows you to simulate previously impractical applications with a high degree of fidelity and confidence.

Applications include vehicle water management, fuel spray breakup, e-motor cooling and household appliance fluid management. The hybrid multiphase approach is built around several key phase interactions:

- *Hybrid VOF-film (resolved film):* Model fluid films of varying thickness than can transition seamlessly into VOF when the mesh is fine enough or the amount of fluid becomes great enough (and back again when it is not). Include the effects of key physics such as surface tension across the transition

- *VOF-Lagrangian resolved transition:* Capture important physics such as jet breakup with VOF while using the cheaper Lagrangian model for the resultant droplets

- *LMP-film impingement and stripping:* Models Lagrangian droplets impinging into and stripping from fluid film, which includes effects of splashing
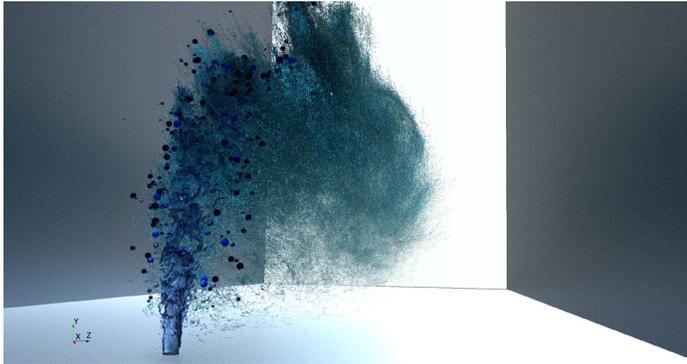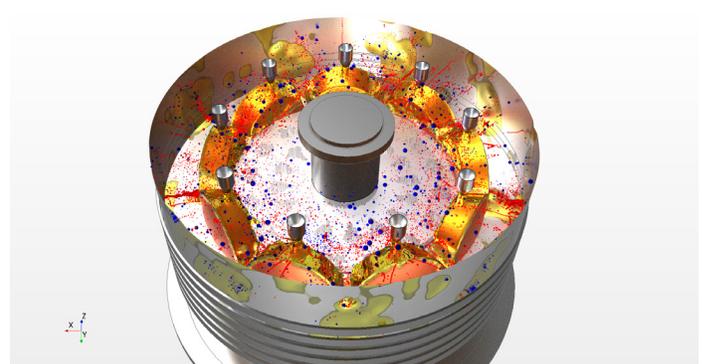
Figure 3. Jet breakup (VOF-LMP).

Figure 4. E-motor cooling (VOF-film-LMP).

Along with these interactions, you can include more complex physics, such as boiling, cavitation and reactions and cater to a range of droplet or bubble sizes with advanced population balance models.

Multiple regime modeling

Alongside hybrid multiphase modeling, Simcenter STAR-CCM+ offers the ability to handle different regimes in the bulk fluid. Two phases will interact differently depending on the nature of the fluids, amount of mixing and resolution of the simulations. Phases can meet at a resolved free surface or form a mixture.

Many multiphase problems cover a range of regimes with free surfaces and mixtures coexisting. This is a challenge for traditional multiphase models since they are only suited for one regime. Using these models for such problems leads to excessive computational cost from resolving small details or errors from failing to capture important physics.

Figure 5. Fluid management in dishwasher (VOF-film-LMP).
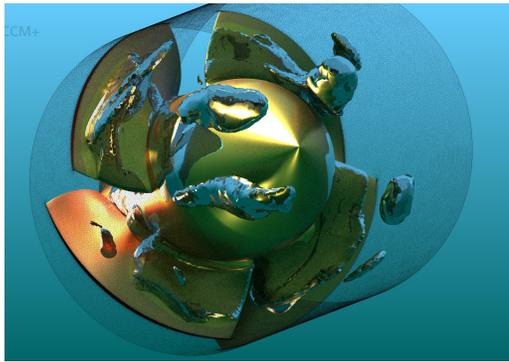
Figure 6. Multiphase pump showing separation of a mixture.
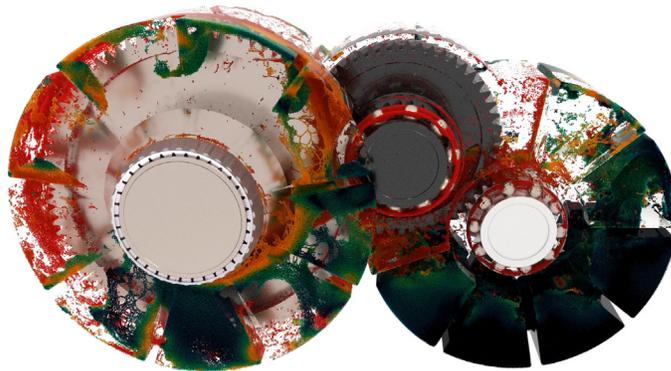
Figure 7. Partially resolved gear lubrication.

Simcenter STAR-CCM+ provides innovative multiphase modeling that can bridge this gap:

- *Large-scale interface (LSI) model:* Allows free surfaces and mixtures to coexist and is available for EMP and MMP models. When used with MMP, it provides a single model with the benefits of VOF for free surfaces and MMP for mixtures. It allows you to rapidly run simulations previously tackled with VOF and eliminates the need to resolve every detail

- *Multiple regime model:* Models what happens when two phases meet at a sharp free surface using the LSI model or a mixed regime, which enables a regime to transition through phase inversion

Smoothed-particle hydrodynamics (SPH)

Simcenter STAR-CCM+ includes a powerful smoothed-particle hydrodynamics (SPH) solver, offering a volume mesh-free approach to modeling complex fluid dynamics. Based on a Lagrangian, particle-based method, SPH is ideally suited for highly dynamic free surface flows with liquid jets and splashes, such as drivetrain lubrication, sloshing, liquid run-off. For targeted applications, SPH significantly reduces setup and solving times, while

enabling accurate simulation of flows with moving boundaries. Integrated within the Simcenter STAR-CCM+ environment, the SPH solver supports high-performance computing and GPUs, making it a robust and rapid choice for transient, high-fidelity CFD applications.

Complementary technologies

Simulating multiple regime flows requires support for different scales from the small bubble or droplet or thin fluid film, to large resolved free surfaces. These varying scales can make simulation expensive. Simcenter STAR-CCM+ provides several tools to achieve an order of magnitude speed up:

- *Model based AMR:* A free surface-based refinement provides an automatic tool to keep free surfaces sharp and only use mesh where needed. This model does not require user input to automatically produce the mesh needed from a coarse initial mesh

- *Model based adaptive time step:* A free surface-based adaptive time step predicts and adjusts the time step needed to capture any small details that may develop, while allowing a larger time step to be used when the flow is calmer
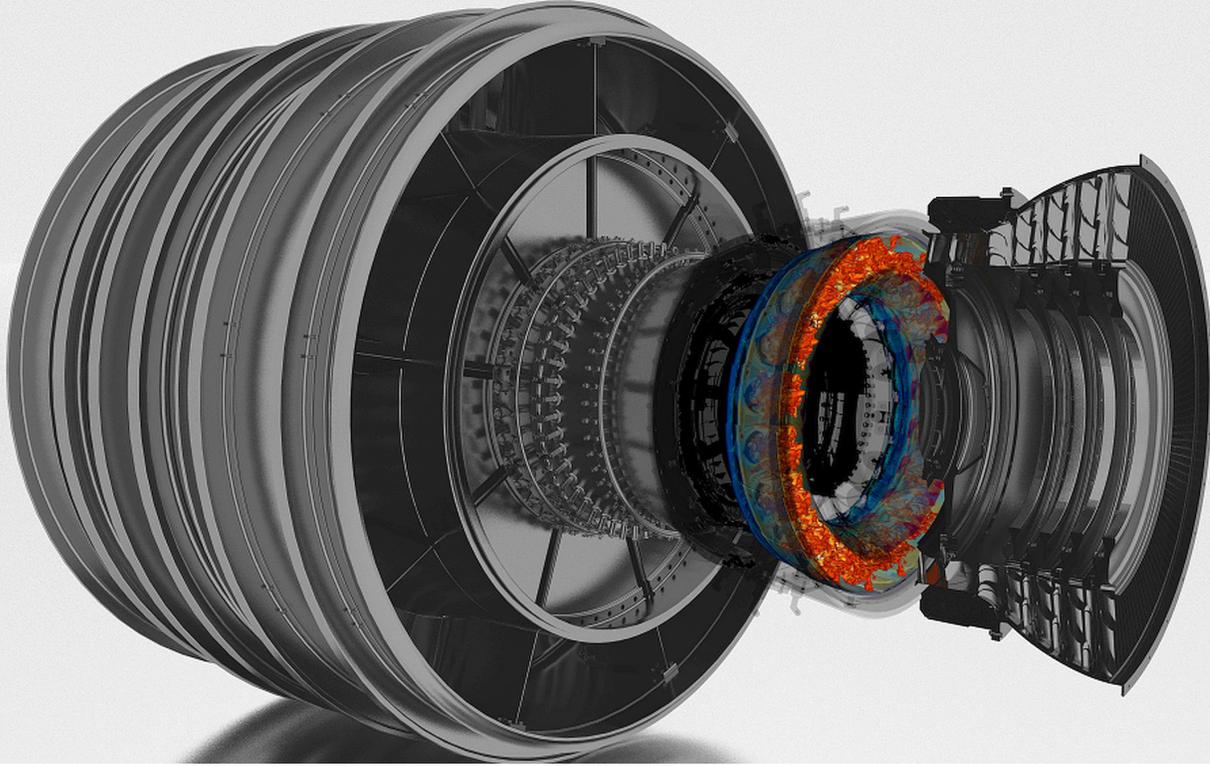
DIGITAL INDUSTRIES SOFTWARE

Simcenter STAR-CCM+ for combustion

Providing a fast and scalable chemistry solver for efficient, high-fidelity combustion simulations

Benefits

- Run more solutions in less time with a fast, scalable chemistry solver

- Provide quick, accurate emissions profiles for combustor design with novel automated reactor network approach

- Ensure computational resources are fully used with highly efficient, scalable solvers

- Use model-specific reacting flow mesh adaption method to ensure accurate results with reduced effort structuring the mesh ahead of time, perfect for transient flames

- Get the high-fidelity answer you need for combustion liners with multi-time scale method for conjugate heat simulations with LES

Summary

Next-generation combustion systems are under increasingly severe constraints. "Tight emissions regulations, a competitive market, new fuels and novel fuel compositions ensure that staying competitive is more challenging than ever.

Additionally, new technologies such as additive manufacturing create limitless possibilities for optimizing combustion chamber geometries. However, without experience in this area it is difficult for engineers to apply these techniques.

LES simulation of Sandia Flame-G: Temperature field.

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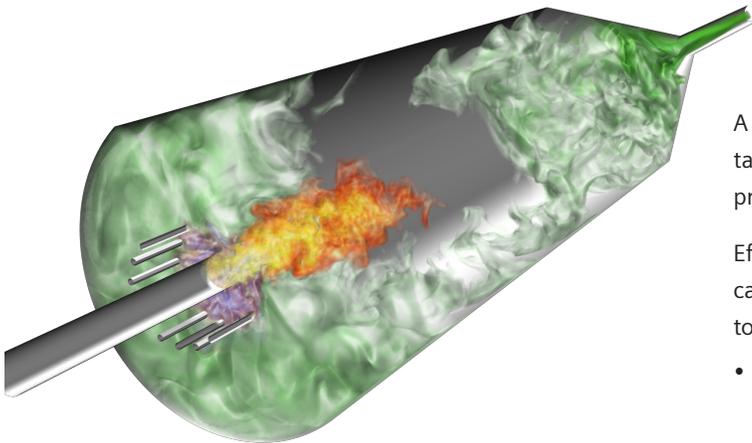
Transient LES simulation of flameless methane combustor from Verissimo et al. The fuel / air mixture is shown in blue with areas of NOx formation formed in green.

A high-fidelity digital twin solves these issues, enabling experimentation, design exploration and optimization before a physical prototype of a product exists.

Effectively evaluating combustion system performance is a significant challenge for today's simulation tools. To be effective, these tools must be capable of:

- High-fidelity analysis to get an accurate evaluation of real-world performance. All the physics must be included, such as thermoacoustic noise interactions, multiple time scales, ultra-low-level emissions production and novel fuel chemistries
- Speed and scalability in order to run simulations with sufficient resolution within practical turnaround times

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- High-fidelity analysis to get an accurate evaluation of real-world performance. All the physics must be included, such as thermoacoustic noise interactions, multiple time scales, ultra-low-level emissions production and novel fuel chemistries
- Speed and scalability in order to run simulations with sufficient resolution within practical turnaround times
- Design exploration, which is necessary to meet complex design constraints, such as emissions profiles, while getting the best competitive advantage with performance
- Complex geometry handling to cope with novel additive manufacturing techniques

Simcenter STAR-CCM+ offers the solution

Simcenter™ STAR-CCM+™ software is a multi-purpose computational fluid dynamics (CFD) tool with comprehensive multiphysics capabilities. With a single integrated user interface (UI), you can use a full suite of coupled physical models to build a high-fidelity digital performance twin of a real-life application.
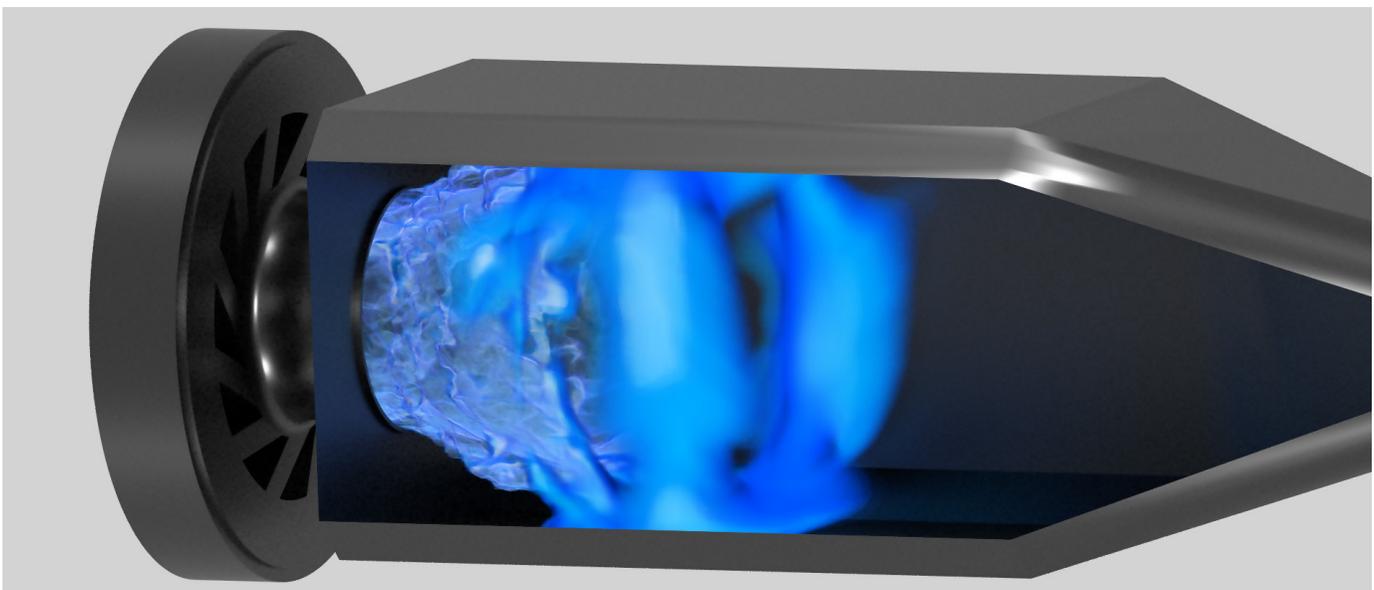
Siemens Industrial Turbomachinery LTD DLE SGT-100. Mixture fraction distribution.
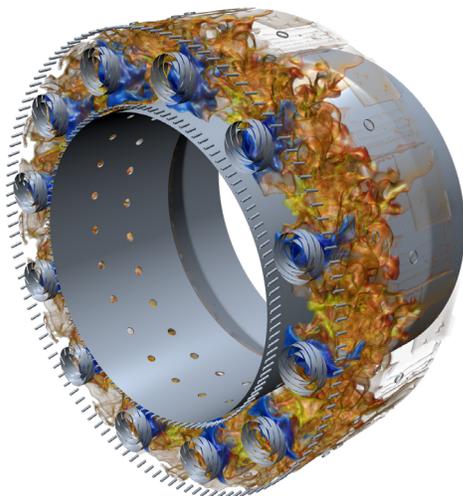
With Simcenter STAR-CCM+ the combustion simulation user bene-fits from improved workflows and functionalities such as:

• A pipelined automated computer-aided design (CAD) to solution workflow for complex and novel combustion chamber geometry simulation

• Automated flamelet workflow including flamelet table generation from mechanism import to table building, integration and analysis

• In-built design exploration to balance the complex tradeoffs needed for modern combustor design when the operating enve-lope is highly constrained

• Innovative data analysis tools, including capabilities such as data focus to answer questions, such as where is soot formation most likely to occur?, as well as collaborative virtual reality (VR) to allow all combustor design stakeholders (heat transfer team, combus-tion team, mechanical integrity team) to review, discuss and critique in real-time as a team

Cutting-edge combustion

Simcenter STAR-CCM+ provides state-of-the-art combustion models from the latest proven research to ensure users have the best capabilities at their fingertips, such as:

• Complex chemistry with turbulent flame closure for accurate emission prediction with flame propagation and positioning

• Thickened flame model for accurate combustion without the need for excessively large meshes

• Reactor network model for quick emissions studies

• Complex ignition models such as imposed stretch spark ignition model (ISSIM) and sub-grid spark to correctly capture ignition events


Coal combustion simulation.

Speed and performance

To meet the severe constraints of the combustion market it is necessary to perform more design iterations early in the design cycle to prevent costly problems from arising in production. Simcenter STAR-CCM+ enables this by ensuring combustion simu-lations work efficiently with our technologies:

• A state-of-the-art, proprietary ordinary differential equation (ODE) chemistry solver that makes all simulations faster, regardless of mechanism size. For large mechanisms with more than 100 transported species, we automatically use the Simcenter STAR-CCM+ sparse solver, significantly speeding up calculations

• Linear scaling, proven to high core counts in benchmarks

• Powerful chemistry acceleration techniques to further reduce run time

• Clustering for large mesh counts to reduce the number of chemistry calculations

• Dynamic mechanism reduction for large mechanisms to reduce the number of chemical paths that are considered

• In-situ adaptive tabulation (ISAT) for small mechanisms reduce the number of chemistry calculations, optimizing runtime

• Our unique pressure-implicit with splitting of operators (PISO) solver formulation gives efficient performance for high-fidelity large eddy simulation (LES) combustion runs

Transient LES combustion in annular gas turbine combus-tor showing the fuel-air mixture fraction.

- Minimizing cell count to achieve fast runtime with our specific reacting flow mesh adaption model to ensure that cells are only placed where the reacting flow needs it

- Multi-timescale modeling approach to couple conjugate heat transfer with LES combustion for highly accurate combustor liner simulations
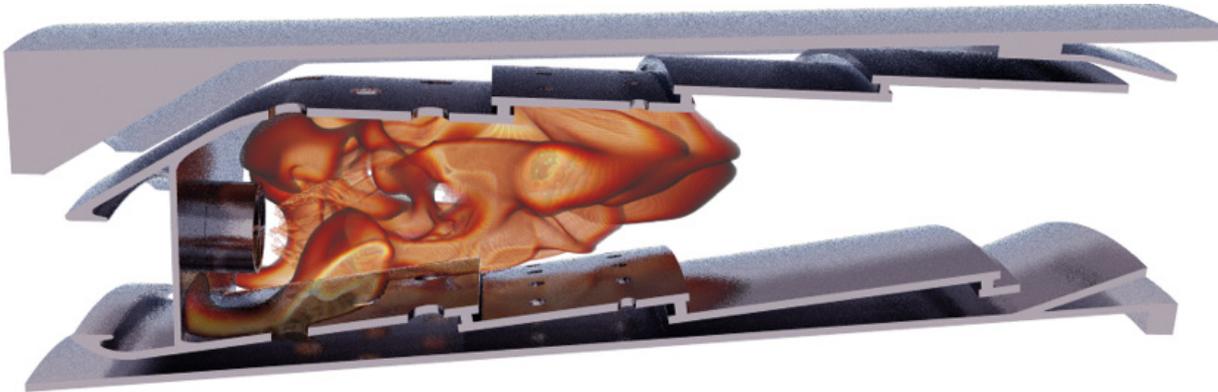
Temperature on flame front in the sector model of a gas turbine combustor liner.
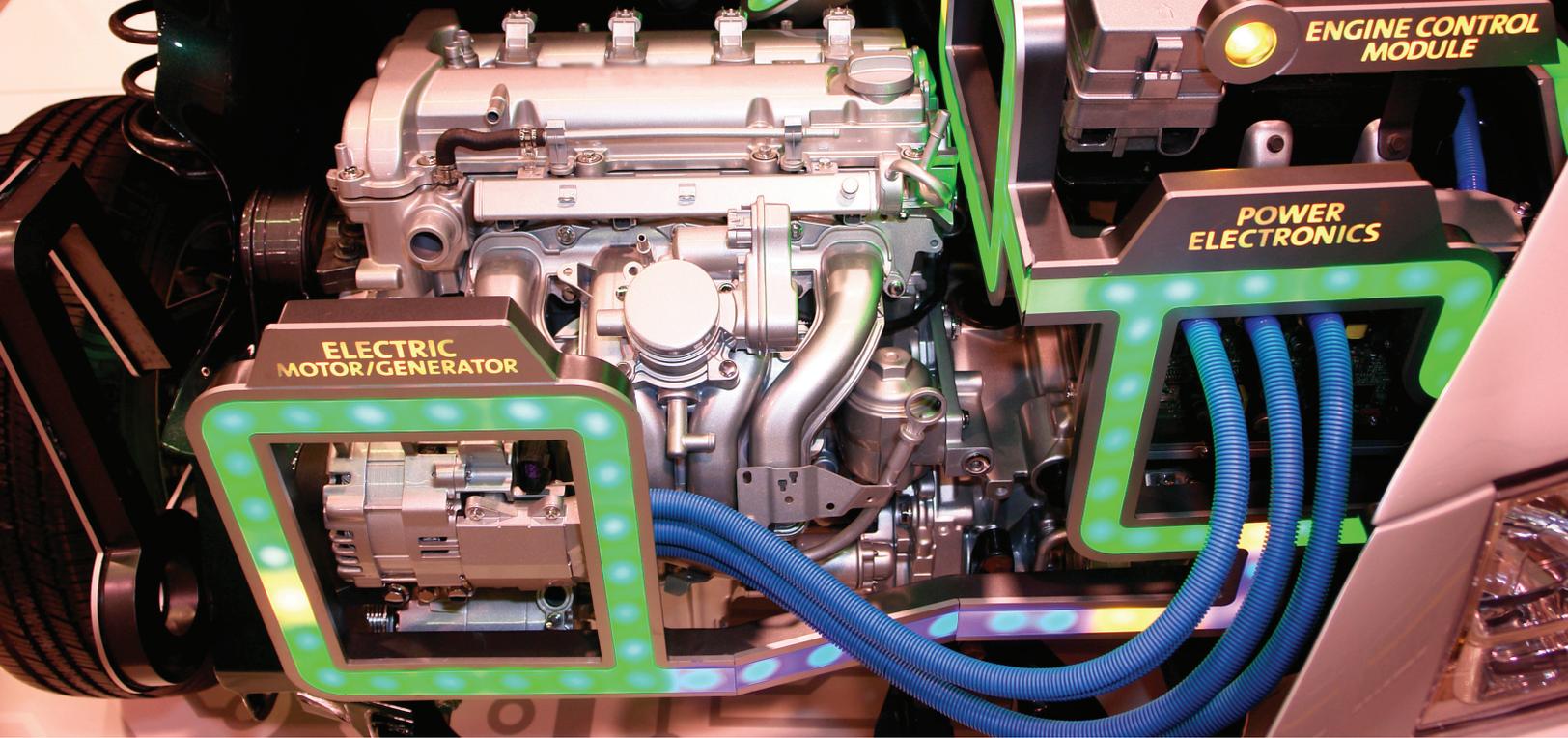
Simcenter STAR-CCM+ electromagnetics

A fast, scalable tool for electromagnetic analysis in a multiphysics environment

Benefits

- State-of-the-art electromagnetic solver enables accurate analysis of low-frequency applications

- Single integrated multiphysics environment expands application coverage and improves physical realism

- Computational electromagnetics can be coupled with computational fluid dynamics (CFD)/thermal physics within the same simulation

- Finite volume and finite element discretizations of low frequency electromagnetism can be used in 2D and 3D

- Fast and scalable solvers allow analysis of industrial scale problems

Today's challenges in electromagnetics

Electrification is one of the major pillars of industrial innovation. In this field, modern design and optimization often require a multidisciplinary approach. For instance, the development of an electric motor may need to account for electromagnetics, heat transfer, fluid dynamics, structural mechanics, and noise and vibration. A realistic design of a circuit breaker may have to include radiation, wall ablation, contact erosion, ferromagnetism and fluid mechanics. To tackle such a level of complexity, advanced numerical simulations are an essential tool for a thorough, cost-effective and comprehensive analysis. The following are additional simulation challenges in electromagnetics today:

- Simulation engineers need to simulate all the required physics for truly innovative and reliable designs

- The number of simulation tools should be minimal and workflows user-friendly

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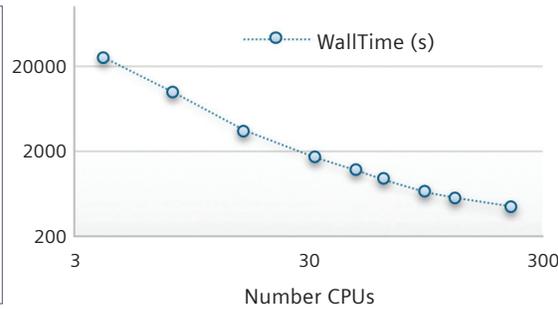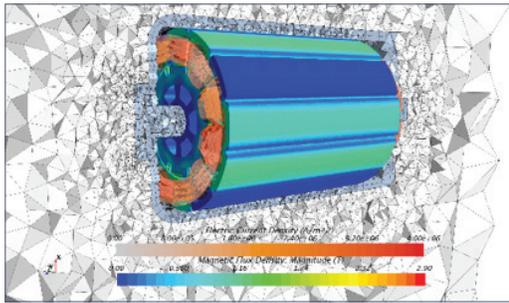
On the left is a realistic e-machine model in 3D. Mesh is 12.8 million elements.
Right, performance on an Intel Xeon CPU E5-2698 version e3, 2.30 GHz, InifiniBand QDR.

- The selected physical models must provide the correct numerical formulation and discretization (finite volume (FV)/finite element (FE), time/frequency domain, 2D/2D-axisymmetric/3D)
- Results must be accurate with fast turn-around times

Simcenter STAR-CCM+ offers the solution

Simcenter™ STAR-CCM+™ software is a multi-purpose CFD tool with expanding multiphysics capabilities. In a single integrated user inter-face, users can utilize a full suite of coupled physics models to build a high-fidelity digital twin of their real-life application. Moreover, the code benefits from a highly scalable high-performance computing (HPC) frame-work enables faster results.
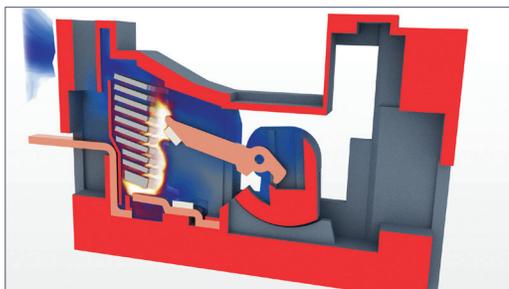
Example of Simcenter STAR-CCM+ multiphysics showing a cross-section of a low voltage circuit breaker simulation.

With Simcenter STAR-CCM+, users can:

- Make use of an accurate, fast, scalable implementation of low frequency electro-magnetics analysis
- Take advantage of a fast development cycle that quickly reacts to and anticipates market needs, releasing new, fully-featured versions three times a year
- Focus on making engineering decisions by reducing time otherwise spent in setting up complex workflows involving different, narrow-purposed tools

Multiphysics

The ability of Simcenter STAR-CCM+ to couple several physics models in one single environ-ment is one of its major advantages, giving users the most physical and accurate digital twin of their application. For example, to develop a robust and high-performance elec-tric motor, simulation experts need to account for the effective cooling of the electric machine, whose simulation often involves advanced multiphase analyses (for example, oil-spray cooling). Similarly, prototyping a reliable circuit breaker often requires detailed simulations of complex physical phenomena.

Typical low frequency applications that are performed using multiphysics capabilities of Simcenter STAR-CCM+ include:

- Electric machines (motors, transformers, generators, converters) and their thermal management
- Magnetohydrodynamics and plasma arcs (circuit breakers, relays, welding devices, thermal spraying, plasma torches)
- Problems involving coupling with solid stress to assess mechanical strength under magnetic loads in short circuit events
- Induction heating and stirring
- Ohmic heating: busbars, fuses, etc.
- Actuators and loudspeakers
- Sensors and flow meters

Accuracy and performance
Users must have full confidence in their virtual models in order to take decisions based on computed predictions. Solution accuracy is paramount and cannot be compromised. For instance, accurate simulations help in understanding whether a switchgear prototype will interrupt a large short-circuit current at a certain voltage. Simulation experts dealing with electric machines need to quantify the impact of geometry changes on the torque supplied by the machine. Safety analysis (dielectric withstand, shielding, lightning protection) requires careful sizing of geometries and gaps between components.
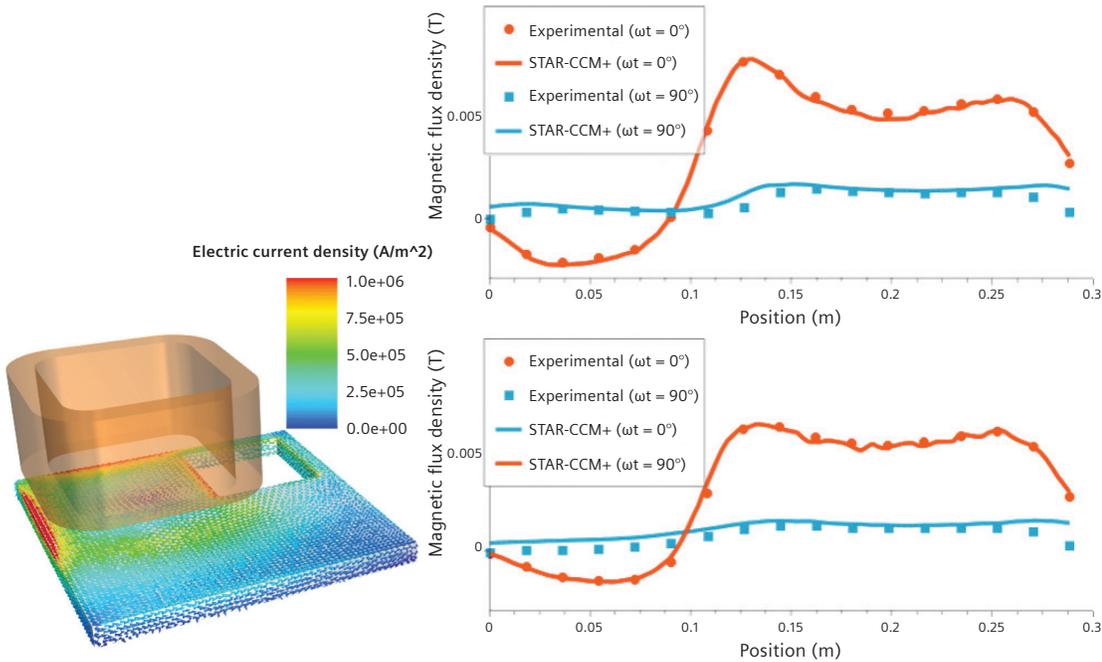
Results from Compumag society benchmark case showing electric current density analysis on the left and comparison with experimental results on the right.
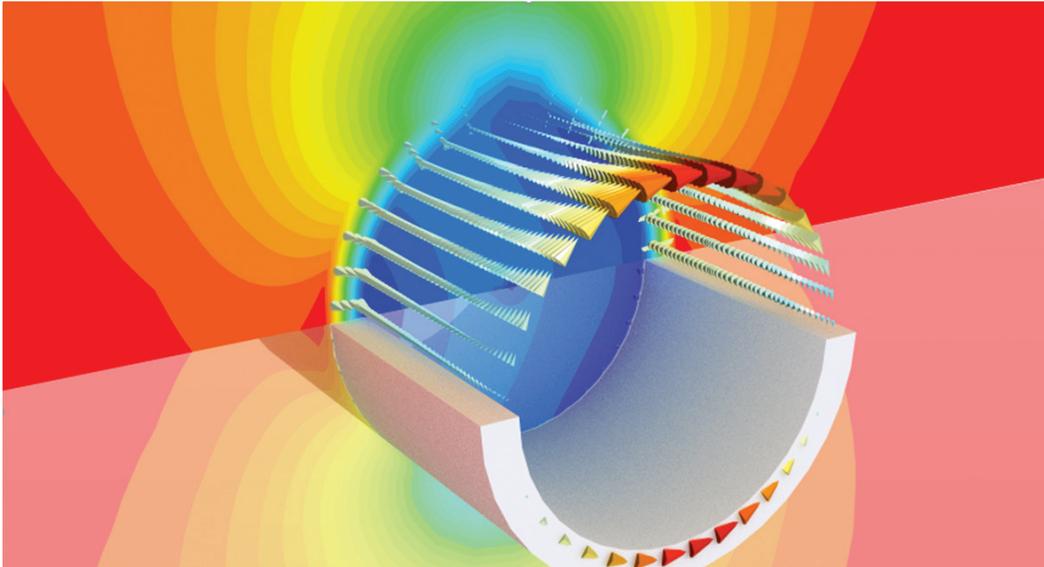
Simcenter STAR-CCM+ offers optimum accuracy, speed and performance – here's how:

- Best-in-class computational electromagnetics (CEM) models ensure coverage of different applications without compromising on speed

- Simcenter STAR-CCM+ models are consistently benchmarked with published results

- HPC framework enables excellent scalability, providing lower turnaround times on more than 200 cores on a cluster

- Users choose between direct and iterative multigrid solvers, taking advantage of their complementary strengths and performances on different mesh sizes

- The FE iterative solver handles large meshes (over 10 million elements) with excellent performance on large cases

- Siemens Digital Industries Software collaborates with relevant academic and industrial partners, whose expertise helps in strengthening accuracy and validation

DIGITAL INDUSTRIES SOFTWARE

Simcenter STAR-CCM+ Power licensing

Unlocking the power of simulation with flexible and powerful licensing solutions

Benefits

- Enhance the power of simulation with powerful and flexible licensing solutions

- Accelerate throughput of large simulations

- Run hundreds of simulations concurrently to find trade-offs in design

- Cost-effectively scale compute resources to meet changes in simulation demand

- Customize licensing solutions for your specific simulation needs

- Maximize return on hardware and software investment

Summary
High-performance computing (HPC) is a key enabler for using high-fidelity simulations to shorten design cycles and drive product innovation. In the age of multicore computing, the cost of software, not hardware, is often the limiting factor in the use of large compute clusters. When analysis software is licensed on a per-core basis using the traditional licensing model, you can end up with compute resources that are underused, restricting your engineering ambitions. Flexible, cost-effective license schemes become essential to make the most of your hardware resource and unlock the power of simulation.

Simcenter STAR-CCM+ offers the solution
Simcenter™ STAR-CCM+™ software, which is a part of the Siemens Xcelerator business platform of software, hardware and services, offers flexible and powerful licensing options that are customizable to meet your simulation needs and throughput requirements. No matter the size or location of your computing resources, our Power licensing options let you fully exploit them to maximize your return on simulation software and hardware investment.

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Features

- Simcenter STAR-CCM+ Power Session: unlimited CPU usage for a fixed price

- Simcenter STAR-CCM+ Power Session Plus: unlimited CPUs and GPUs usage for a fixed price

- Simcenter STAR-CCM+ Power on Demand: pay by the hour for unlimited CPU usage

- Simcenter STAR-CCM+ Power Tokens: flexible needs-based usage

Figure 1. Maximize return on hardware investment with Power licensing.

Our Power licensing makes HPC simulations cost-effective by breaking the link between software cost and core count with three unique licensing solutions:

- *Power Session:* Maximize your hardware investment with unlimited core usage for a fixed price. This license scheme is most beneficial to accelerate throughput of simulations by running on as many cores as possible

- *Power Session Plus:* Increase performance and flexibility with both unlimited CPUs and GPUs usage for a fixed price. This license scheme allows for hardware flexibility and leveraging sustainable GPUs that drastically accelerate throughput of simulations while reducing power consumption compared to the equivalent required CPU hardware

- *Power on Demand:* Only pay for what you need with unlimited Power Session access by the hour. This license scheme is most beneficial for cloud computing, burst capacity or infrequent usage

- *Power Tokens:* Needs-based usage provides you with the most flexibility to adapt to your evolving simulation needs and cost-effectively deploy design space exploration

  This includes:
  – Access to pre- and postprocessing sessions using 10 Power Tokens

  – Parallelize single simulations as one Power Token activates one core

  – Adapt to your available resources to maximize throughput when exploring the design space
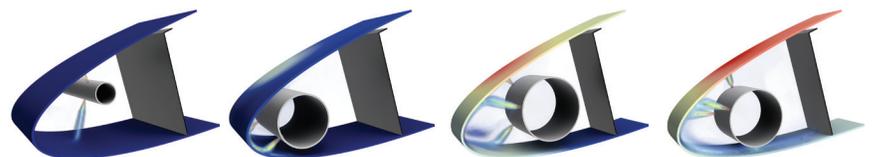
Figure 2. Improving the heat transfer performance of an aircraft ice protection system (courtesy: Honda Aircraft).

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For users who run smaller simulations on fewer cores, we also offer traditional pay-by-the-core licensing. However, if you run on or more than 12 cores, the Power Session license is the optimal solution.

We can put together a customized configuration with a unique combination of Power license ingredients that meets your specific simulation and throughput requirements.

Maximizing throughput in large simulations

Simcenter STAR-CCM+ is optimized for high parallel efficiency and scalability. This enables running on higher core counts to reduce simulation turnaround time and quickly gain insight into industrial engineering problems. The Power Session and Power Session Plus license schemes will help you:

• Deploy all your available hardware resources for a single fixed price

• Achieve enhanced scalability for large simulations and get results in hours instead of days. As an example, running on 10,000 cores incurs the same software costs as running on 100 or 20 cores. Likewise running on 100 GPUs is the same software licensing as 1 GPU with Power Session Plus

Unlocking the power of design space exploration

Exploring design space early in the process is the key to increase product performance and drive innovation. Power Tokens provide you with the most flexibility to cost-effectively
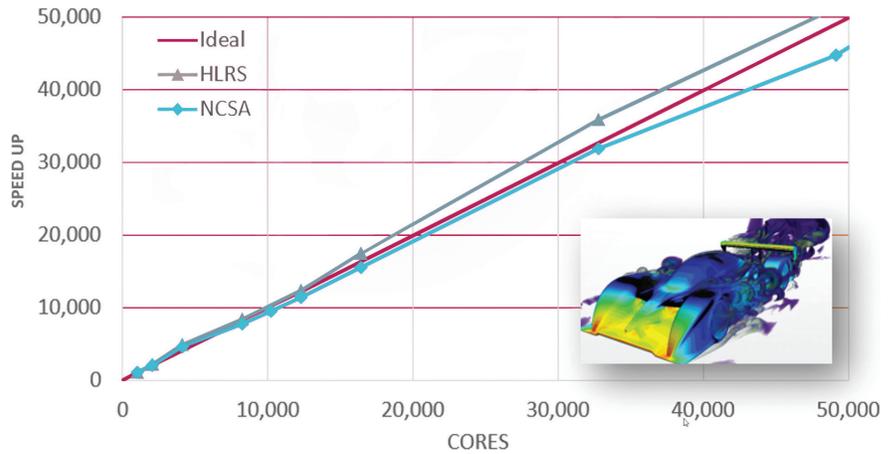
Figure 3. Simcenter STAR-CCM+ scales well at high core counts.

deploy design space exploration as they pay for either adding an additional core or a new variant in your exploration study. For example, if you buy 100 Power Tokens and one Simcenter STAR-CCM+ session, you can:

1. Either access 10 pre- and postprocessing sessions.

2. Or run a single simulation on 100 cores.

3. Or run a design exploration study with:
   – 5 simultaneous designs on
     20 cores each
   – or 10 simultaneous designs on
     10 cores each
   – or 100 simultaneous designs on
     one core each

This way, you can easily adapt your resource allocation to your study requirement and project deadlines.

Leverage burst capacity at times of peak demand

Power on Demand is a licensing scheme counted by the wall hour that allows you to open unlimited sessions and run unlimited simulations on an infinite number of cores. This way you can:

- Get unlimited burst capacity for peak project loads, run multiple jobs at once and pay only for what you use

- Use it from any public/private cluster, network or cloud infrastructure

- Track billable hours and share between colleagues, subsidiaries and projects

For example, with 500 hours you can use:

- 1 job for 500 hours on 16 cores

- 5 jobs for 100 hours each on 128 cores

- 50 jobs for 10 hours each on 1,500 cores
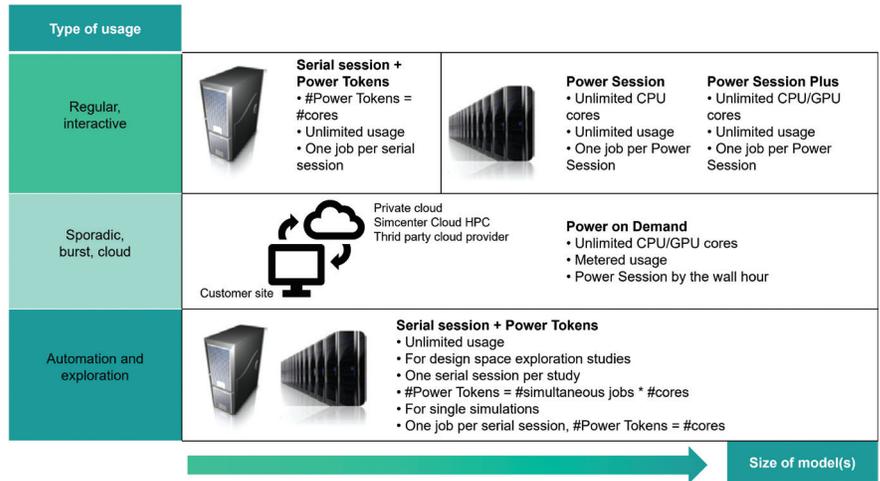
Figure 4. Simcenter STAR-CCM+ flexible licensing options.

DIGITAL INDUSTRIES SOFTWARE

Simcenter STAR-CCM+ design exploration

Enhancing product performance by exploring the design space early in the process

Benefits

- Improve product performance by exploring the design space early in the process

- Evaluate real-world behavior of complex systems using multiple what-if scenarios in a cost-effective manner

- Use simulation to drive innovation and gain market share with better designs

- Increase product knowledge to enhance confidence in design decisions

- Improve product reliability to reduce risk and cost

- Align resources with the value of simulation for a higher ROI

Summary

Simulation is a critical tool in troubleshooting and preventing in-field failures, validating product performance and predicting how designs perform in real-world conditions. To keep a competitive edge in today's fast-paced market, companies must use simulation to drive innovation. Design space exploration takes engineering analysis to the next level by driving design decisions based on appropriate engineering and performance objectives. Although companies agree they need to rethink their simulation practices to stay in the race, some challenges and roadblocks remain, such as:

- Driving parametric modifications of computer-aided design (CAD) models
- Robustly automating the CAD-to-results process
- Efficiently and effortlessly searching the design space
- Managing and extracting insights from large data sets

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Simcenter STAR-CCM+ offers the solution

Using Simcenter™ STAR-CCM+™ software allows you to unlock the power of simulation and drive innovation. Instead of using simulation to evaluate the performance of one design, you can define the desired performance objectives and let our embedded search technology identify better-performing designs. With its integrated CAD-to-exploration approach, Simcenter STAR-CCM+ removes all existing bottlenecks and allows you to:

- Explore early and often using an **integrated automated process**
- Leverage your resources with **efficient resource management**
- Affordably deploy design exploration with **flexible license schemes**
- Discover better designs faster with our **intelligent search** method
- Find novel and nonintuitive designs with the robust **integrated adjoint** solver
- Easily gain insight into product behavior with **effective visualization**

Integrated automated process

Seamlessly deploy design space exploration in a single user environment:

- Effortlessly re-execute model updates with a robust, automated workflow

REACTIVE	PROACTIVE	INNOVATIVE
Troubleshoot issues	Validate designs	Drive performance

with Simcenter STAR-CCM+
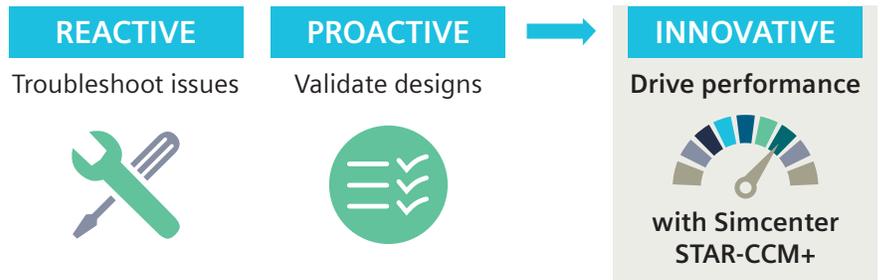
Redefining simulation strategy for innovation.

- Create or modify parametric CAD models using the built-in 3D CAD modeler
- Easily define and control design and operating condition parameters
- Explore designs using native CAD tools using CAD Clients
- Evaluate your CAD model upfront with the CAD robustness study
- Automatically run defined what-if scenarios with manual and parameter sweep studies
- Seamlessly extend to optimize with the Simcenter STAR-CCM+ Intelligent Design Exploration add-on license
- Save time and increase accuracy by optimizing your methodologies' simulation parameters
- Perform nonparametric optimization using the adjoint solver
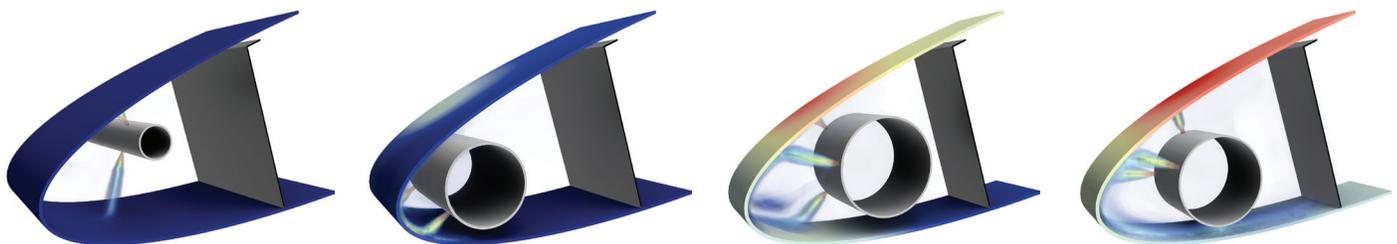
Improving the heat transfer performance of an aircraft ice protection system (courtesy: Honda Aircraft).

Efficient resource management

Easily leverage available computing resources to increase simulation throughput:

- Integrate easily with existing hardware and software environment with multiple submission modes

- Meet your priorities with upfront pre-allocation of hardware and license resource

- Seamlessly submit, monitor and control studies on Linux clusters with job manager

- Automatically orchestrate different simulation operations across resources and operating systems

HP Multi Jet Fusion 5200 3D printer ventilation system optimization, delivering 22 percent improved efficiency (courtesy: HP).
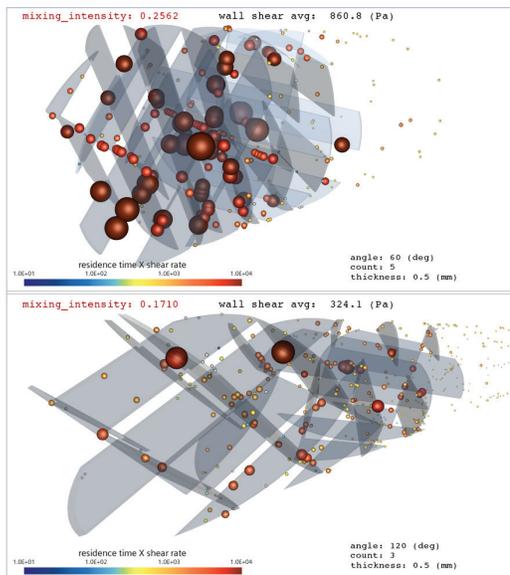
Comparison of static mixer designs showing areas where material will be exposed to higher shear for longer periods of time. A total of 192 designs were explored.

Flexible license schemes

Affordably deploy design space exploration:

- Simcenter STAR-CCM+ Power Session: unlimited number of cores per session at a fixed price

- Simcenter STAR-CCM+ Power on Demand: pay-as-you-go on an unlimited number of cores

- Simcenter STAR-CCM+ Power Tokens: adaptable use of licenses based on number of simultaneous design runs and cores needed per study

Intelligent search

Discover better designs with our embedded HEEDS™ software intelligent search:

- Requires only variables, objectives, constraints and time budget as inputs

- Leverages multiple global and local search strategies

- Adapts the search as it learns more about the design space

- Finds better design alternatives in the allotted time

- Cost-effective on complex models, no matter the number of parameters and constraints

- Allows collaborative optimization to benefit from user knowledge

Effective visualization

Gain insight into product behavior to drive design decisions:

- Compare multiple variants or studies simultaneously to identify families of top-performing designs

- Highlight design dependencies and common trends using parallel plots

- Understand tradeoffs across designs for multi-objective optimization with Pareto plots

- Monitor your study convergence with live postprocessing updates

- Facilitate design comparison with interactive linked snapshots

- Quickly navigate large data sets with interactive and synchronized design table, snapshots and plots

Pareto plot: uniformity versus pressure drop

Parallel coordinates

☐ Baseline • Pareto front – Pressure drop constraint – Velocity constraint
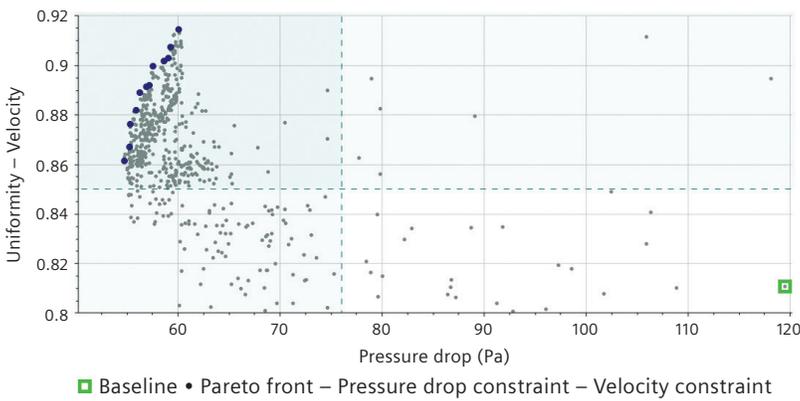
Understand tradeoffs across designs with Pareto plots.
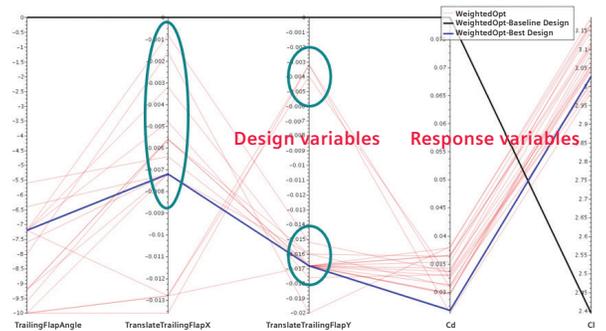
Identify common trends with parallel plots.

DIGITAL INDUSTRIES SOFTWARE

Topology optimization with Simcenter STAR-CCM+

Generate optimal additive manufacturing designs to meet engineering requirements early on

Benefits

- Generate optimal additive manufacturing designs

- Meet engineering requirements early in the design process

- Generate designs that satisfy the available space restrictions

- Improve product performance by optimizing heat efficiency and flow paths

Summary

Generative engineering is gaining more attention with the industrialization of additive manufacturing. Using topology optimization (TO) for structural problems was adopted early on to accommodate for out-of-the-box generative engineering needs. In the past, flow-centered problems usually focused on trial-and-error design methods, which led to conservative designs that were unable to unlock additive manufacturing benefits.

TO for fluid flow takes advantage of additive manufacturing's full potential. It enables you to:

- Automatically generate optimized designs using powerful gradient-based optimization methods

- Create early design concepts, which are driven by engineering targets without needing a starting design

- Design better performing products that naturally fulfill packaging constraints

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Simcenter STAR-CCM+ offers the solution
Using TO in Simcenter™ STAR-CCM+™ software, which is part of the Siemens Xcelerator business platform of software, hardware and services, offers an integrated solution for fluid/thermal problems. To run an adjoint TO, you need to only define your design envelope and flow/thermal objectives by cost functions. This method will chisel away the parts of your geometry that hinder the cost function, which turns them into a solid and defines the optimal flow path shape. It allows you to solve engineering problems with competing objectives in a streamlined manor.

These competitive attributes are key to the additive manufacturing landscape. Simcenter STAR-CCM+ provides:

• Productivity with reduced engineering time and an easy-to-use pipelined workflow, which is delivered from a single and integrated user interface (UI)

• A competitive method based on the level set approach, which enables clean designs by employing a moving interface around the predicted flow path

• A flexible and powerful optimization method with versatile cost function and constraint definitions to tackle a variety of engineering problems
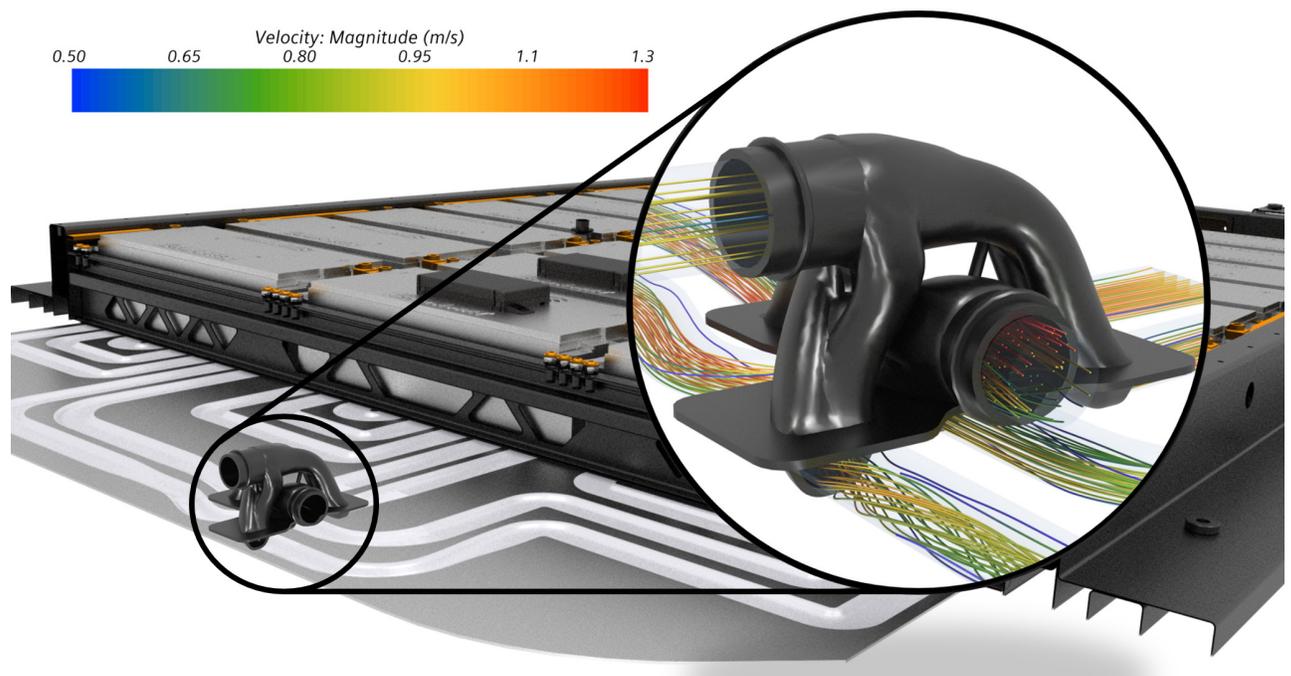
Figure 1. Design evolution of battery-cooling manifold.

Productivity

Using Simcenter STAR-CCM+ enables an efficient and customizable workflow with:

- Automated and repeatable TO execution for efficient problem solving

- Geometry transfer to and from NX™ software, which enables you to seamlessly integrate the new design in the additive manufacturing production chain

- A clean flow path with the level set approach, which significantly reduces turnaround time by minimizing manual geometry cleanup and computer-aided design (CAD) reproduction

- Automatic mesh adoption of the evolving fluid/solid interface, which balances computational effort and accuracy

- Automatic generation of a closed surface, which provides a new watertight design to directly export the resulting geometry or use it inside Simcenter STAR-CCM+
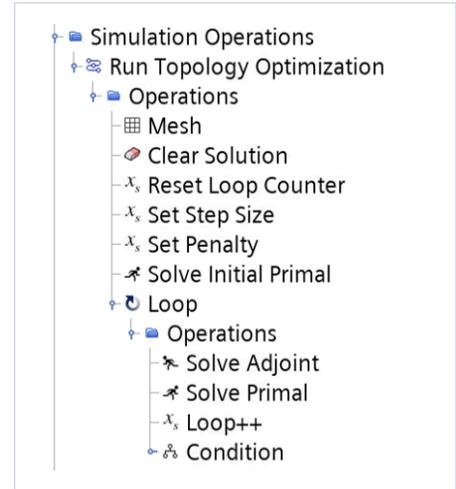
Figure 2. Simulation operations used to drive the TO process from start to finish.
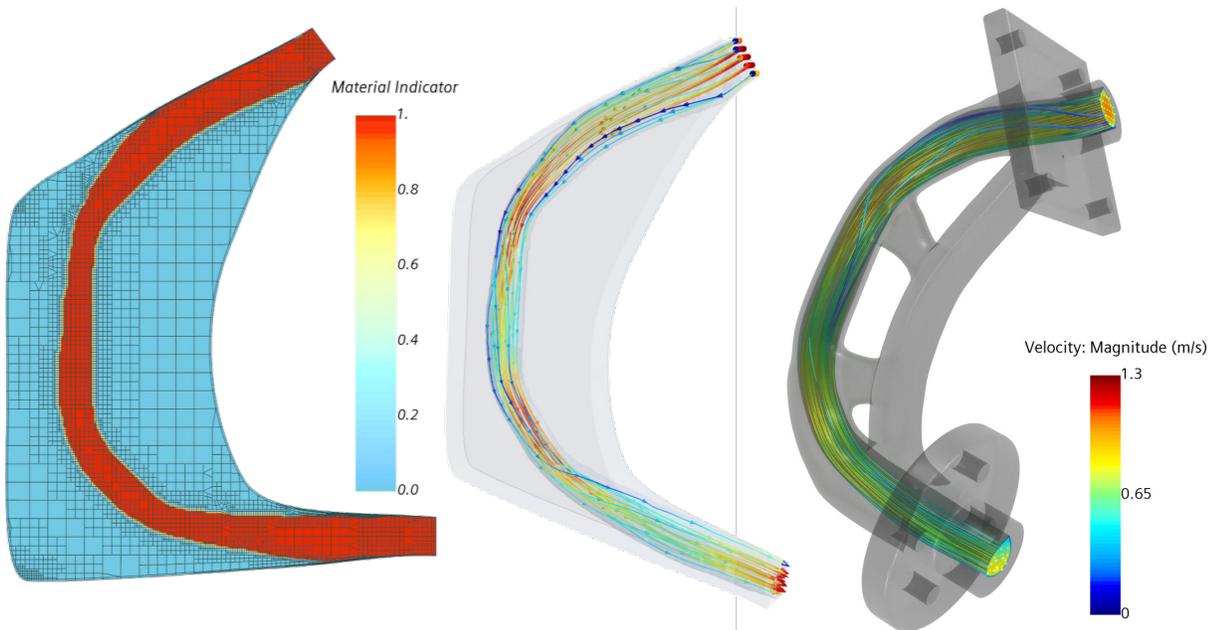
Figure 3. TO of a fuel injector: adaptive mesh refinement (AMR) used to resolve the new design interface (left) and the combination with structural TO (right).

Competitiveness

Achieve high-performing designs using Simcenter STAR-CCM+ with a unique level set approach:

- Reduce the clean-up and CAD reproduction time, which minimizes production cost with a cleaner interface between solid and fluid. This reduces kinks and folds in your designs and eliminates the spare pockets of flow created by traditional, porosity-based methods of topology generation. It creates

a robust optimization process, which allows users to run with semi-converged adjoint and flow solutions for the intermediate optimization steps

- Clearly define the interface between the fluid and the fictitious solid surrounding the design to apply treatments and mimic a boundary. This can be turbulent wall treatment or AMR of the fluid/solid interface
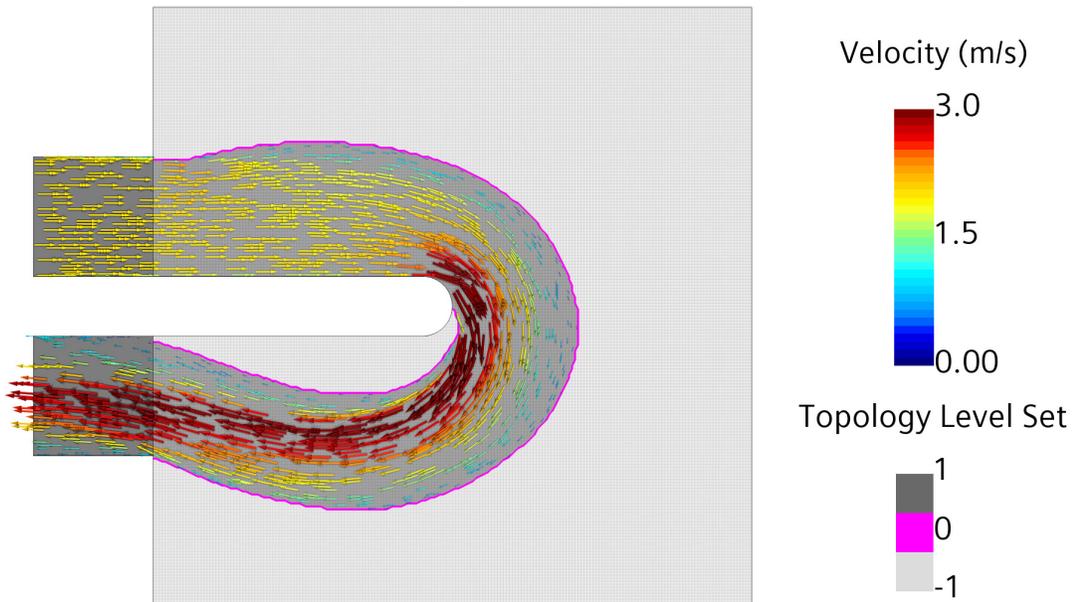
Figure 4. Level set field for robust TO, which leads to clearly defined fluid-solid interfaces.

Flexibility

Supplying solutions for a vast array of engineering problems makes TO meaningful in day-to-day operations such as:

- Solving engineering problems with competing attributes using a constrained optimization method. Users can define one objective with multiple flow/thermal and volume constraints

- Balancing tradeoffs between engineering performance and the design's volume via the integrated volume constraint. It allows the user to specify the domain percentage to occupy with flow or solid

- Solving a larger class of engineering problems by expanding beyond structural TO. User-defined cost functions enable quick definition and analysis of various fluid flow and thermal scenarios
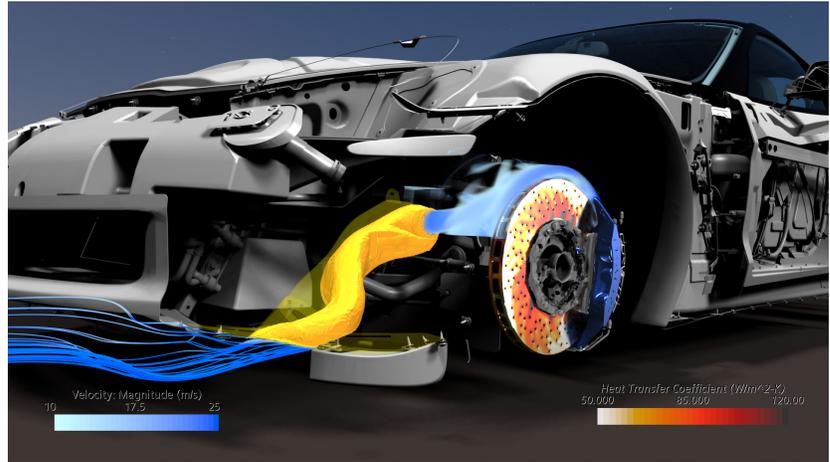
Figure 5. New brake cooling duct for automotive brakes.
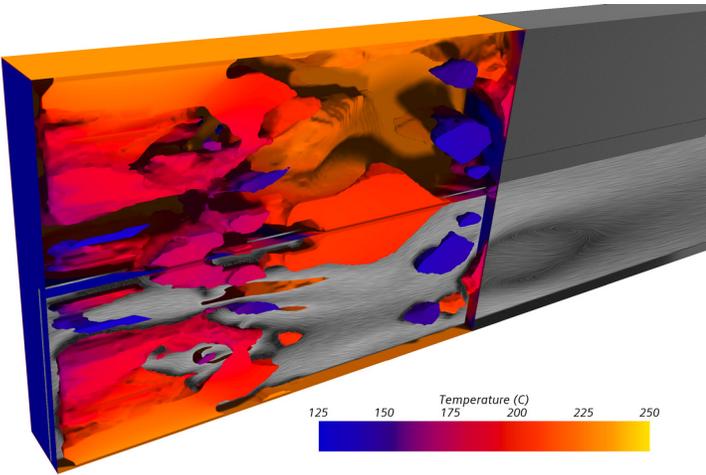
Figure 6. Conformal cooling for injection molding part.
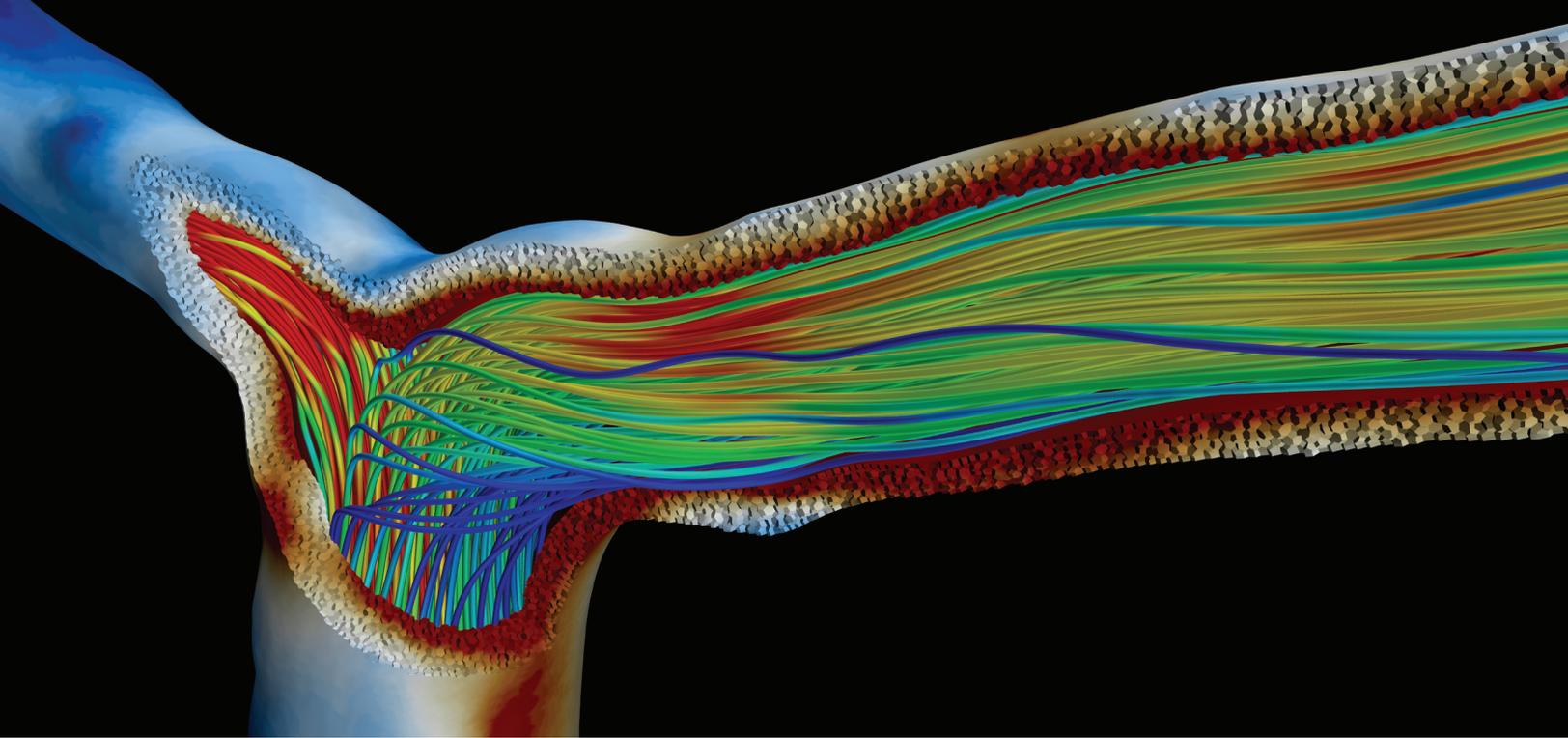
DIGITAL INDUSTRIES SOFTWARE

Simcenter STAR-CCM+ data analysis

Using interactive analysis tools to enhance confidence in design decisions

Benefits
- Save engineering time by working in a familiar, single and fully integrated environment
- Clearly communicate results to stakeholders with leading qualitative photorealistic visualizations
- Collaborate in immersive environments with Simcenter STAR-CCM+ Virtual Reality at every step of your simulation
- Increase confidence in design decisions using comprehensive quantitative reporting, monitoring and plotting tools

Summary
Improving simulation technologies and hardware capabilities enables companies to realize the full potential of simulation-driven design, accelerating the pace of product development cycles. Increasing simulation throughput provides a constant stream of information to guide your design process. It is critical that your analysis toolset can:
- Increase productivity to gain insight into the performance of your designs
- Drive decisions with advanced quantitative data analysis
- Communicate your results with qualitative visualization
- Make informed choices in collaborative environments

This release contains semiconductor scheduling enhancements, a new wafer-based sampling capability, user experience improvements to work-in-progress (WIP) main advanced user interface (UI) along with Rest API enhancements.

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Solution Time 0.6408 (s)
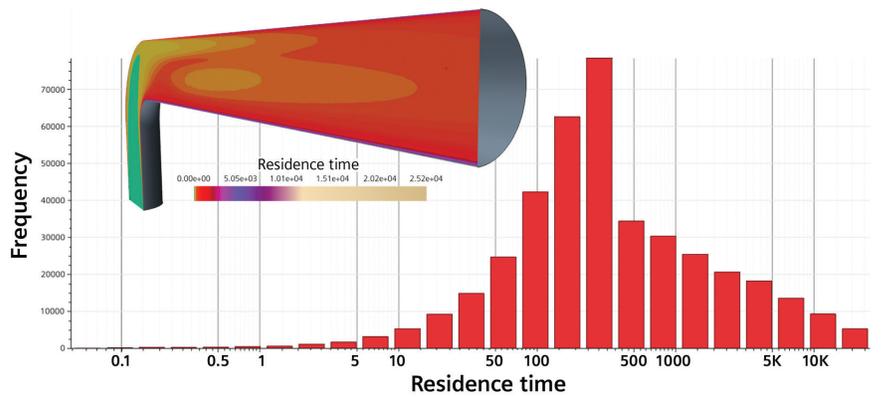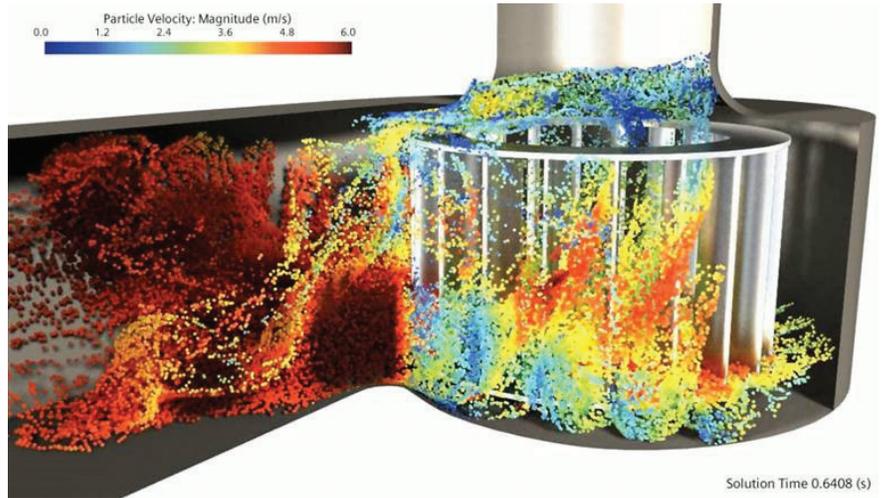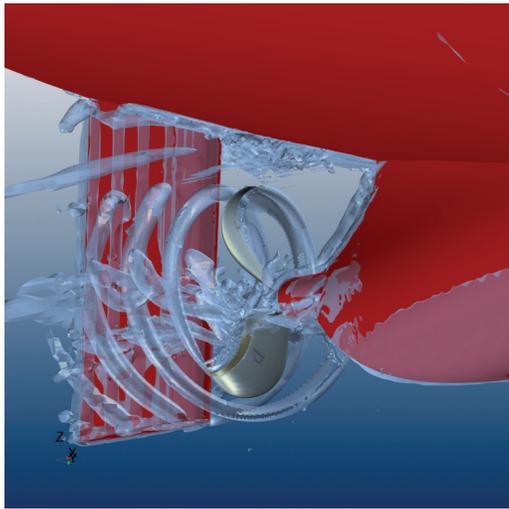
Simcenter STAR-CCM+

Simcenter™ STAR-CCM+™ software saves valuable engineering time when managing, assembling, presenting and sharing simulation results. With Simcenter STAR-CCM+, Simcenter STAR-CCM+ Viewer and Simcenter STAR-CCM+ Virtual Reality, you can:

• Create information-rich reports and visually compelling plots
   in one environment

• Easily analyze and compare results from hundreds of simulations

• Avoid moving large data files by automatically identifying your best
   rendering resources for images and animations

• Work with the smallest amount of data necessary to make decisions with
   efficient transient data management tools

Capabilities

Productivity

- Watch your results evolve in real time with live (in-situ) processing or perform comprehensive analyses after your simulation runs are complete

- Automatically utilize the best rendering resources available regardless of whether you are working on your local workstation or a cluster

- Store only the needed information with Field/Solution histories for best-in-class transient data management

- Use logic-based automation and Java™ macros to save time and make your data analysis workflows more robust and repeatable

Quantitative data analysis

- Draw from an extensive set of pre-defined reports to produce actionable information

- Create customizable monitor-based statistical reports or use field monitors to gain deeper insight

- Use standard plotting tools (XY, chart, histogram, bubble) to show trends and effectively present numerical data

- Perform signal processing with data set functions (Fourier transforms, frequency bands), leveraging solution histories for transient data management

- Use field histories to create time derivative field functions using stored results for different time steps

Qualitative data analysis

- Use Screenplay (keyframe animation tool) to create animations to effectively communicate results to a broad range of stakeholders

- Apply photorealistic rendering techniques to any scene to reduce the time and effort needed to comprehend complex geometries and results

- Add supporting context to your scenes and plots with annotations

- Choose from a large set of derived parts to visualize results on plane cuts, use streamlines for flow patterns and apply volume rendering techniques to gain a deep understanding of complex physical phenomena

Temperature (K)
2200.
1250.
300.

Modify data focus for O2
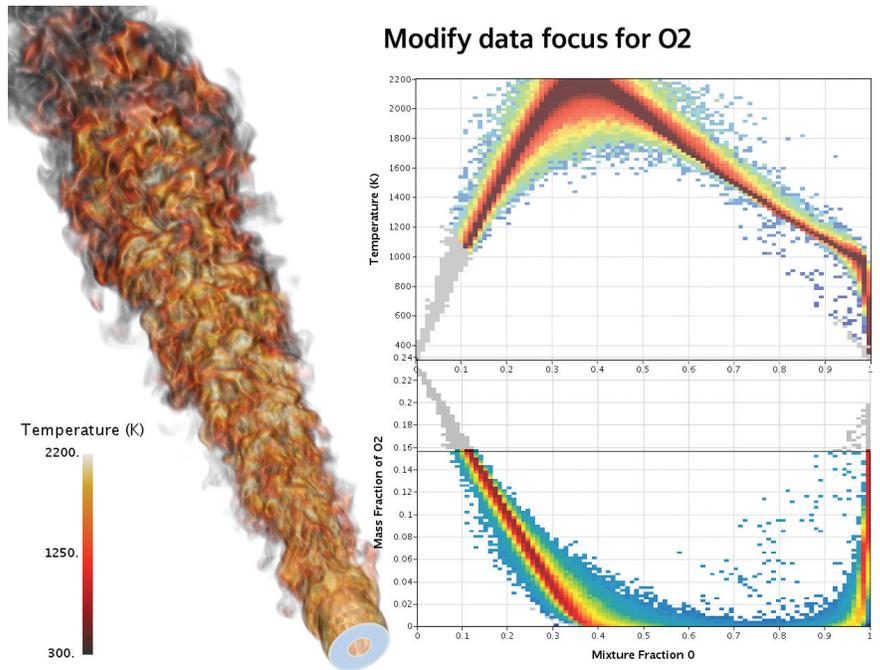
Decision making

- Use synchronized side-by-side views to quickly and interactively identify visual differences between multiple simulations

- Use dashboard-style layouts and design manager to standardize data analysis across simulations

- Easily share results with Simcenter STAR-CCM+ Viewer, a free standalone tool with no license required

- Make more informed decisions by using Data Focus to create plots and charts with interactive criteria of interest to analyze complex relationships in data

- Use collaborative virtual reality (VR) in real-time immersive environments to accelerate decision making irrespective of your team's location

Simcenter Battery Design Studio

Use Simcenter Battery Design Studio™ software to design better battery cell packs by leveraging detailed geometrical cell specifications and cell performance simulation.

Study design and performance of Li-Ion battery cells

Using Simcenter Battery Design Studio supports engineers in digitally validating lithium ion (Li-ion) cell designs thanks to detailed geometrical cell specifications and cell performance simulation. Extensive components of a battery cell are available as well as a material database to support your model development.

Quickly set up simulations with a dedicated user environment

With a dedicated user interface (UI) tailored towards battery cell design engineering, you can set-up your cell simulations studies in minutes. The terminology and inputs are familiar to cell designers. Templates are available for various cell types and a comprehensive material database makes it easy to set up accurate cell models. The tool supports you with an automatic setup of performance analysis.

Replicate real laboratory duty cycles controls for accurate performance simulations

Using Simcenter Battery Design Studio offers several levels of performance models for users, including a physics-based macro-homogeneous model to get insights into the cell's electrochemical mechanisms; and an equivalent RCR circuit model, which is an empirical approach to modeling the cell's behavior in a very computationally effective way. Based on these accurate physics and thanks to fast running simulations, you can leverage controls capabilities to run complete duty cycles to assess battery performance under realistic operating conditions.

Optimize the cell design and control parameters

Using Simcenter Battery Design studio leads to a greater understanding for your design decisions and their impact on your system performance. Thanks to parallel simulation capabilities including multi-threading, you can run extensive design exploration studies to make better battery cell design decisions.
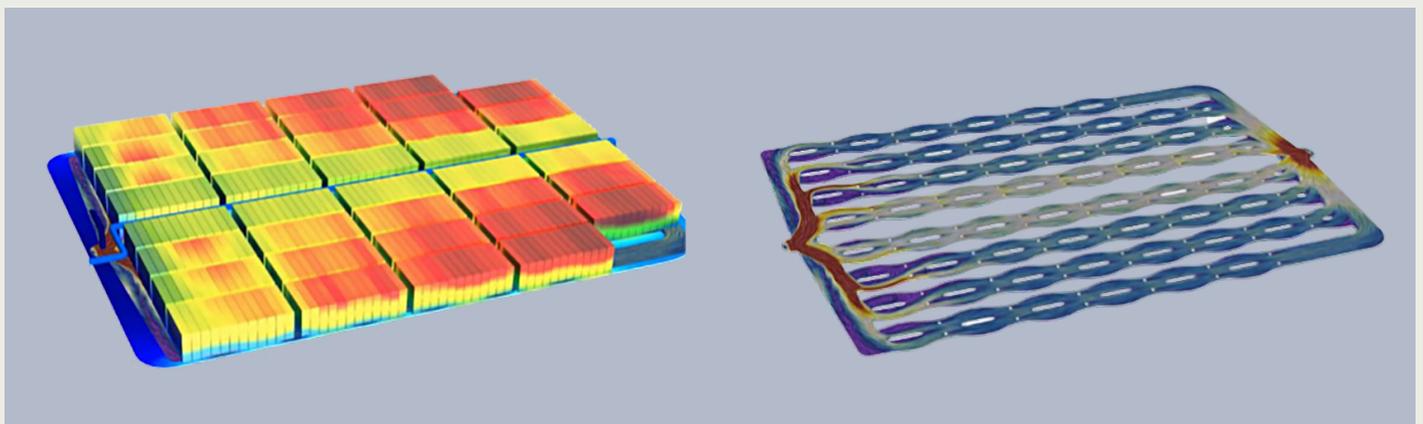
Seamlessly link to 3D battery pack CFD and 1D system simulations

The battery design process typically involves multiple stakeholders across the supply chain. Using Simcenter Battery Design Studio makes it easy to incorporate cell level performance predictions into 3D CFD simulation for package design and 1D system simulations for complete battery system studies. You can use Simcenter Battery Design Studio to encrypt your designs to protect your intellectual property if such system and pack level simulations are carried out by third parties.

Solution benefits
- Rapidly study design and performance of Li-Ion battery cells
- Perform optimization of the cell design and control parameters
- Quickly setup simulations with a dedicated user environment
- Replicate real laboratory duty cycles controls for accurate performance simulations
- Seamlessly link to 3D battery pack CFD and 1D system simulations

Temperature (C)
< 17.50   22.50   > 27.50

Battery SOC
< 0   50   > 100

Battery Volumetric Heat (W/m^3
< 0   12500   > 25000
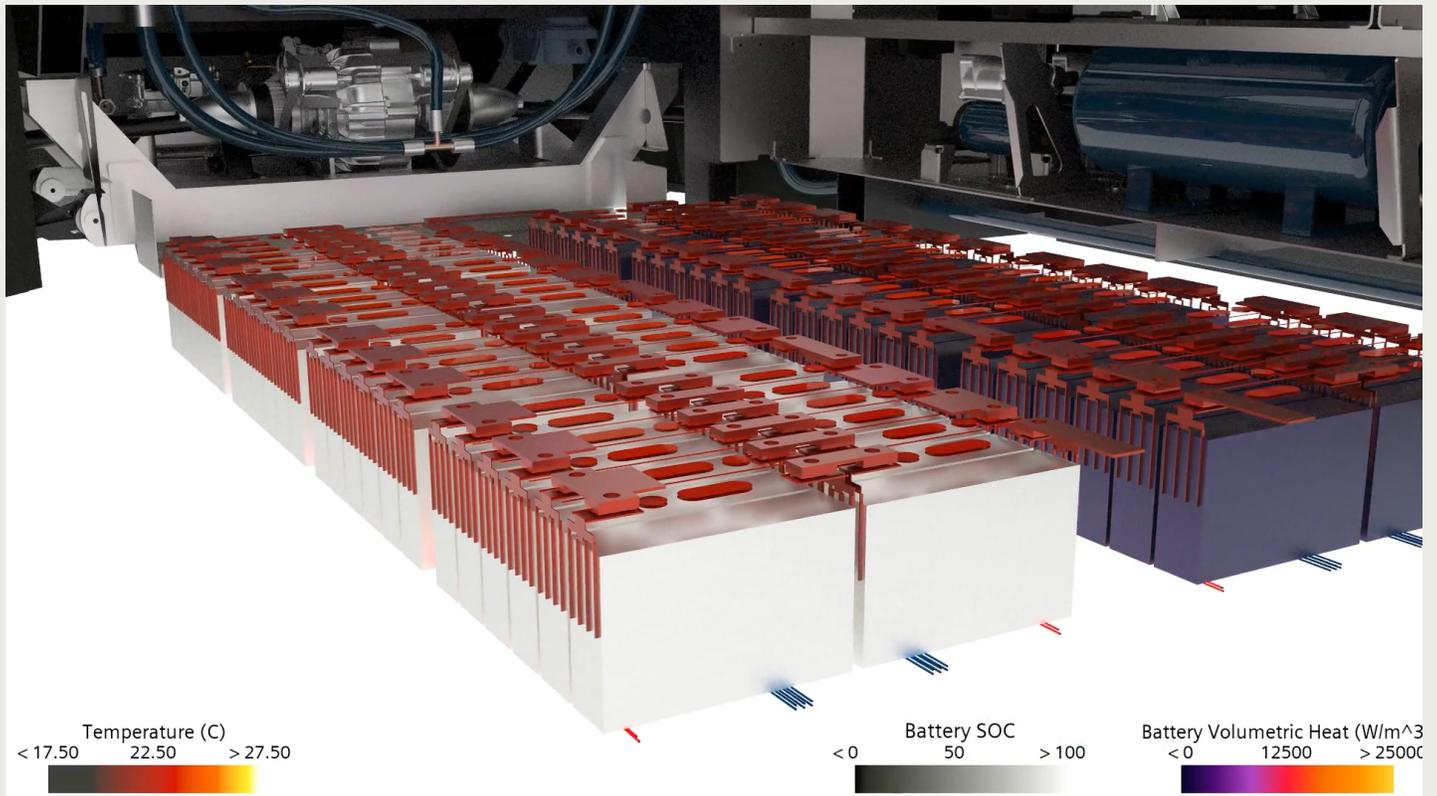
DIGITAL INDUSTRIES SOFTWARE

Simcenter Battery Design Studio

Using rapid cell simulation to engineer better lithium-ion batteries

Benefits
- Rapidly set up and run accurate cell performance simulations to engineer better lithium-ion batteries
- Predict and understand real-world behavior of Li-ion cells
- Explore many design variants early in development to make the best possible decisions
- Easily leverage cell level simulation results in 3D CFD and system simulations

Summary
Using Simcenter™ Battery Design Studio™ software supports you in digitally validating lithium-ion (Li-ion) cell design thanks to detailed geometrical cell specifications and performance simulation.

You can quickly and easily develop models using extensive battery cell component libraries and a comprehensive material database. Simcenter Battery Design Studio, which is part of the Siemens Xcelerator business platform of software, hardware and services, offers several levels of performance models to simulate the cell's behavior in a computationally effective way.

The additional understanding gained by using Simcenter Battery Design Studio leads to improved design decisions and understanding the impact of those decisions on your system performance. With its direct link to computational fluid dynamics (CFD) and system simulation, you can easily leverage cell level characteristics in system and battery pack simulations. Using Simcenter Battery Design Studio supports you in making the best choices for your battery.

Battery cell design modeling is critical to predict and understand the behavior of battery cells in real world conditions and find battery cell designs that fit

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your application requirements. Battery cell simulations enable you to:

- Assess the trade-off between energy, power, cost, safety and lifetime
- Understand and tailor capacity and current-voltage characteristics of cells
- Study underlying physics of rate limiting capability of a cell
- Perform virtual assembly and testing of cells

Thanks to rapid cell simulations you can explore many design variants early in development. Such design exploration studies allow you to:

- Maximize overall performance
- Optimize material usage in cells
- Reduce cell mass and increase capacity
- Minimize impedance evolution to improve lifetime
- Expore innovative cell designs

Using Simcenter Battery Design Studio supports you in digitally validating Li-ion cell design thanks to detailed geometrical specifications and accurate yet computationally efficient cell performance simulations.

Capabilities

Quick and easy setup

With a dedicated cell design workflow and a user interface (UI) tailored to battery cell design engineering you can set up your cell simulations studies in minutes. The terminology and inputs are familiar to cell designers. Templates are available for a wide range of cell types and a comprehensive material database makes it easy to set up accurate cell models. Furthermore, the tool supports you by automatically setting up performance analysis.

A simulation tree that is simple to navigate assists with the setup of:

- Electrodes (active materials, binders, aids, etc.)
- Separators, collectors, tabs
- Physics models

Data analysis tools to understand complex codependent relationships and reproduce test bench results:

- Profile viewers
- Output viewers
- Bill-of-materials (BOM)
- Jelly roll viewer

Simcenter Battery Design Studio workflow
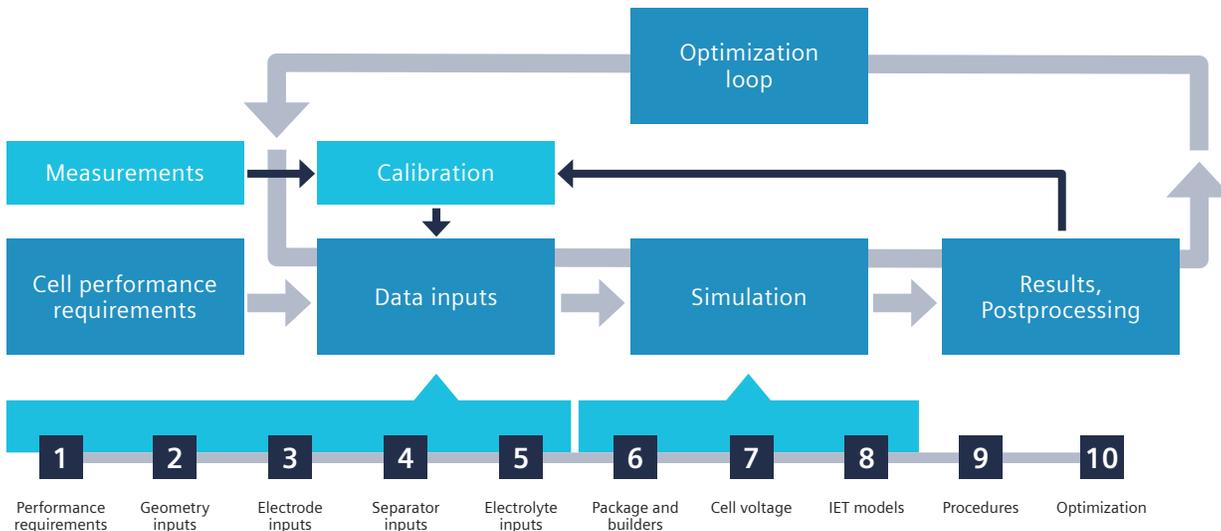
Wide range of cell types

Simcenter Battery Design Studio supports a wide range of Li-Ion cell types. You can define conventional Li-ion cells and investigate initial design of solid-state batteries using the following templates for cell types:

- Simple
  (used for coin cells or parallel plate cells)
- Stacked plate cells
- Spirally wound cells
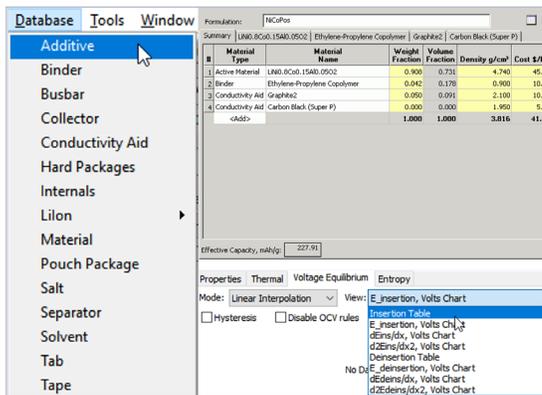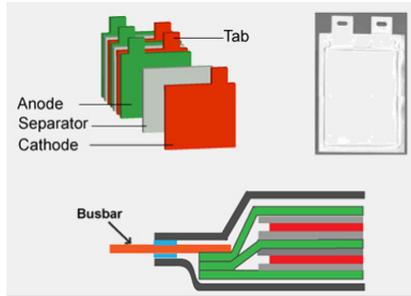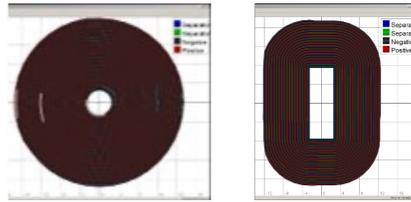
Built-in material databases

For a straightforward and consistent setup, Simcenter Battery Design Studio offers material properties for a range of active materials, binders, conductivity aids, additives, tabs, tape, collectors, separators, packages, etc.

- Leverage detailed information such as voltage equilibrium curves, entropy, diffusion coefficient inputs, insertion tables, deinsertion tables, etc.
- Customize and create new materials data with an easy-to-use property editor
- Check input data with direct access to material plots and charts

Fast and accurate simulations

Using Simcenter Battery Designs Studio offers a flexible approach combining methods to balance speed and accuracy:

- Instantaneous or near instantaneous results for various modeling options
- The ability to compute in parallel thanks to multiple threading capabilities that help in expediting simulations using physics-based models
- Coupling electrochemical cell performance model with thermal cell performance

Li-ion cell design modeling	Consumer electronics, EV	HEV/PHEV module/pack	Cell design
DISTNPibuted 3D model	NTG	RCR	DISTNPNP
RCR 3D model			
NTG 3D model			
	Simple, easy to create model, best for simple discharging, thermal analysis	Quick response for frequent charge/discharge like HEV/PHEV energy storage	Solves transport and kinetics equations to fully characterize a cell
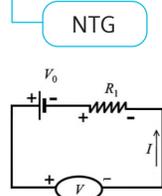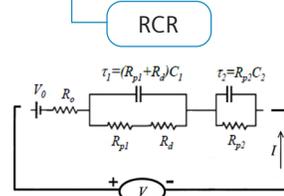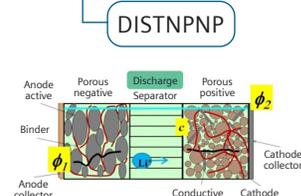
A choice of Institution of Engineering and Technology (IET) models allows for balance between fidelity, run time and accuracy:

- Simple model for discharge and thermal analysis
- Resistance/capacitance model to model frequent charge/discharge
- Detailed electrochemical and thermal model to capture transport kinetics and aging

Also, the discretization level of models can be selected to balance compute time and accuracy. Each of the IET models can be run in either 3D or 1D modes with single or multiple Ecell grids for fast and accurate models.

- 3D model effects are especially important for larger format cells where temperature varies more significantly throughout the cell
- 1D models are significantly faster to run and are in many cases sufficient

Design exploration

Thanks to an automated workflow linking geometry and analysis tools, Simcenter Battery Design Studio can be used to facilitate quick design changes. Design parameter sweeps can be easily performed using built-in capabilities. In addition, Simcenter Battery Design Studio can also be easily driven by HEEDS™ software, which is also part of Siemens Xcelerator, when performing a multi objective optimization study thanks to a dedicated portal. Such an intelligent design space exploration algorithm enables you to gain better insight and find better cell designs faster:

- Maximize overall performance
- Optimize material usage in the cell
- Minimize impedances for improving lifetime capabilities
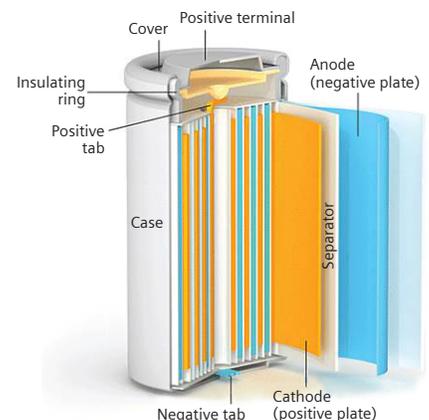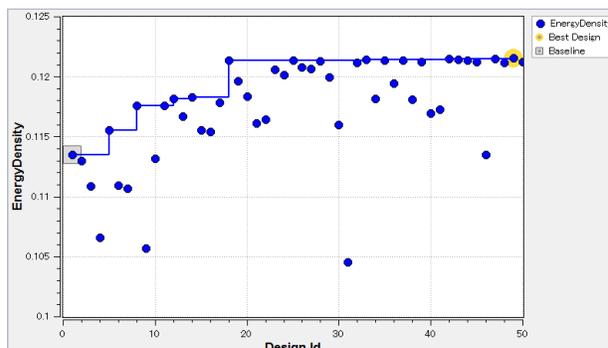
Furthermore, Simcenter Battery Design Studio includes data fitting tools to regress model parameters against experimental test data to configure the equivalent circuit model.

Collaboration across disciplines and supply chain

The battery design process typically involves multiple stakeholders across the development process and the supply chain. Therefore, using Simcenter Battery Design Studio makes it easy for you to incorporate cell level characteristics predictions into 3D CFD simulation for package design and 1D system simulations for complete battery system and thermal management studies. Using Simcenter Battery Design Studio while sharing confidential performance data
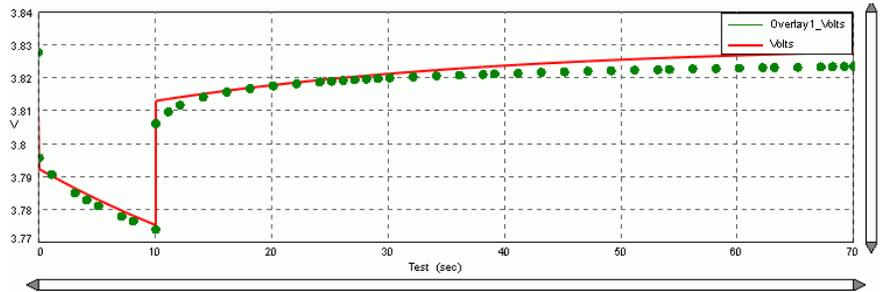
to enable collaboration allows the user to protect intellectual property (IP) thanks to encrypted cell files. This encryption protects the design against accidental or intentional alteration, and limits access to commercially sensitive designs.

Encrypted file

Simcenter Battery Design Studio
- Button cell
- Formulations
- Test results

Material developer (cathode, anode, separator, electrolyte, etc.)

Encrypted file

Cell designer/ OEMs cell buyer
- Model selection
- Electrodes including tabbing
- Separator
- Cylindrical, prismatic, pouch

Simcenter STAR-CCM+
- Performance estimation
- Model selection
- Series/parallel cells
- Cooling

Module/pack developer

Simcenter FLOEFD

Leverage fully CAD-embedded CFD software for designers to shorten development by evaluating fluid flow and heat transfer earlier using NX™ software, Solid Edge® software, CATIA and Creo.

Simcenter FLOEFD™ software is a fully CAD-embedded CFD software with multiphysics capabilities. With Simcenter FLOEFD, designers and analysts can shorten development times by up to 65-75 percent compared to typical CFD processes by frontloading fluid flow simulation and thermal analysis earlier using native geometry in the CAD interface.

Frontload CFD simulation earlier to shorten development

Using Simcenter FLOEFD enables design engineers to perform simulation earlier in the design process where it is more cost effective to identify and fix problems or explore improvements. Integrated in CAD, Simcenter FLOEFD can improve productivity by a factor of two-to forty-times faster.

Leverage an intuitive CFD interface

Engineers who are not full-time analysts can overcome traditional barriers to CFD and eliminate typical process time overheads of designers waiting on results from other resources. Using a CAD-embedded interface, guided simulation set up, intelligent automation technologies and straight forward viewing of results allows design engineers to explore design performance earlier and make informed decisions.

Perform CFD directly on native CAD geometry and eliminate CFD overheads

Eliminate delays in geometry translation between tools and minimize preparation of CAD geometry for CFD analysis. Simcenter FLOEFD technology uses native CAD geometry directly for meshing and solution through to visualized results so you can evaluate design performance more efficiently. Simcenter FLOEFD has key strengths in robust automated meshing and unique SmartCells™
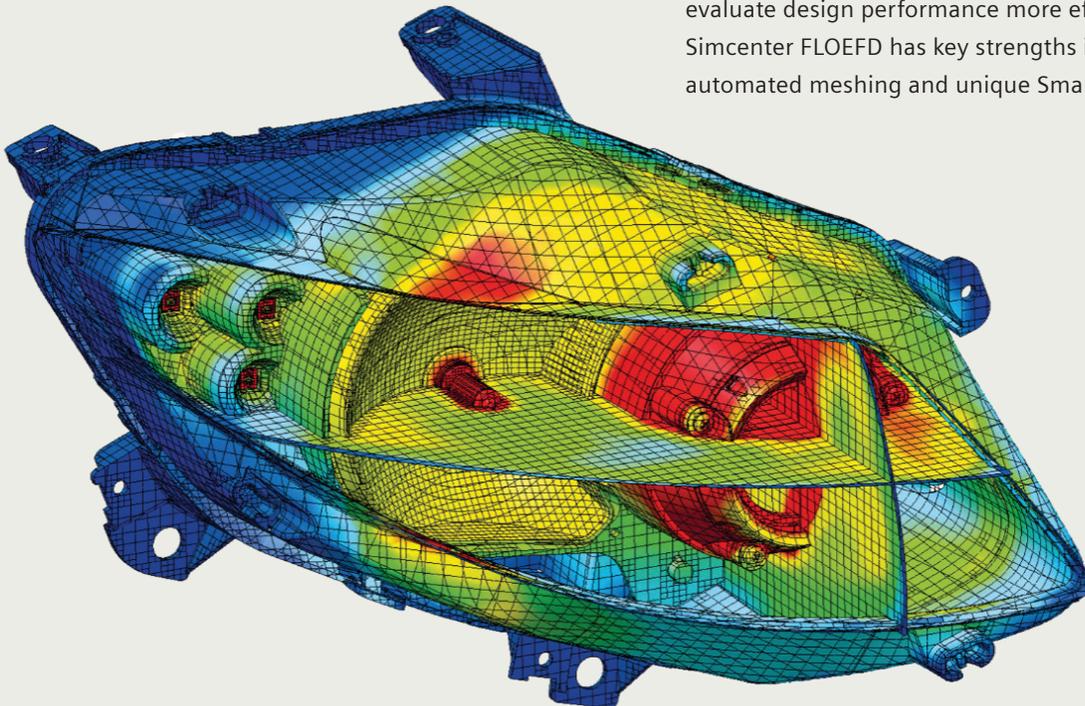
technology that enables CFD analysis on CAD geometry of any quality. It can handle small narrow gaps in assemblies and surface inconsistencies easily that often cause preprocessing delays for traditional CFD tools. Simcenter FLOEFD also has intelligent automation for preprocessing such as automatic sealing of CAD geometry and leak identification. Using Simcenter FLOEFD enables you to eliminate or minimize the need to simplify CAD for CFD and significantly speed up overall CFD simulation process time so you focus on the simulation results to improve performance.

Simulation driven design – explore, compare and optimize

Leverage parametric studies and design exploration functionality to evaluate more design options within the time available and evaluate what-if scenarios to ensure product performance and reliability in different conditions. You can easily compare designs using side-by-side CFD results visualizations, plots and tabular results beside generating reports. Once confident with your optimized design, you can directly communicate a CAD model to other engineering functions immediately.

Source: Prof. Dr. Martin Eigner, VPE, TU Kaiserlautern
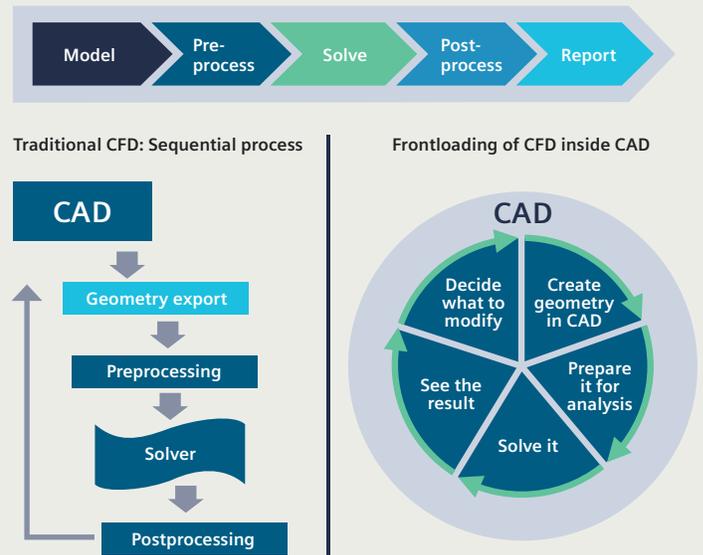
The CAE simulation process (Sabeur, 2015).
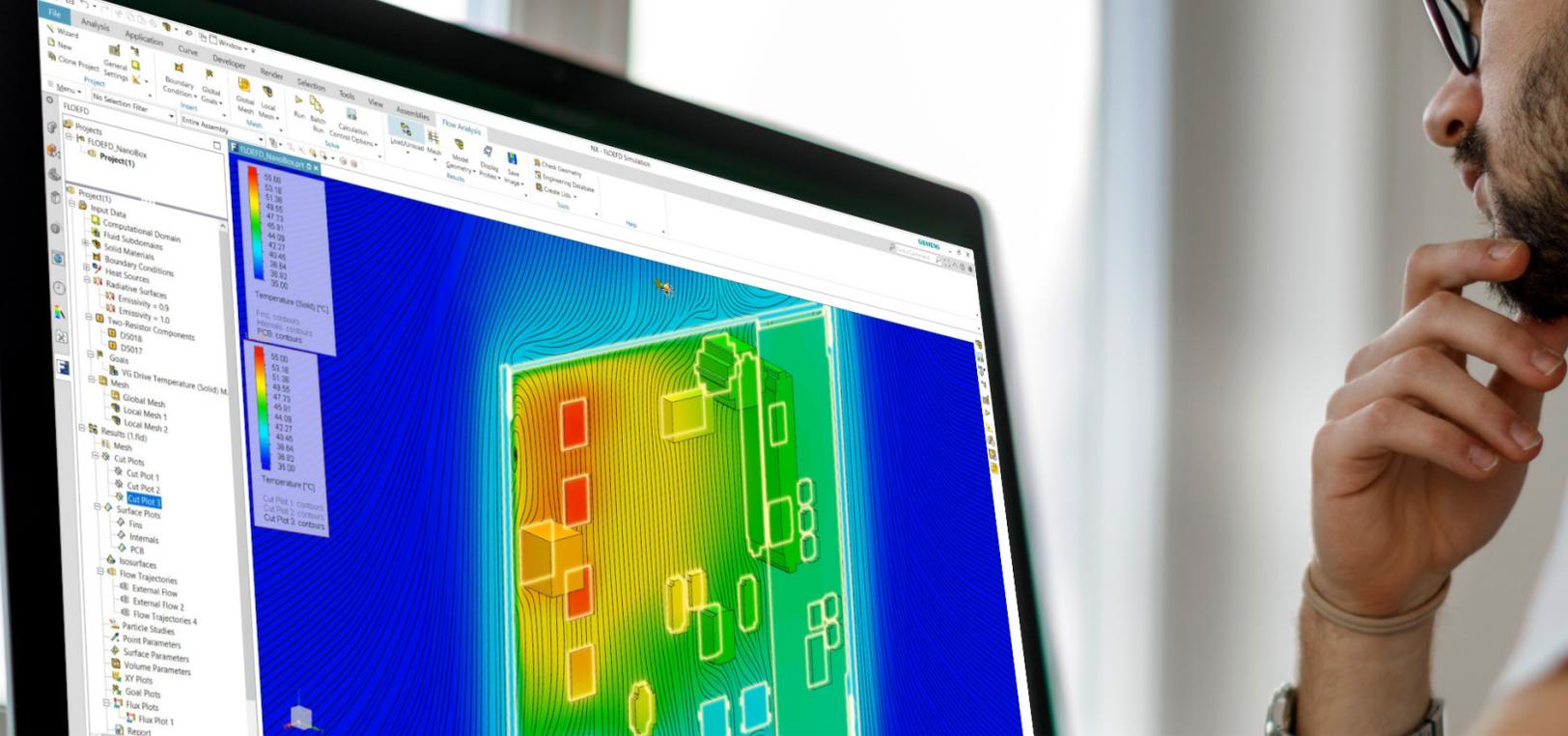
Solution benefits
- Front-load CFD simulation earlier to shorten development
- Leverage an intuitive CFD interface for designers
- Perform CFD directly on native CAD geometry and eliminate CFD overheads
- Simulation driven design – explore, compare and optimize

DIGITAL INDUSTRIES SOFTWARE

Simcenter FLOEFD Electronics Cooling Center Module

Combining the best electronics related capabilities of Simcenter FLOEFD and Simcenter Flotherm for accurate thermal simulation of electronics inside CAD

Benefits

- Frontload powerful thermal design simulation and design space exploration in CAD to prevent re-spins and eliminate costly physical prototyping

- Access best-in-class functionality both Simcenter FLOEFD and select technology from Simcenter Flotherm to make thermal analysis accurate, fast and easier to integrate with electronic and mechanical design workflows

- Validate electronics cooling system performance to ensure reliability and long product life

Summary

Part of the Siemens Xcelerator business platform, Simcenter™ FLOEFD™ is a simulation software tool for frontloading computational fluid dynamics (CFD) earlier in product development that is fully embedded in computer-aided design (CAD) software. You can simulate fluid flow and heat transfer directly using 3D CAD geometry without the need for data translations to a separate analysis environment. Depending on your needs, there are several electronics cooling specific modules which may suit your needs.
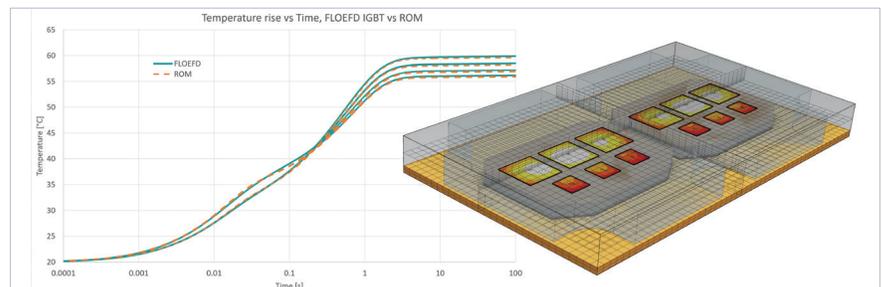
3D thermal simulation of a power electronics component compared with a BCI-ROM simulation.

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The Simcenter FLOEFD Electronics Cooling Center module combines several key technologies from Simcenter Flotherm™ software with Simcenter FLOEFD inside your preferred CAD environment including NX™ software, Solid Edge® software, Creo and CATIA V5. It features powerful functionalities to help you quickly and accurately predict thermal behavior of electronic devices, validate electronics cooling system performance to achieve long product life and easily explore methods for cooling in complex electronic assemblies.
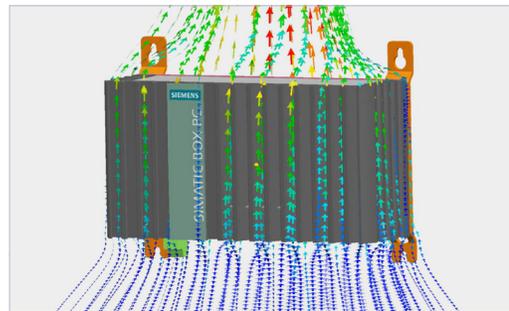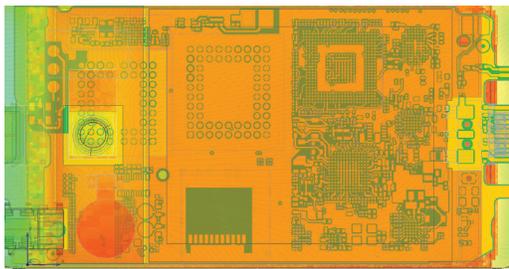
The Simcenter FLOEFD Electronics Cooling Center is a compilation of several modules and functionalities namely:

**Simcenter FLOEFD
Electronics Cooling Module**
This module offers:

• Joule heating for calculating steady-state direct electric current in electro-conductive solids. The calculations of electric potential and current can be performed only in conductive solids; for example, metals and metal-

containing composite materials. Electrical resistivity of the material may be isotropic, anisotropic or temperature dependent.

• Compact models for facilitating simulation of electronics equipment. This module offers two-resistor compact model that is test-based on an approved Joint Electron Device Engineering Council (JEDEC) standard; built-in library of two-resistor models of standard JEDEC package outlines; Heat pipe compact models.

• PCB generator for obtaining the bi-axial thermal conductivity values. Thermal conductivities can be automatically derived from the PCB structure and the properties of the specified conductor and dielectric materials can be accessed.

• Robust materials library: In addition to the basic materials, the following databases are also included: 1,000+ fans from different manufacturers; solids materials such as alloys, ceramics, metals, polymers, laminates, glasses and minerals and semiconductors; integrated circuit (IC) packages; single- and multi-stage thermoelectric coolers (TEC); interface materials (contact thermal resistance); and two-resistor components.

For more detailed information please refer to the Simcenter FLOEFD Electronics Cooling Module flyer.
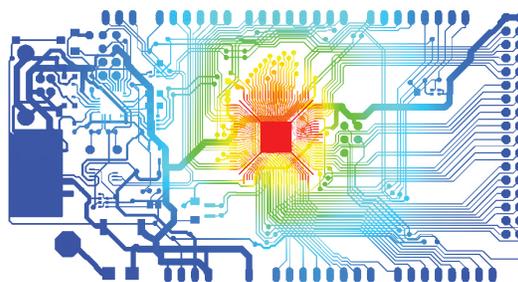
Simulation of an electronics device.

Simcenter FLOEFD EDA Bridge Module

The powerful Simcenter FLOEFD EDA Bridge lets users import detailed PCBs with material and integrated circuit (IC) thermal properties into Simcenter FLOEFD for thermal analysis either on their own, or as part of a larger system-level assembly.
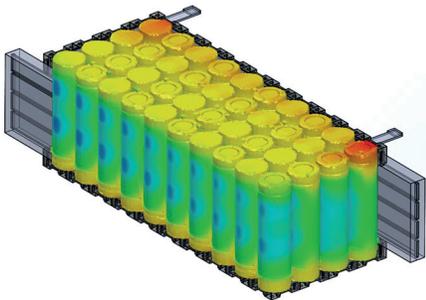
From EDA data to 3D CAD imported PCB.

The imported PCBs can be represented as fully detailed 3D geometry with copper traces, a PCB component with bi-axial thermal conductivity values or as a Smart PCB. Using the Smart PCB, the copper and dielectric within a fully routed board are modeled using a network assembly which is very computationally efficient for faster solution time. In addition, it allows the import of PDML files.

The following PCB import file formats are supported: IDF, CC and CCE (native file format for Siemens Digital Industries Software's Xpedition™ software and PADS™ software), ODB++ (neutral file format for PCB manufacturing), ProStep (*.idx, *.idz, *.xml) as well as IPC2581B (neutral file format of the IPC Digital Product Model Exchange consortium).

For additional information, please refer to the Simcenter FLOEFD EDA Bridge Module flyer.

Simcenter FLOEFD T3STER Automatic Calibration Module

This module helps you achieve highest fidelity modeling of IC packages in your simulation through automatic calibration using thermal test data.

Semiconductor package characteristics data used in simulation can differ from reality due to the lack of knowledge about the internal structure. Simcenter Micred™ T3STER™ hardware measures transient thermal response quickly and accurately to an applied power step. Processing of this junction temperature data allows the generation of a structure function, representing the heat flow path from device junction to ambient as a profile of thermal resistance versus thermal capacitance.

Using this module, users import test data and then calibrate their thermal model to match the structure function closely. The calibration mode of the parametric study searches for package dimensions and material properties to fit the measurement so your model represents the thermal behavior of the package structure and material properties to provide highest fidelity.

For additional information, please refer to the Simcenter FLOEFD T3STER Automatic Calibration Module flyer.
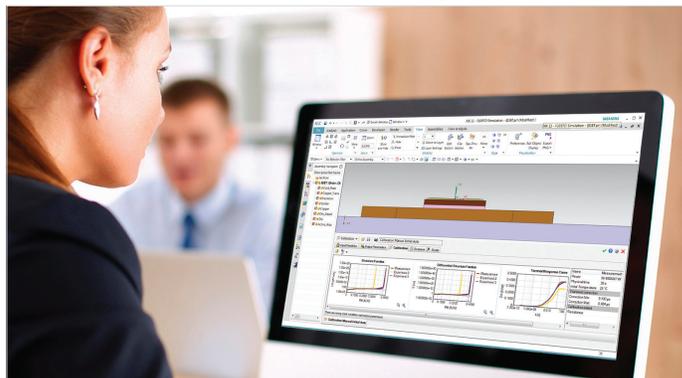
Automatically calibrated package thermal model.

Simcenter FLOEFD BCI-ROM and Package Creator Module

This module allows users to generate a Boundary Condition Independent Reduced Order Thermal Model (BCI-ROM) that offers fast, accurate modeling in any thermal environment. The reduced order model is extracted from a conduction only analysis and is particularly useful for transient analysis. The users specifies the range of heat transfer coefficients for extraction. A BCI-ROM preserves the close accuracy in space and time to the 3D thermal model while solving orders of magnitude faster. BCI-ROM exports are in three primary formats:

- **Matrices format** (for standalone solution)
- **VHDL-AMS format** (for circuit simulation tools electrothermal analysis, for example, PartQuest Explore or Xpedition AMS)
- **FMU forma**t for 1D system simulation tools, for example, Simcenter Amesim™ software or Simcenter Flomaster™ software

Additionally, Simcenter FLOEFD can export a thermal netlist in a SPICE format valid for a set range of boundary conditions.

Thermal simulation of a power electronics package.

The Package Creator application allows you to create clean 3D CAD based detailed thermal model geometry quickly in minutes from a library of the most common IC package families. To create a package, you can specify various components such as the encapsulant, die, die-attach, leadframe, die-attach pad and bond wires for a more accurate thermal model.

For additional information, please refer to the Simcenter FLOEFD BCI-ROM and Package Creator Module flyer.

Electrical element

This thermo-electric compact model allows you to add a component into a direct current (DC) electro-thermal calculation by the given component's electrical resistance. The corresponding Joule heat is calculated and applied to the body as a heat source. There are two types of electrical elements, resistors and wires: the resistor element uses the total electrical resistance provided and the wire element automatically calculates the resistance based on the wire's material properties, length and cross section area. Optionally you may also specify the thermal resistance of the wire's insulator.

Simulations, using accurate thermo-electrical compact models.
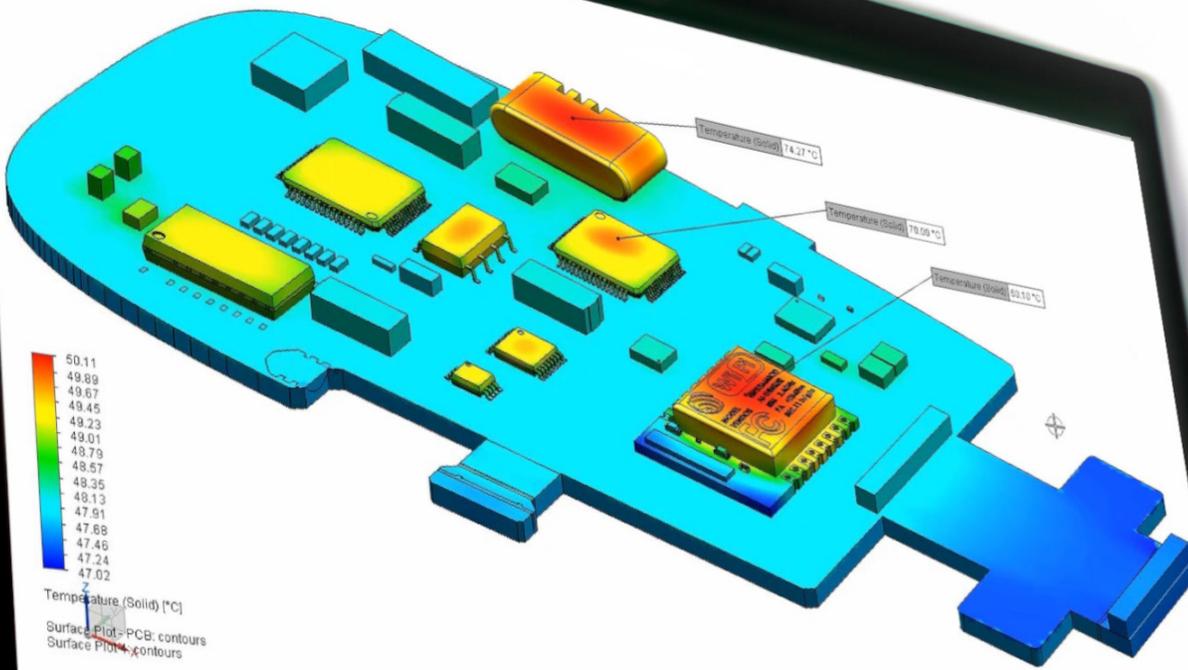
DIGITAL INDUSTRIES SOFTWARE

Simcenter FLOEFD Electronics Cooling module

Achieving highly accurate thermal simulation of electronic devices

Benefits

- Accurately predict thermal behavior of electronic devices with compact models

- Validate electronics cooling system performance to achieve long product life

- Efficiently explore methods for cooling electronic devices

- Enable joule heating analysis in complex electronic assemblies

Summary

Siemens Digital Industries Software is a leader in electronics thermal analysis software and thermal characterization test hardware. Simcenter™ FLOEFD™ software is a front-loading computational fluid dynamics (CFD) solution that is designed to work with computer-aided design (CAD) software, so you can simulate airflow and heat transfer using 3D CAD models without the need for data translations or copies. Based on Navier-Stokes equations, it facilitates predicting both laminar and turbulent flows. Simcenter FLOEFD employs one system of equations to describe both laminar and turbulent flows. Moreover, transitioning from a laminar to turbulent state and/or vice versa is handled automatically.

The Simcenter FLOEFD Electronics Cooling module enables you to accurately predict thermal behavior of electronic devices with compact models, validate electronics cooling system performance to achieve long product life, efficiently explore methods for cooling electronic devices and enable joule heating analysis in complex electronic assemblies.

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The Simcenter FLOEFD Electronics Cooling module provides additional capabilities for the analysis of electronic devices. The physical capabilities in Simcenter FLOEFD Electronics Cooling include:
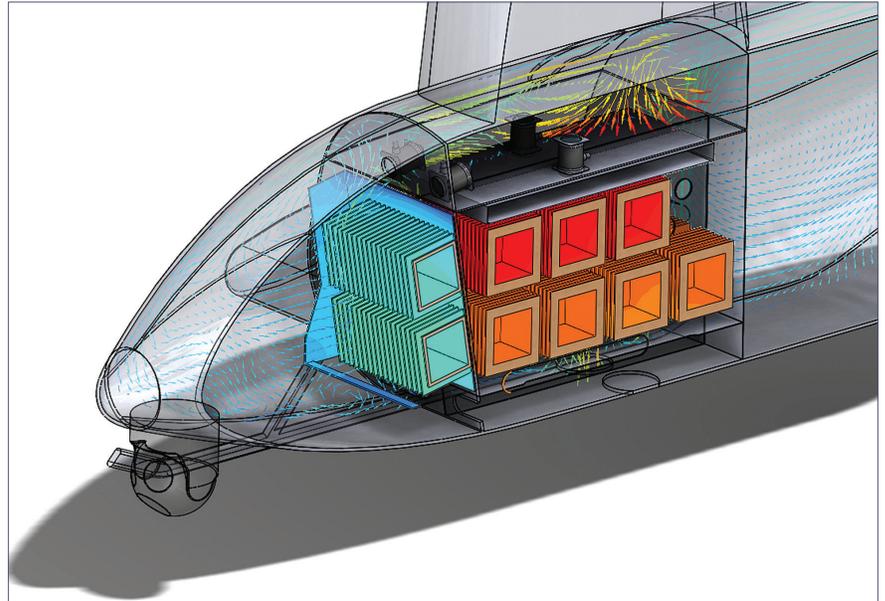
Joule heating

The Simcenter FLOEFD Electronics Cooling module can be used to calculate steady-state direct electric current in electro-conductive solids:

- The Joule heating effect is automatically calculated and included in heat transfer calculations

- The calculations of electric potential and current are performed only in conductive solids; for example, metals and metal-containing composite materials

- The electrical resistivity of the material may be isotropic, anisotropic or temperature dependent
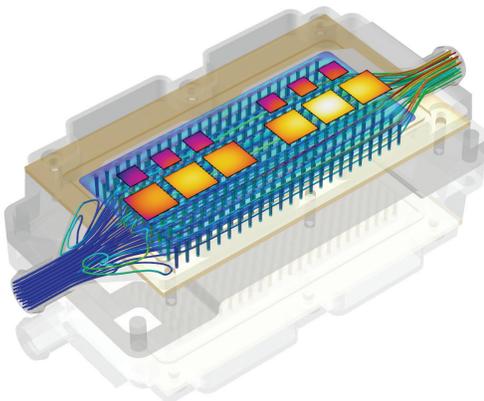
Compact models

To facilitate simulation of electronics equipment, this module offers the following compact models:

- Two-resistor compact model that is test-based on an approved Joint Electron Device Engineering Council (JEDEC) standard

- Built-in library of two-resistor models of standard JEDEC package outlines

- Heat pipe compact model

- Printed circuit board (PCB) model, including PCB generator (more details hereafter)
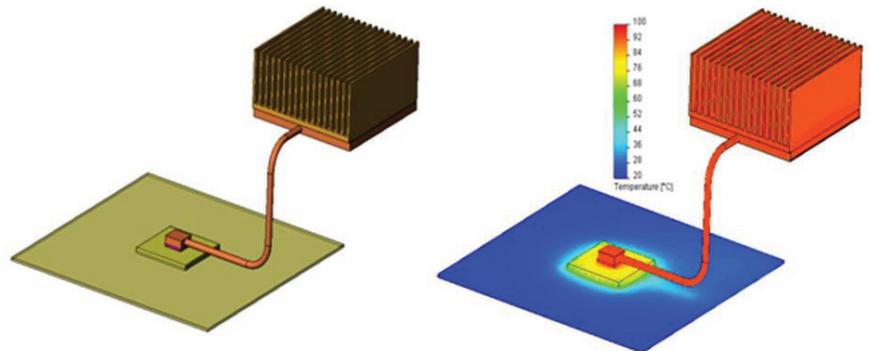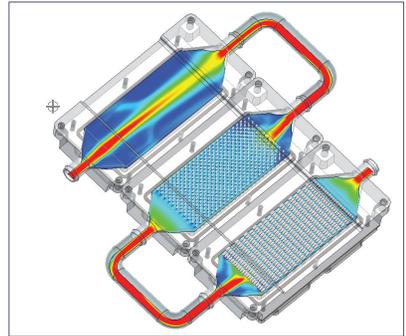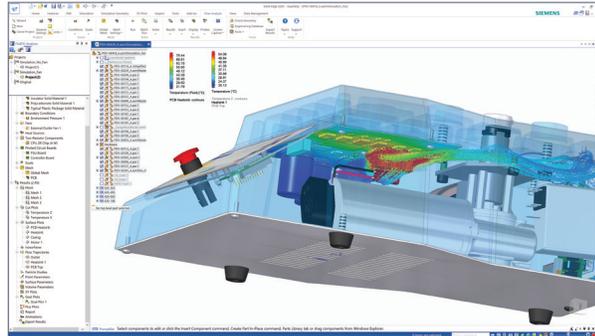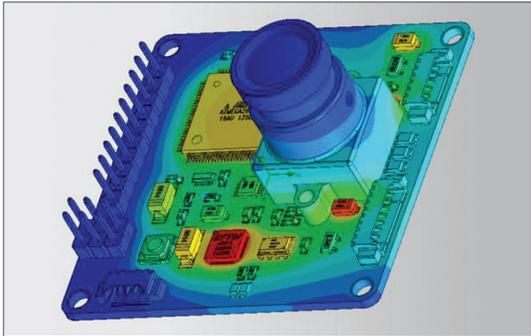
PCB generator

To obtain the bi-axial thermal conductivity values, the following functionality is also available:

- Normal (through plane) and in-plane thermal conductivities automatically derived from the PCB structure and the properties of the specified conductor and dielectric materials

- The board can also be arbitrarily oriented with respect to the global coordinate system; for example, angled PCBs can be modeled
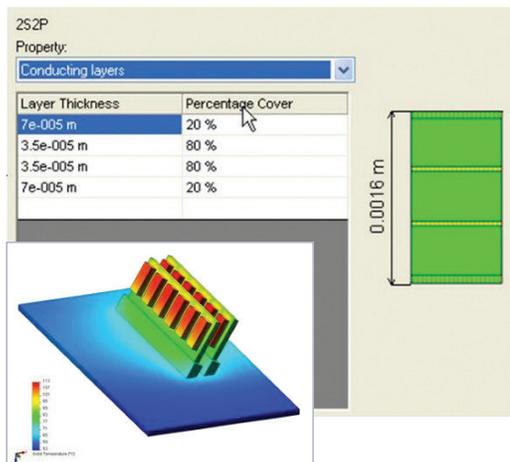

Materials library

In addition to the basic materials, the following are also included in this module:

- More than 1,000 fans from different manufacturers

- Database of solids materials such as alloys, ceramics, metals, polymers, laminates, glasses and minerals and semiconductors

- Database of integrated circuit (IC) packages

- Database of single- and multi-stage thermo-electric coolers (TEC)

- Database of interface materials (contact thermal resistance)

- Database of two-resistor components

Simcenter FLOEFD EDA Bridge is an optional add-on module

For more advanced electronics cooling simulation and interfaces to electronic design automation (EDA) tools, Siemens Digital Industries Software recommends the FLOEFD EDA Bridge module.
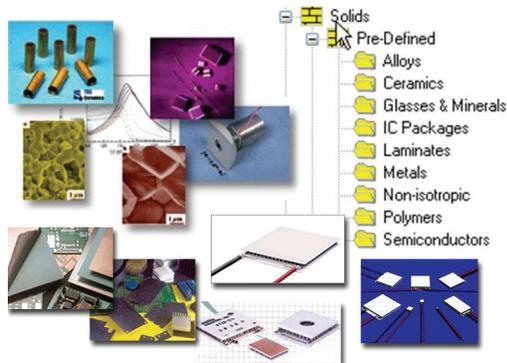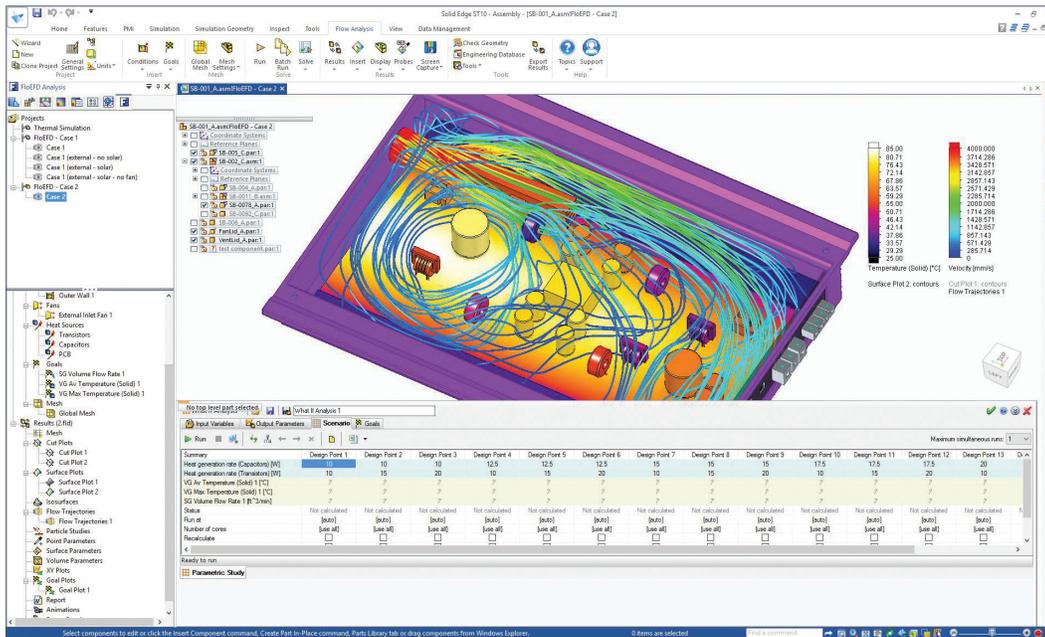
What-if testing made easy

One of the most powerful features of Simcenter FLOEFD is the ease with which you can conduct what-if analyses.

Simcenter FLOEFD makes it simple to modify your models and analyze design variations. First, create your base model and analyze it. Then create multiple variations of your design by modifying the solid model without having to reapply material properties, etc. Using its parametric study and design comparison functionality, you can easily compare the results among the various options to choose your best possible design.

When you are satisfied with your design, publish your report with the touch of a button. You can even publish a fully interactive 3D dynamic plot and share it with colleagues or customers.
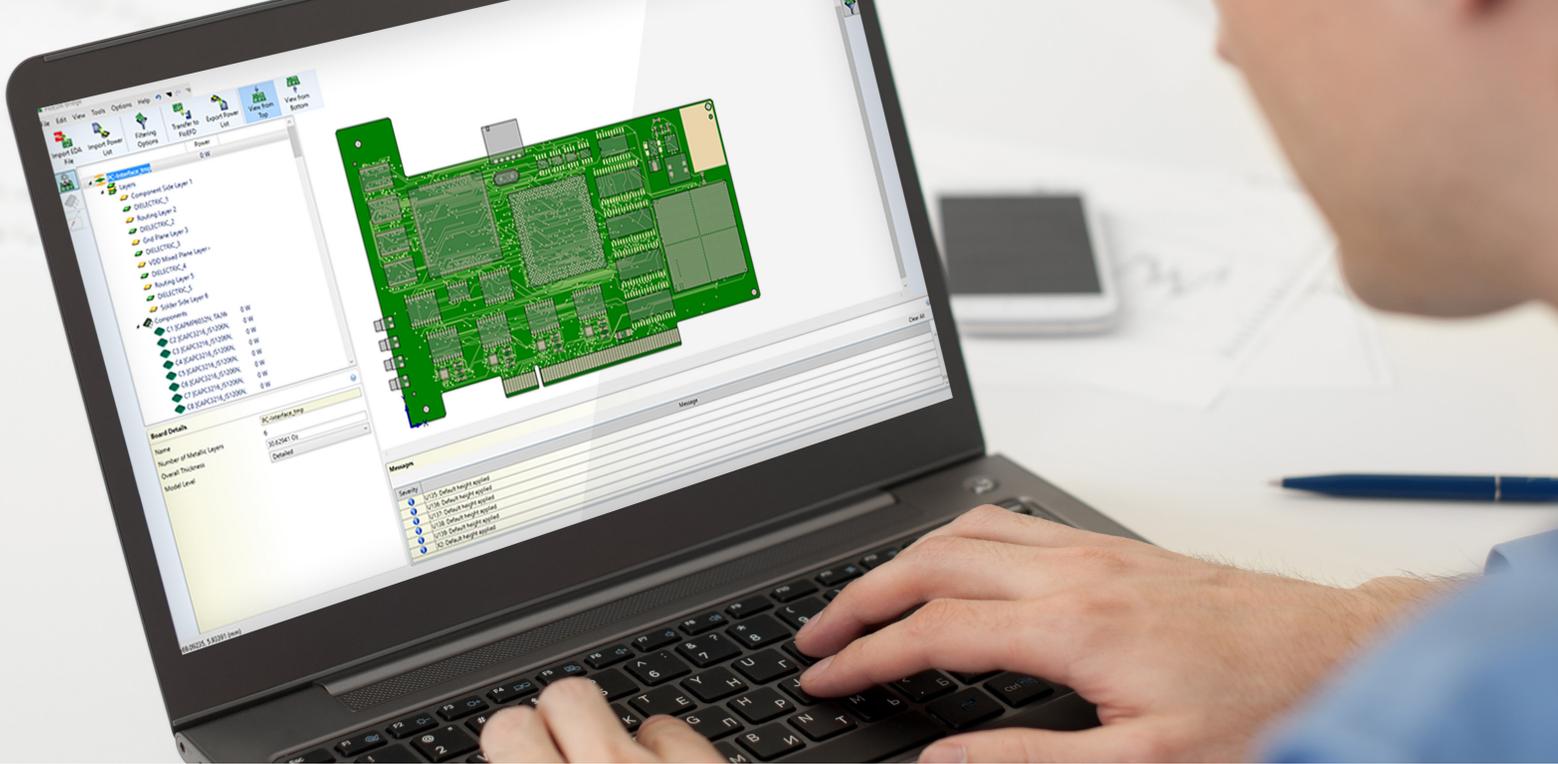
Simcenter FLOEFD EDA Bridge module

Using imported detailed PCB designs and IC thermal properties to streamline thermal analysis

Benefits

- Save time and effort by using imported detailed PCB designs and IC thermal properties for analysis

- Rapidly import detailed PCB data into Simcenter FLOEFD

- Improve analysis accuracy with more detailed thermal modeling of electronics

Summary

Simcenter™ FLOEFD™ software, EDA Bridge module provides capabilities for detailed import of printed circuit boards (PCBs) into your mechanical computer-aided design (MCAD) tool of choice in preparation for thermal analysis. Historically, the best way to access PCB data was to use Intermediate Data Format (IDF) file pairs, which have significant shortcomings, especially regarding the copper geometry in the PCB.

The Simcenter FLOEFD EDA Bridge enables detailed PCB import with material and integrated circuit (IC) thermal properties into Simcenter FLOEFD for thermal analysis either on its own, or as part of a larger system-level assembly.

PCB import file formats

The Simcenter FLOEFD EDA Bridge can use four file formats for import:
- IDF
- CC and CCE (native file format for Siemens Digital Industries Software's Xpedition™ software and PADS™ software)

- ODB++ (neutral file format for PCB manufacturing)
- IPC2581B (neutral file format of the IPC Digital Product Model Exchange consortium)

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The benefit of using either CCE, ODB++ or IPC2581B is the PCB stack up and copper geometry can be read and used to create 3D geometry. This is particularly useful when thermal considerations, such as thermal vertical connect access (vias) or copper pours, have been designed into the board.

PCB modeling levels

A PCB can be modeled in one of four ways using Simcenter FLOEFD: compact, layered, explicit or using the novel smart PCB. The most suitable approach depends on the granularity required from the thermal simulation judged against time available for analysis in a project and the constraints of available EDA data at the design stage.

Further information on each approach:

Compact: An orthotropic material property is created to account for the in-plane and through-plane thermal conductivities based on the copper content within the board.

Layered (detailed): Each layer has its own material property based on the layer copper coverage, this includes dielectric layers with vias.

PCB material thermal conductivity modeling options for compact and layered approaches:

Analytical: A well-known legacy approach where effective properties are determined based on volume averaging of the copper and dielectric of either the individual board layers or entire board.

Empirical: A unique, patented approach where effective properties are based on a percent coverage correlation to explicit copper representation. Multiple validation examples have shown the results based on empirical effective thermal conductivities more accurately predict component temperatures than the analytical method.

Explicit: Explicit copper modeling can be performed at more mature design stages when a fully routed board information is available. You can import CCE, ODB++ or IPC-2581B files that contain the board netlist and copper layout and then all appropriate 3D geometry is created.

You can alternatively take the subset approach to model individual nets for Joule Heating analysis using the e*xplicit net* approach: Specific nets can be selected and modelled as explicit. The software will then create 3D geometry to resemble that entire net, including vias, in Simcenter FLOEFD.

Smart PCB: A novel approach where the copper and dielectric within a routed board are represented using a network assembly. For a fully routed board, this is a very computationally efficient method for faster solution time. The fidelity of the representation can be adjusted by switching between fine, which ensures two network assemblies across the width of the smallest trace, or averaging, which allows for full control to either coarsen or refine the network assembly.

**Thermal territories –
Localized PCB modeling fidelity**

Defining enhanced localized modeling fidelity supports faster, more computationally efficient PCB thermal analysis. It eliminates the requirement to model the entire PCB explicitly, without sacrificing accuracy where it is most needed. In order to accurately account for copper trace and layer complexity influences where it is most critical, users can select an area under a critical component (a standard thermal territory), or set a defined rectangular area arbitrarily anywhere on the PCB to encompass the board properties under a group of components (standalone thermal territory). Multiple thermal territories can be defined on a single board and set as compact, layered (detailed) or explicit type in conjunction with how the overall board thermal modeling level has been set.
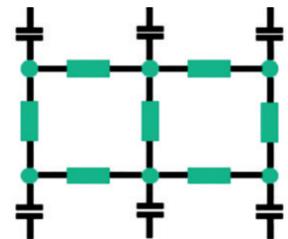
Compact
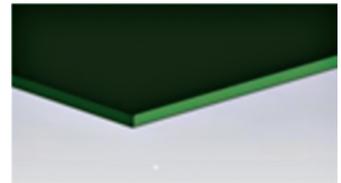
Layered (detailed)
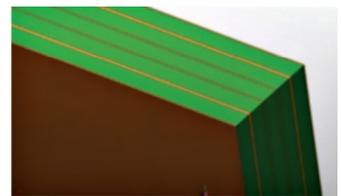
Explicit

Smart PCB

Network assembly

IC modeling

Components or IC packages can be thermally represented in several ways for electronics cooling simulation.

Within EDA Bridge you can set during import the following models. If component heights are not set in the electronic design automation (EDA) tool, then a default can be specified in EDA Bridge:

1. **Simple:** Use block representations of the components. The size is based on the assembly or placement outline with the material properties defined.

2. **Two-resistor:** Use Joint Electron Device Engineering Council (JEDEC) θJB and θJC thermal resistances.

Once a PCB is transferred to Simcenter FLOEFD from EDA Bridge, users can then manually replace these models with the following types as suitable:

3. **DELPHI multi-resistor:** JEDEC guideline compliant advanced thermal resistance network with additional network nodes imported as a network assembly.

4. **Detailed** models represent the full 3D materials and geometry of a component.

Note: Clean 3D CAD geometry based detailed models can be generated using Simcenter FLOEFD Package Creator application in minutes. Please see details in the "BCI-ROM and Package Creator Module" fact sheet.

PDML import

The PDML was originally a Simcenter Flotherm™ software format that is often used by vendors to supply users with IC package simulation model. This IC package definition in *.pdml format can be imported into Simcenter FLOEFD and contains information about the geometry, power load, material properties or the thermal compact model definition and surface radiative properties.

Electronic component filtering

ICs, resistors and other components can be filtered based on one or more criteria. This is designed to enable users to remove thermally insignificant components from the analysis to speed up computational time. Mounting holes can also be filtered.

Users can filter parts based on: footprint dimension, height, power, power density or reference designator.
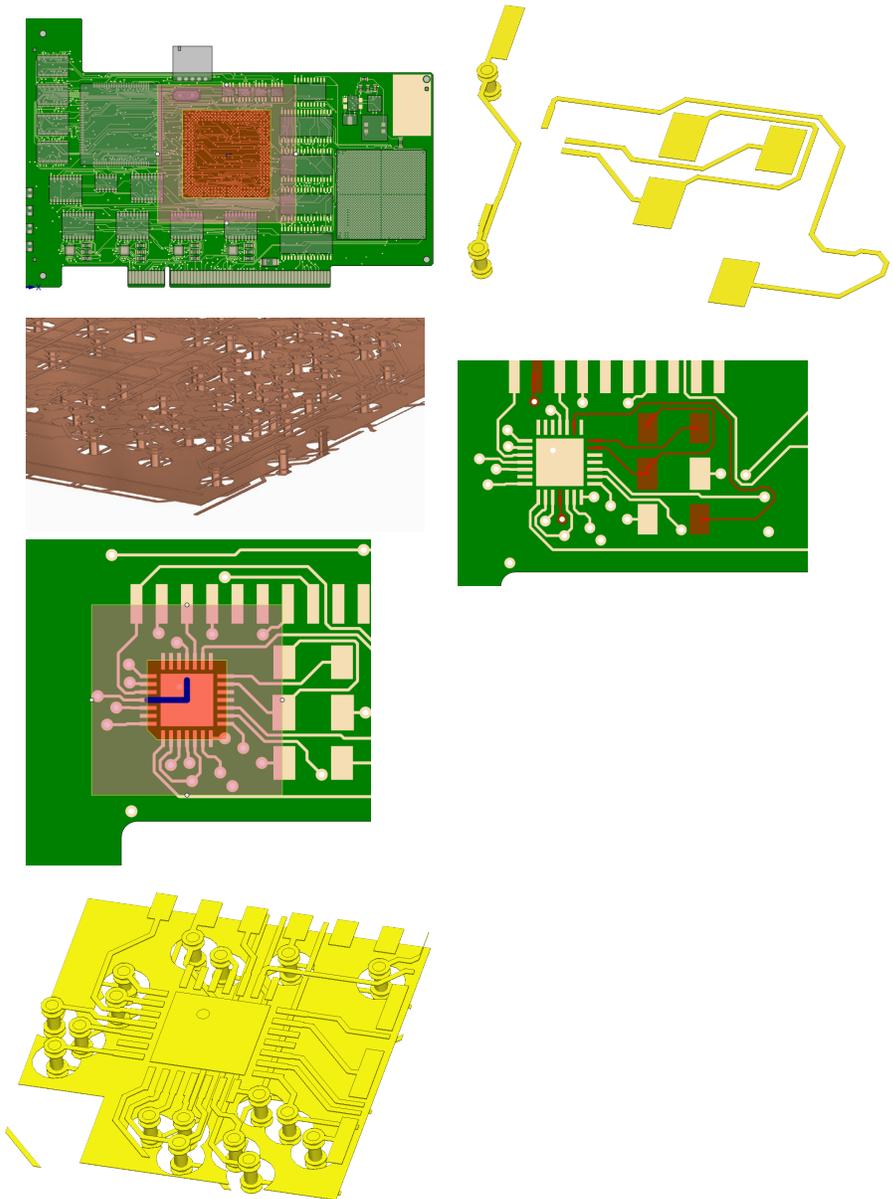
Import power list

A comma separated values (CSV) file containing the reference designator and a number can be used to apply multiple boundary conditions in one operation rather than on a part-by-part basis. This functionality is useful when many components are present. A CSV file can be exported for later use or editing if needed.

Possible imported boundary conditions range from IC modeling type and properties to their dissipated power.

PCB electrothermal co-simulation

Using the Smart PCB generated in EDA Bridge and transferred to Simcenter Flotherm to model a board as a network assembley, users can set up a co-simulation with HyperLynx™ PI DC drop analysis software. This co-simulation more accurately represents board copper trace power dissipation by modeling electrical resistance changes versus temperature. It is set up in the PCB properties sheet and a user selects appropriate nets to model.

At each iteration in the co-simulation, temperature results are passed into a DC drop analysis to better model copper electrical resistance changes with temperature, and then an updated joule heating power map from the PCB electrical net is fed into system level thermal analysis for accurate temperature prediction and so on. It is also possible to control the frequency at which thermal information is passed between the two tools by setting the periodicity of co-simulation. Overall this electro-thermal modeling solution allows engineers to better predict temperature influences more accurately and then to identify areas of excessive voltage drop and high current density that can cause malfunctions.

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Simcenter FLOEFD T3STER Automatic Calibration module

Increase accuracy of electronics cooling studies

Benefits

- Achieve high accuracy prediction of junction temperature for package thermal models (>99.5% accuracy is possible in certain cases)

- Overcome prohibitive time constraints associated with traditional manual calibration

- Explore package dimensions and material property changes needed for measurement based calibration easily

- Leverage calibrated highest accuracy transient thermal models in CFD studies to better evaluate design thermal reliability and validate cost reduction decisions

Summary

The automatic calibration module for Simcenter FLOEFD, CAD embedded CFD software helps increase accuracy by calibrating a thermal model to thermal transient test data quickly and easily.

Automatic thermal model calibration

Enhanced thermal analysis accuracy is critical to meet increasingly demanding design requirements in many modern electronics products. Calibrating simulation to a measurement is of proven value to achieve highest fidelity component thermal modeling accuracy, however manual calibration adjustments of models can be prohibitively time consuming. As part of Siemens Xcelerator portfolio, Simcenter test and simulation tools provide unique automatic calibration technology.

Simcenter Micred T3STER hardware is an advanced thermal transient test solution for thermal characterization of IC packages, power semiconductors, LEDs and electronic systems. The equipment uses an electrical test method to deliver

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recognized highly accurate, repeatable junction temperature transient measurement. During a typical test of an electronic device or IC package, a heating or cooling transient response to a power step is precisely measured. This is post processed to generate a Structure Function, which represents the heat flow path from device junction to ambient as a profile of thermal resistance vs thermal heat capacitance. By automatically calibrating a simulation based Structure Function in Simcenter FLOEFD to match an imported measurement generated Structure Function, engineers can now achieve a highly accurate thermal model and use it confidently for transient analysis.

Prerequisite

Simcenter Micred T3STER SI, T3STER or Power Tester hardware equipment measurement data.

Simcenter FLOEFD T3STER Automatic Calibration Module

The Simcenter FLOEFD automatic calibration module enables users to first import a measurement based structure function from a Simcenter Micred T3STER hardware thermal transient test study and compare it to simulation based structure function. The engineering user can then explore package model internal dimensions and material properties changes through automation within the calibration capabilities of the parametric study

tool. This automatic procedure ensures that the simulation model transient thermal behavior matches test data. The result is a highly accurate calibrated detailed 3D model for transient analysis.

An accurate, calibrated thermal model for transient analysis has high value for application uses such as:

- power electronics mission profile based thermal analysis for thermal reliability insights e.g power semiconductor junction temperature prediction within an vehicle inverter for a given EV drive cycle

- digital electronics e.g modeling power mode change thermal response or throttling control influences

- supply chain support whereby semiconductor OEMs provide highest accuracy test calibrated detailed thermal models to their electronics clients for market differentiation value

- a highest fidelity 3D detailed thermal model is also beneficial basis to generate any reduced order fast, solving models for electrothermal circuit simulation or system simulation. (for more details on boundary condition independent reduced order models see the Simcenter FLOEFD BCI-ROM and Package Creator Module)
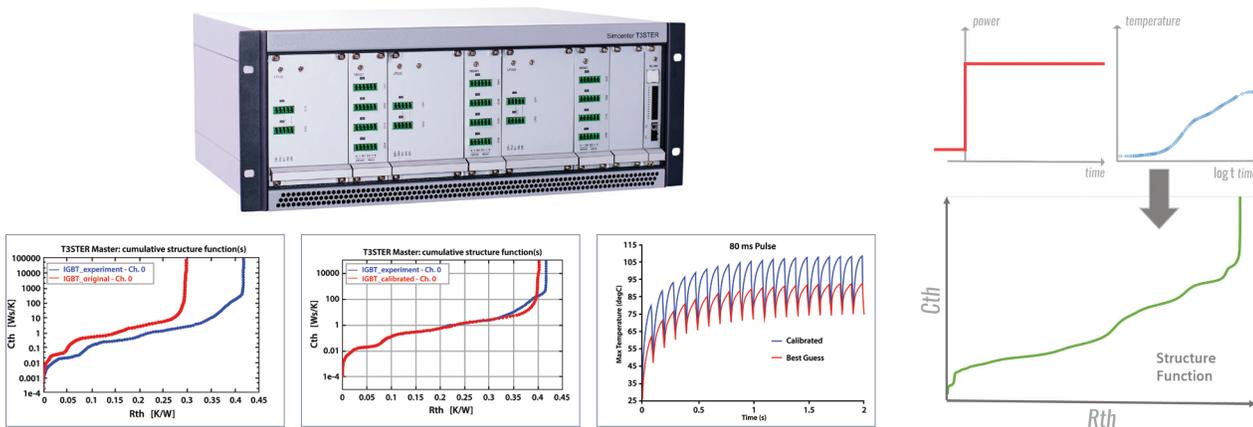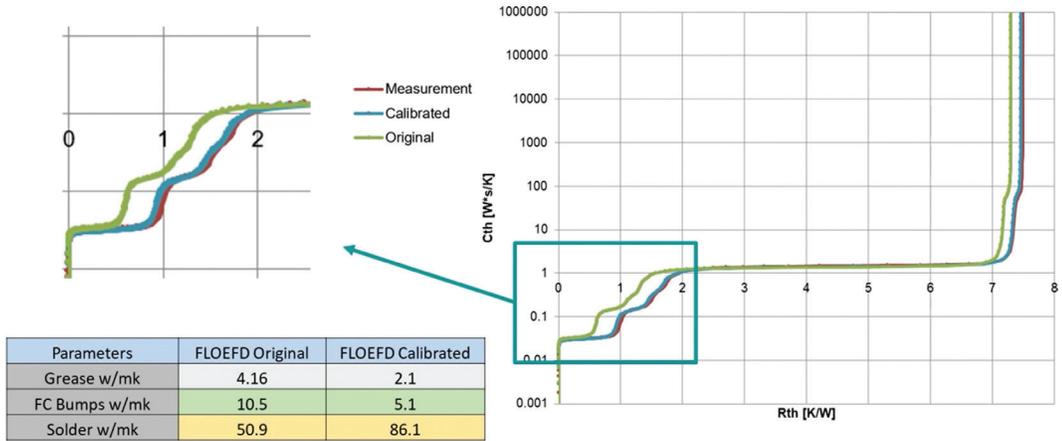

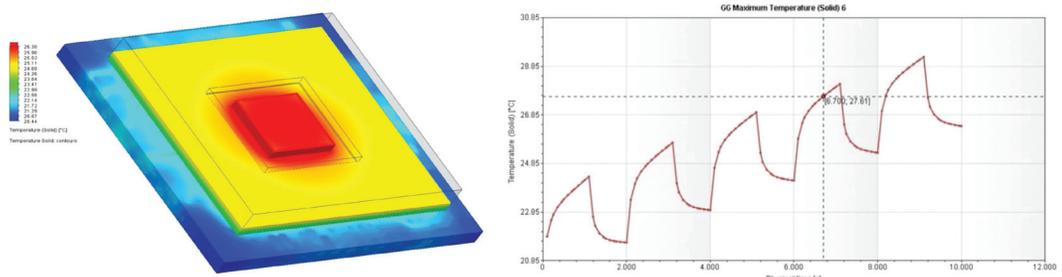Thermal transient test, structure function generation and comparing uncalibrated vs calibrated thermal models.

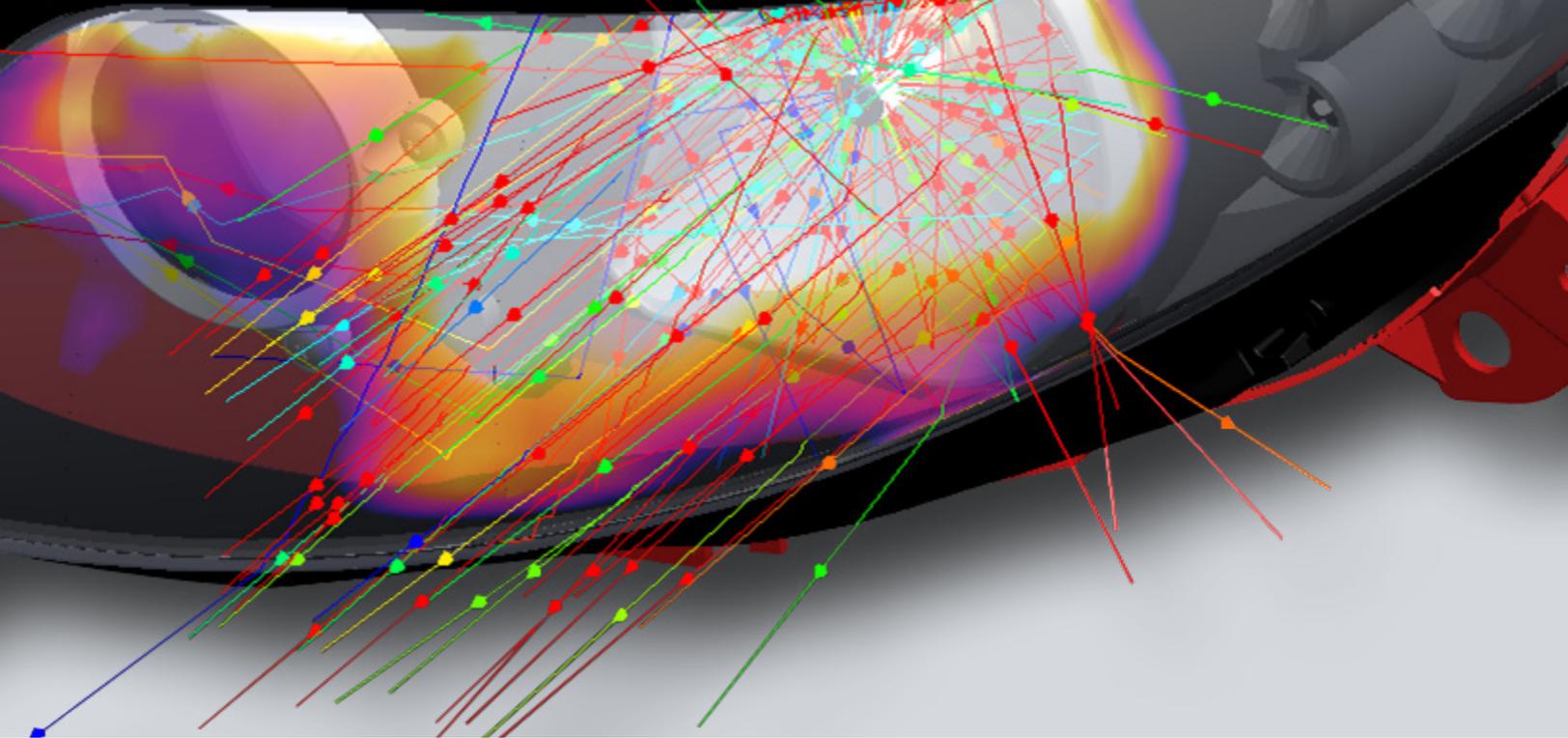## Process of automatic calibration

Structure function

Parameters	FLOEFD Original	FLOEFD Calibrated
Grease w/mk	4.16	2.1
FC Bumps w/mk	10.5	5.1
Solder w/mk	50.9	86.1
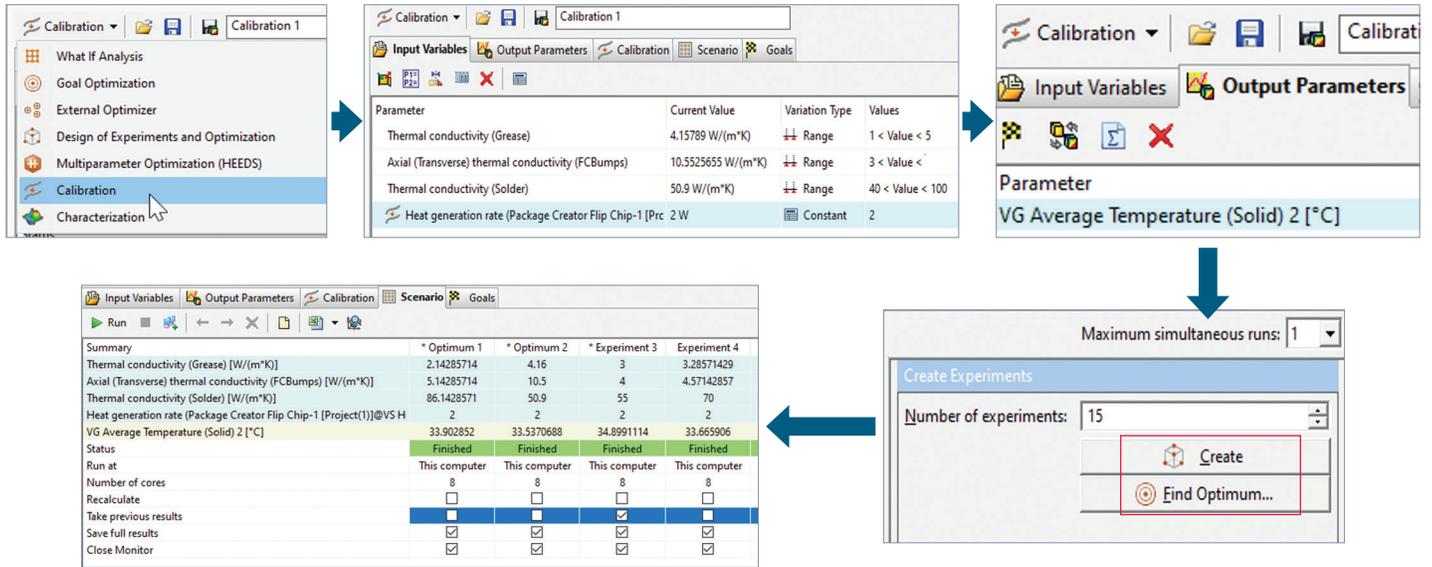
Structure function calibration close up.

Accurate transient response modeling using an automatically calibrated ic package thermal model.

Simcenter FLOEFD Lighting module

Accurate thermal and optical simulation for successful product design

Benefits

- Advanced lighting focused simulation capabilities for designers to analysts

- Predict accurate operational LED light output (hot lumens) and temperature

- Achieve highly accurate radiation simulation using an advanced Monte Carlo radiation model with spectral absorption, reflection, refraction and scattering characteristics

- Enable LEDs to operate within the limits of the vendor's specs and avoid reliability issues and warranty recall costs

- Simulate transient condensation scenarios

Summary

Simcenter™ FLOEFD™ is a fully CAD-embedded computational fluid dynamics (CFD) software for frontloading fluid flow simulation and heat transfer analysis earlier in product development. By enabling lighting engineers and designers to perform simulation directly in the CAD environment, and using native geometry directly, you can eliminate tool and data translation delays for a shorter, more efficient analysis workflow. The Simcenter FLOEFD Lighting module provides
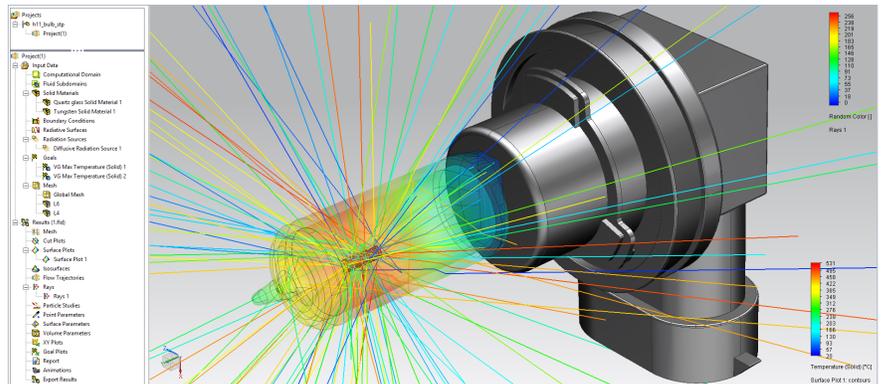
A halogen bulb modeled for automotive headlights.

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Benefits *continued*
- Enable import of detailed LED thermal and photometric models

- Specify forward current for LEDs enabling users to calculate the correct thermal heating power, and hence, the correct operating temperature
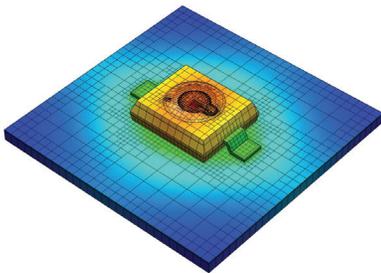
additional capabilities for radiation analysis, condensation simulation and highest fidelity modeling of light-emitting-diode (LED) thermal and optical performance.

Simcenter is part of the Siemens Xcelerator business platform of software, hardware and services.

Accurate modeling of radiation and condensation/icing
- Monte Carlo radiation model for simulating absorption and scattering of radiation in semi-transparent solids such as glass as well as considering effects such as refraction, specular reflection and wavelength dependency (spectrum properties of the radiation)

- Discrete Ordinates – this radiation model solves the radiative transfer equation for a finite number of discrete solid angles, each associated with a vector direction which allows the solution of radiation in absorptive (semi-transparent) media and to model spectral dependencies

- Condensation model capable of simulating thin film condensation, evaporation and icing/de-icing and a water absorption model that enables solids to absorb humidity and release it again in the right environmental conditions
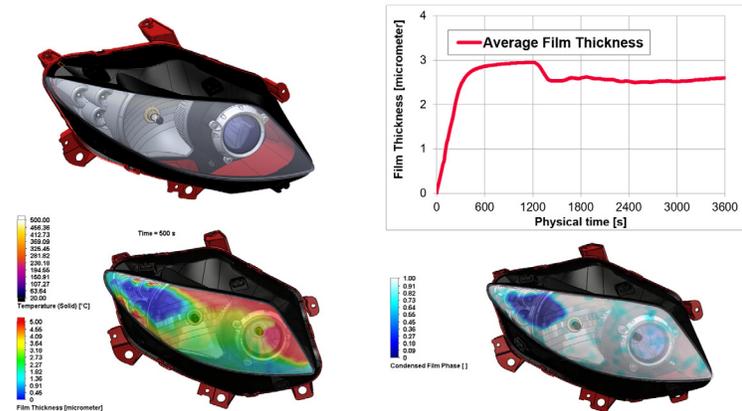
Evaluate lighting performance with advanced radiation results visualization
- Ray trajectories can be plotted from Monte Carlo radiation studies

- Near field illuminance and far field luminous intensity (luminous flux per unit solid angle) calculations help engineers analyze the optical performance of a light-emitting system when modeled with Monte Carlo radiation and using spectral characteristics defined

A combined thermal and photometric model for LEDs
- Import RC-ladder compact thermal models using measurement data from Simcenter™ Micred™ T3STER hardware and also optical test data

- Starter pack of LEDs for popular lighting applications: Cree XT-E, Osram Golden Dragon, Seoul P4 and Philips Luxeon Rebel

- Import your own LED models into an engineering database

## Precise LED optical performance prediction at operating junction temperature

- Calculate the light output (lumen) of LEDs to see if these meet design goals for light output and uniformity

- Pulse-width modulation, to control the brightness of LEDs, can be modeled for thermal-electrical-optical LED models. You can set the duty cycle as a percentage which allows for an easier and more accurate definition of the LED boundary condition

- Photoluminescence and Mie scattering of phosphor particles can be simulated. Temperature dependency of the luminous efficiency is taken into account. You can improve accuracy and detail for LED models as well as LASER lights where originally blue light gets converted to white light

Advanced lighting thermal and optical simulation directly in your CAD environment

Design reliable, high performance lighting products faster using Simcenter FLOEFD, fully CAD embedded CFD simulation software. The Simcenter FLOEFD Lighting module advanced capabilities enhance virtual development for traditional lighting, LED and LASER lighting applications in consumer, industrial, to automotive industries and beyond.
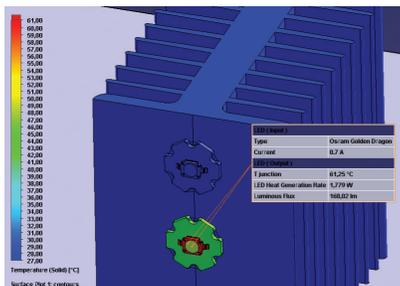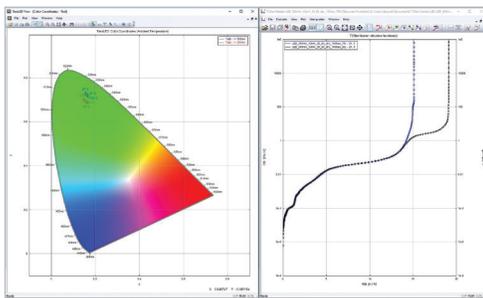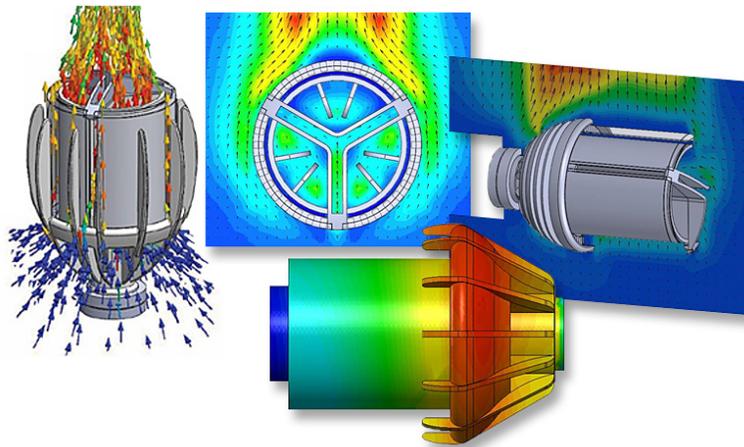
LED thermal and radiometric characterization measurement data imported into Simcenter FLOEFD for modeling.
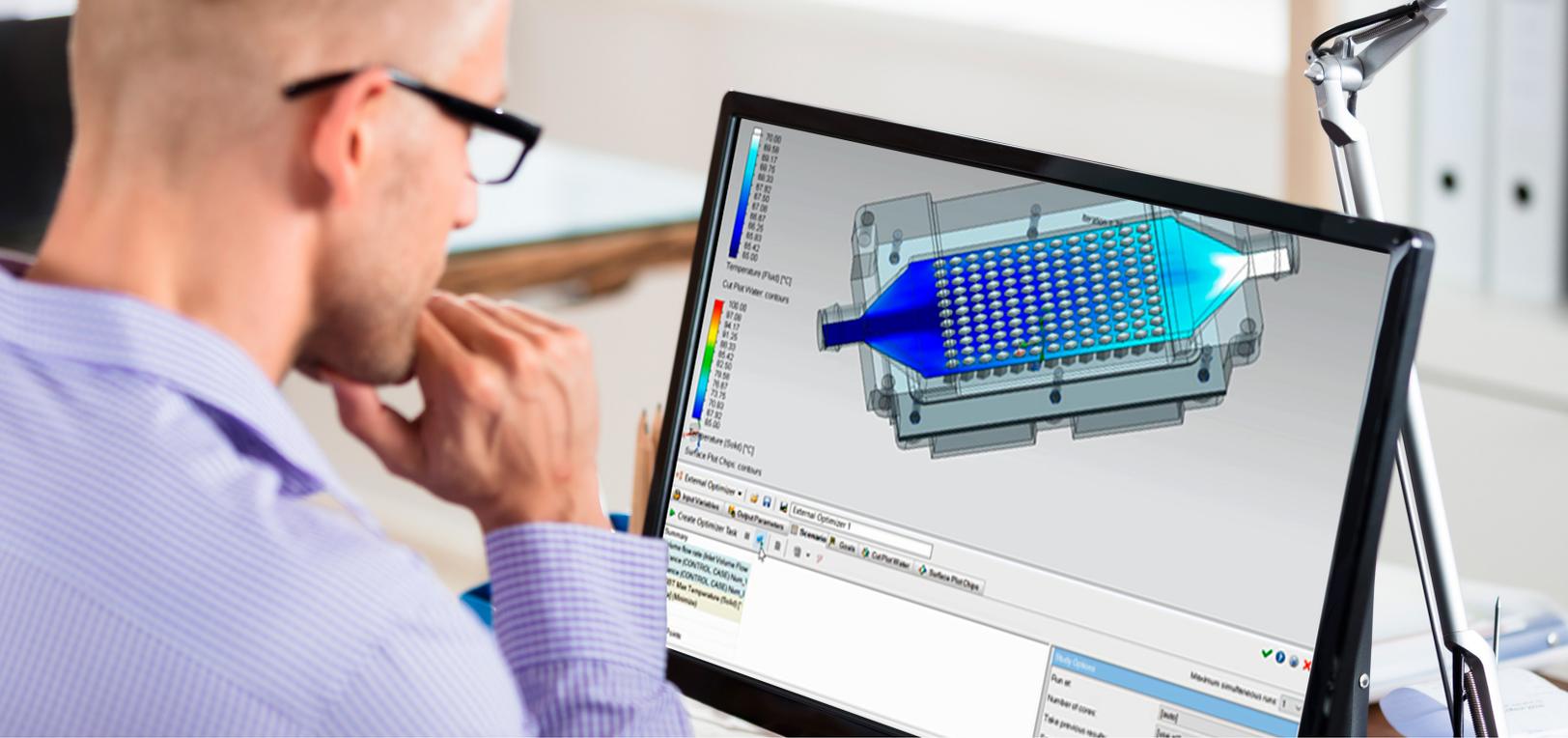
Simcenter FLOEFD extended design exploration module

Expanding CFD capabilities with design exploration and optimization

Benefits

- Expand CFD capabilities with design exploration and optimization

- Identify higher-performing families of designs

- Discover better designs faster

- Use simulation to drive innovation

- Minimize simulation time and cost

Summary

Simcenter™ FLOEFD™ software is award-winning front-loading computational fluid dynamics (CFD) software that works inside computer-aided design (CAD) to simulate fluid flow and heat transfer using 3D CAD models without the need for data translations or copies. Simcenter FLOEFD is part of the Siemens Xcelerator business platform of software, hardware and services.

With the module, you can extend the Simcenter FLOEFD parametric study and design comparison functions to drive innovation with design exploration, moving beyond troubleshooting and evaluating designs to discovering better designs faster.

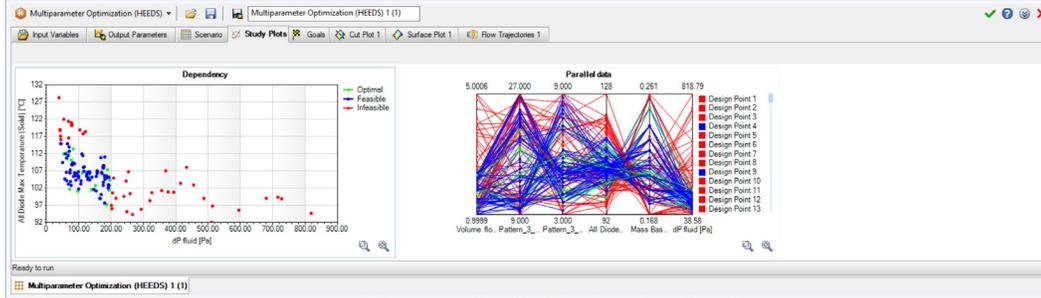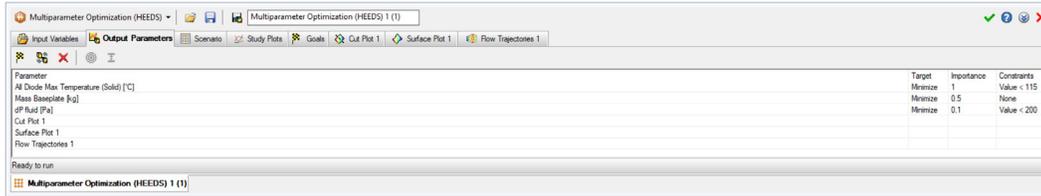## SIEMENS

siemens.com/simcenter

Features

- Powerful design exploration engine

- Robust optimization and search functionality using SHERPA algorithm

- Leverages multiple global and local search strategies

- Intelligent adaptive search
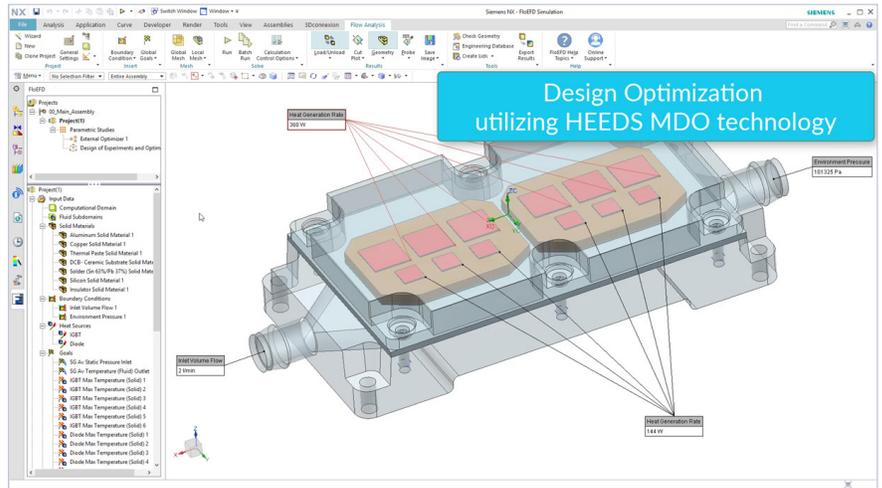
A multi-parameter geometry optimization of an IGBT power electronics liquid-cooled cold plate design helps reduce pressure loss and maximum temperature.

The efficient and robust optimization and search functionality of the HEEDS™ software SHERPA algorithm embedded in Simcenter FLOEFD leverages multiple global and local search strategies and adapts the search as it learns more about the design space. It doesn't require specialized algorithmic search expertise and incorporates user intuition with its collaborative search capabilities. The process allows you to identify higher-performing families of designs with minimal simulation time and cost.
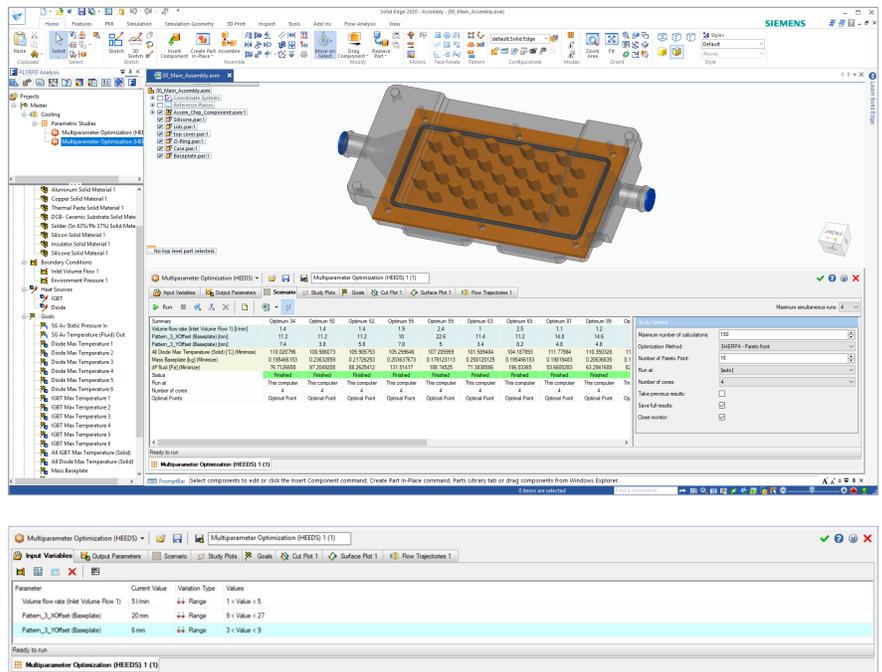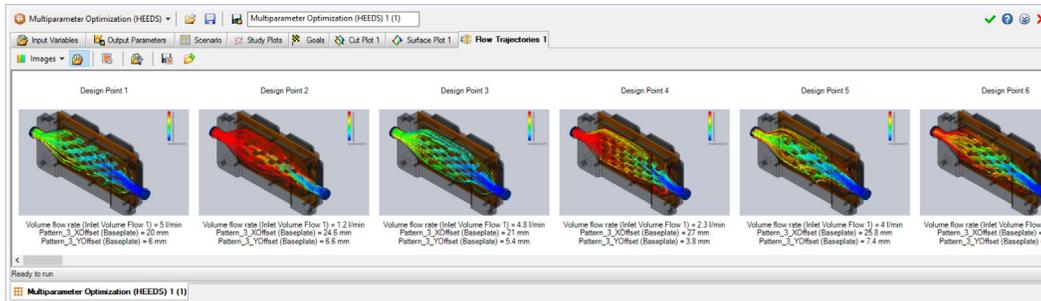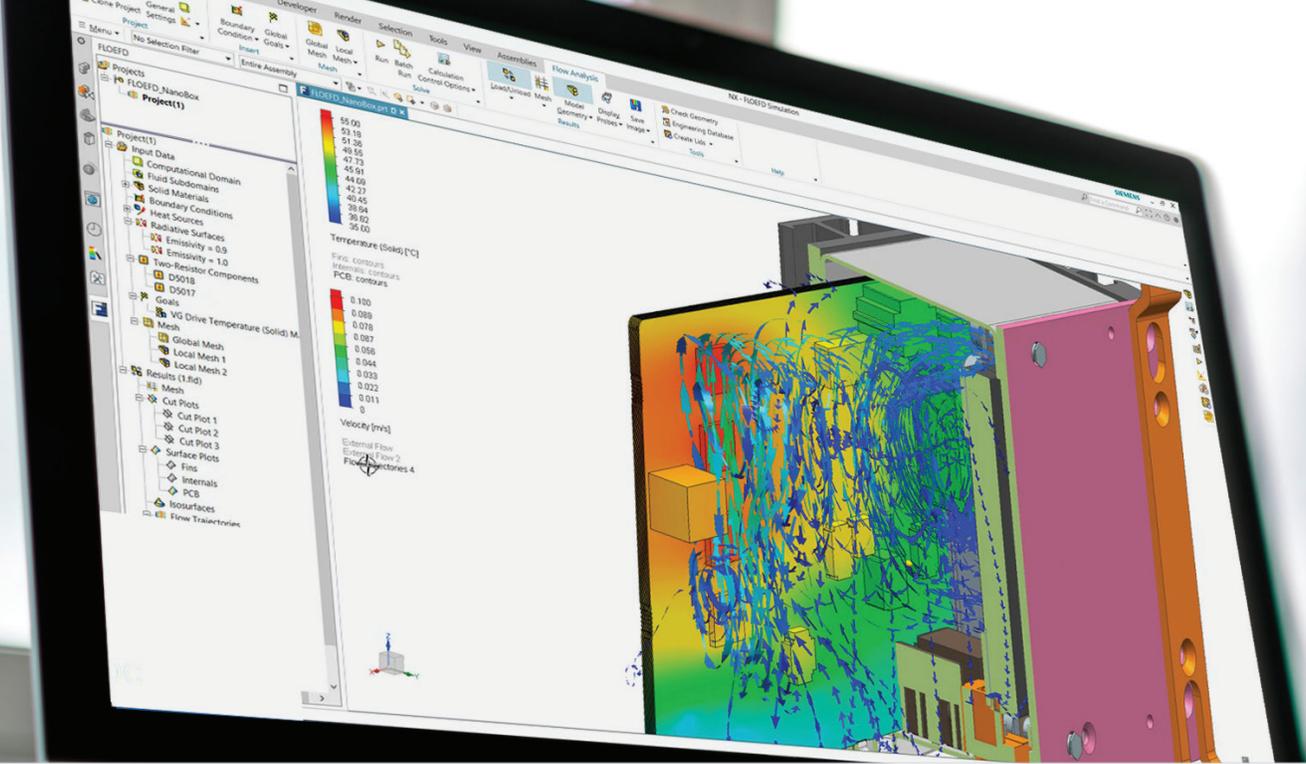
DIGITAL INDUSTRIES SOFTWARE

Simcenter FLOEFD for Siemens NX

CAD-embedded front-loading computational fluid dynamics (CFD) software

Summary

Simcenter™ FLOEFD™ for NX™ software is an easy-to-use, fast and accurate CFD analysis tool that is fully embedded in NX. It enables engineers to front-load simulation by moving CFD simulation early into the design process, thus, enabling design engineers to examine and evaluate design options earlier to obtain optimized product performance and reliability.

Simcenter FLOEFD features intelligent automation at its core to make front-loading of CFD a reality:

- An intuitive user experience – short learning curve

- Use of native NX CAD data – no translation or fluid body creation

- Automatic recognition of model change – geometry and simulation data are synchronized

- Fast automated mesher – fast and easy SmartCell™ meshing

- Unique solver – getting accurate results fast for highly complex geometry

- Powerful parametric study and design comparison functionality for easier what-if analysis

SIEMENS

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Simcenter FLOEFD can be easily inserted into your current NX design flow without any disruption to your existing process and reduce your overall simulation time by as much as 75 percent.
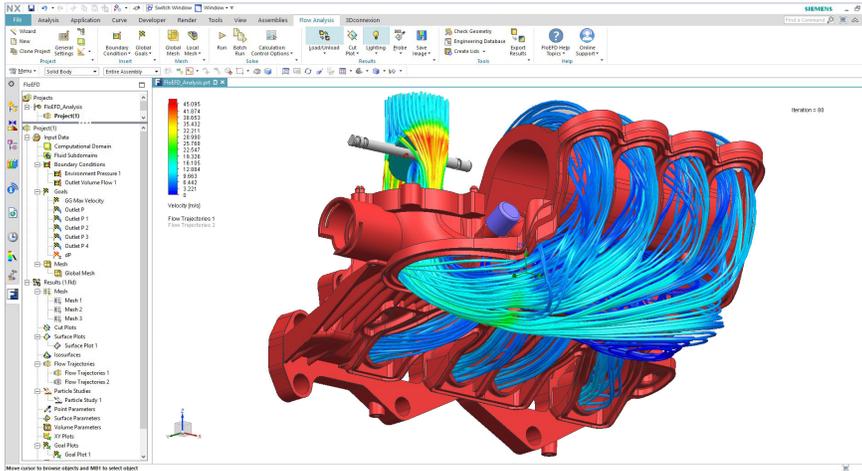

"As a Simcenter product, FLOEFD is fully embedded in Siemens NX which is our design platform of choice; therefore, the entire development cycle can be done in Siemens NX CAD. In addition, FLOEFD has a wide range of technologies to help make CFD accessible. Its high degree of automation, modeling and meshing efficiency including a unique boundary layer model, helps us to obtain faster results without loss of accuracy. As a result, we can frontload CFD and move it early into the design process where obtaining useful and timely information for decision making purposes is crucial."
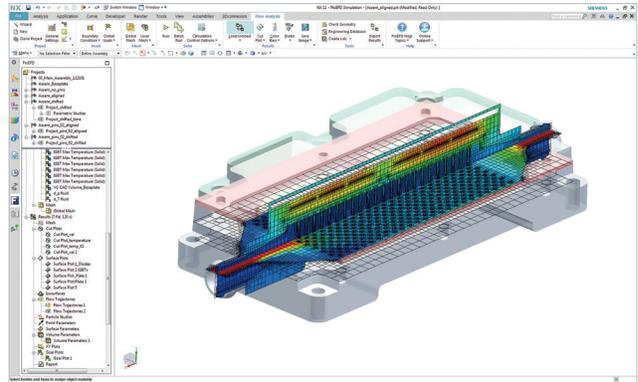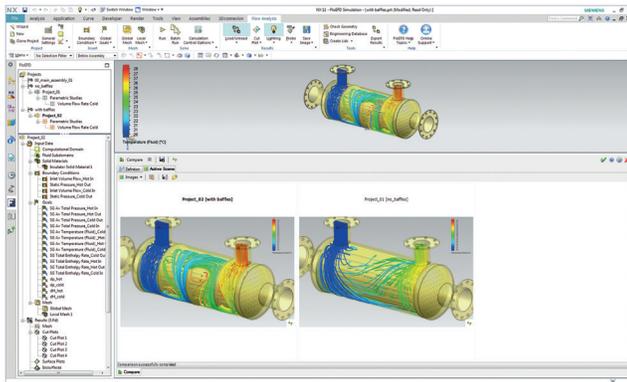
Ural Locomotives, LLC

Simcenter FLOEFD for Siemens NX

Tight CAD-integrated CFD simulation
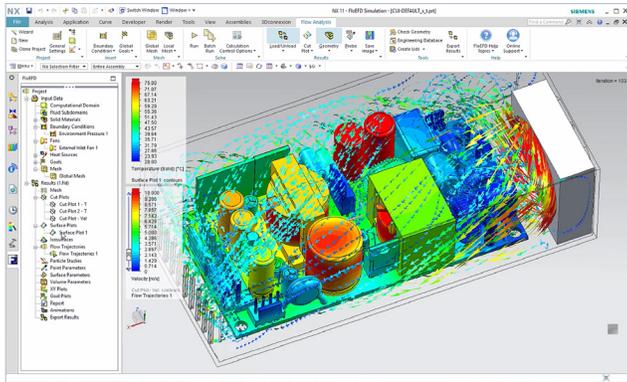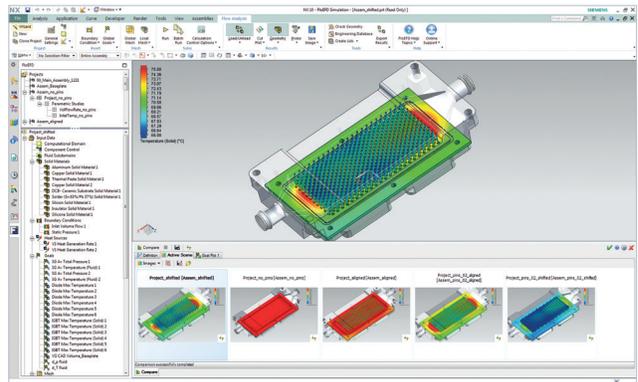

Fast and robust automated meshing technology
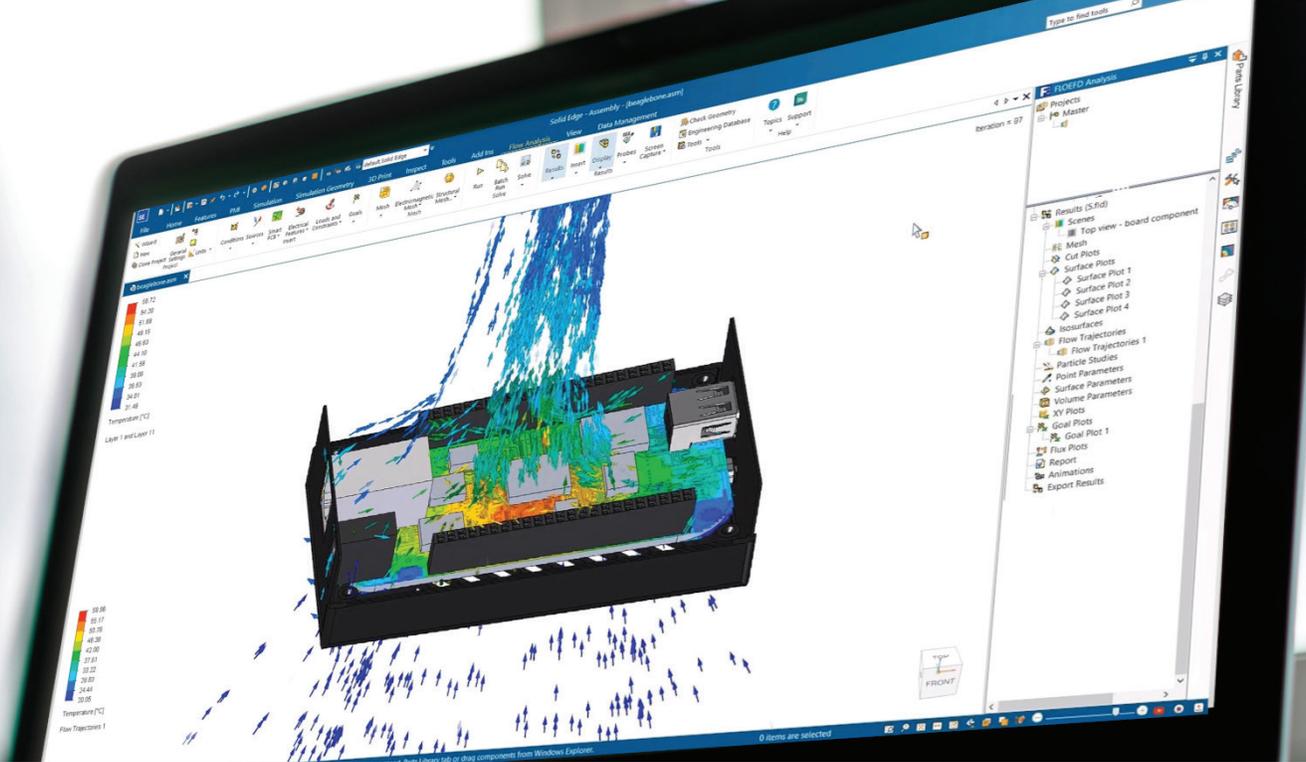

Intuitive user experience

Parametric studies and design comparison

If you use Siemens NX take a closer look at Simcenter FLOEFD – the only fluid-flow and heat transfer simulation tool that fits into your design process without requiring you to change the way you design products.

Contact us to arrange for a free trial.

DIGITAL INDUSTRIES SOFTWARE

Simcenter FLOEFD for Solid Edge

Facilitating rapid and accurate fluid flow and heat transfer analysis in Solid Edge

Benefits

- Rapid and accurate simulation of fluid flow and heat transfer

- Frontloads simulation without disrupting the design workflow

- Delivers powerful parametric studies and design comparison functionality for easier what-if analysis

Summary

Simcenter FLOEFD™ for Solid Edge® delivers the industry's leading computational fluid dynamics (CFD) analysis tool for fluid flow and heat transfer. Fully embedded in Solid Edge, FLOEFD has intelligent technology at its core to help make CFD easier, faster and more accurate. It also enables design engineers to frontload CFD, or move simulation early into the design process, allowing users to identify and fix problems earlier, saving time and money and enhancing productivity by up to 40 times.

Underlying technology

Fast and powerful, Simcenter FLOEFD for Solid Edge takes advantage of synchronous technology and uses native geometry. Users don't lose time transferring, modifying or cleaning a model, or generating extra geometry to represent the fluid domain. As soon as the model has been created in Solid Edge, it can be prepared for analysis. For effective design validation, users can create variants of their concept and analyze them immediately in Solid Edge.

SIEMENS

solidedge.siemens.com

Features

- Fluid body creation from native Solid Edge CAD data

- Provides an intuitive user experience

- Guided problem setup and automated, accurate, fast and easy meshing

- Robust solver for highly complex geometry

- Provides timely feedback

- Visualization tools
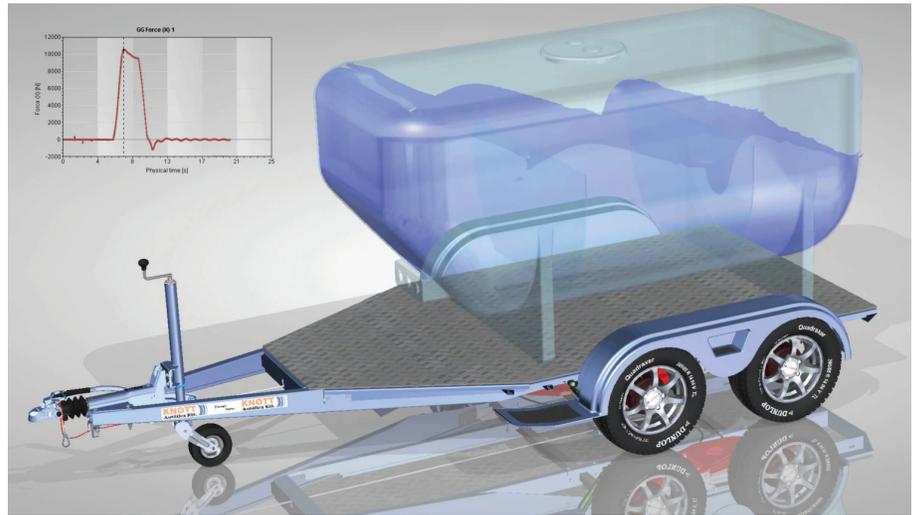
Unique SmartCells™ technology allows use of a coarse mesh without sacrificing accuracy, and a robust mesher easily captures arbitrary and complex geometry. As a result, the meshing process can be completely automated and requires less manual input.

Simcenter FLOEFD for Solid Edge also delivers engineering outputs in a timely and intuitive manner, including reports in Microsoft Excel and Word.

The expandable power of Simcenter FLOEFD

Simcenter FLOEFD is extensible with the aid of optional modules for advanced analyses, including:

- Advanced CFD module for special applications such as hypersonic flow for up to Mach 30, orbital radiation simulation such as for satellites, the NIST real gas database and gas combustion simulation

- Heating, Ventilation and Air Conditioning (HVAC) module for designing occupied spaces, including buildings and vehicles. It includes special simulation capabilities, including comfort parameters and tracer studies, an additional radiation model and an extended database for building materials

- Electronics Cooling module for detailed simulation of electronics systems. It includes an extended database, packaging materials and physics such as joule heating

- Light-Emitting Diode (LED) module for all lighting-specific simulations with the Monte Carlo radiation model, and a water film model for condensation and icing simulation of water films

- Electronic Design Automation (EDA) Bridge for importing data from EDA software, including Siemens Digital Industries, Cadence, Zuken and Altium, as well as import power and
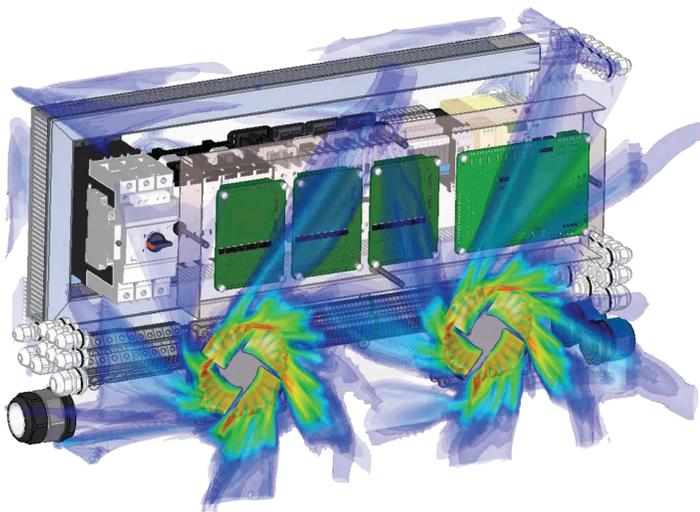
materials maps (SmartPCB) of printed circuit boards (PCB) and definitions of thermal territories and network assemblies (Delphi model)

- Structural module specifically designed for Finite Element Analysis (FEA) of electronics cooling cases, leveraging the SmartPCB FE model; allows for a direct use of temperature and pressure loads from the CFD simulation all within one simulation run

- Extended Design Exploration module for multi-parameter optimizations leveraging the advanced HEEDS Sherpa solver

- Electromagnetic (EMAG) module for simulation of low frequency electromagnetic effects of Alternating Current-induced (AC) ohmic and iron losses, as well as permanent magnets and the direct coupled CFD simulation, in order to consider these losses in the thermal simulation of components such as in transformers, bus bars and induction heaters

- Power Electrification module for more accurate thermal simulation of batteries with Equivalent Circuit Model (ECM) and Electrochemical-Thermal Coupled Model (ECT)

- T3STER Automatic Calibration module for the design of calibrated thermal semiconductor models from Simcenter Micred T3Ster measurements such as integrated circuits (IC) and insulated gate bipolar transistors (IGBT)

- BCI-ROM + Package Creator module, which comprised of the Boundary Condition Independent Reduced Order Model (BCI-ROM) feature, for extracting dynamic compact thermal models from a 3D model; thermal netlist extraction, for converting a 3D model into an electrothermal model for Simulation Program with Integrated Circuit Emphasis (SPICE); and package creator tool, for the rapid creation of thermal models of electronic packages

- Electronics Cooling Center module, offers the ultimate solution for electronics cooling, includes the BCI-ROM + Package Creator, EDA Bridge, Electronics Cooling and T3STER Automatic Calibration modules and more

Extending value
The Solid Edge portfolio is an integrated set of powerful, comprehensive and accessible tools that advance all aspects of the product development process. Solid Edge addresses today's complexity challenges with automated digital solutions that cultivate creativity and collaboration.

By harnessing the latest innovative technologies in mechanical and electrical design, simulation, manufacturing, publications, data management and cloud-based collaboration, Solid Edge dramatically shortens time-to-market, provides greater production flexibility and significantly reduces costs with its collaborative and scalable solutions.

Minimum system configuration
- Windows 10 Enterprise or Professional (64-bit only) version 1809 or later
- 16GB RAM
- 65K colors
- Screen Resolution: 1920x1080
- 8.5GB of disk space required for installation
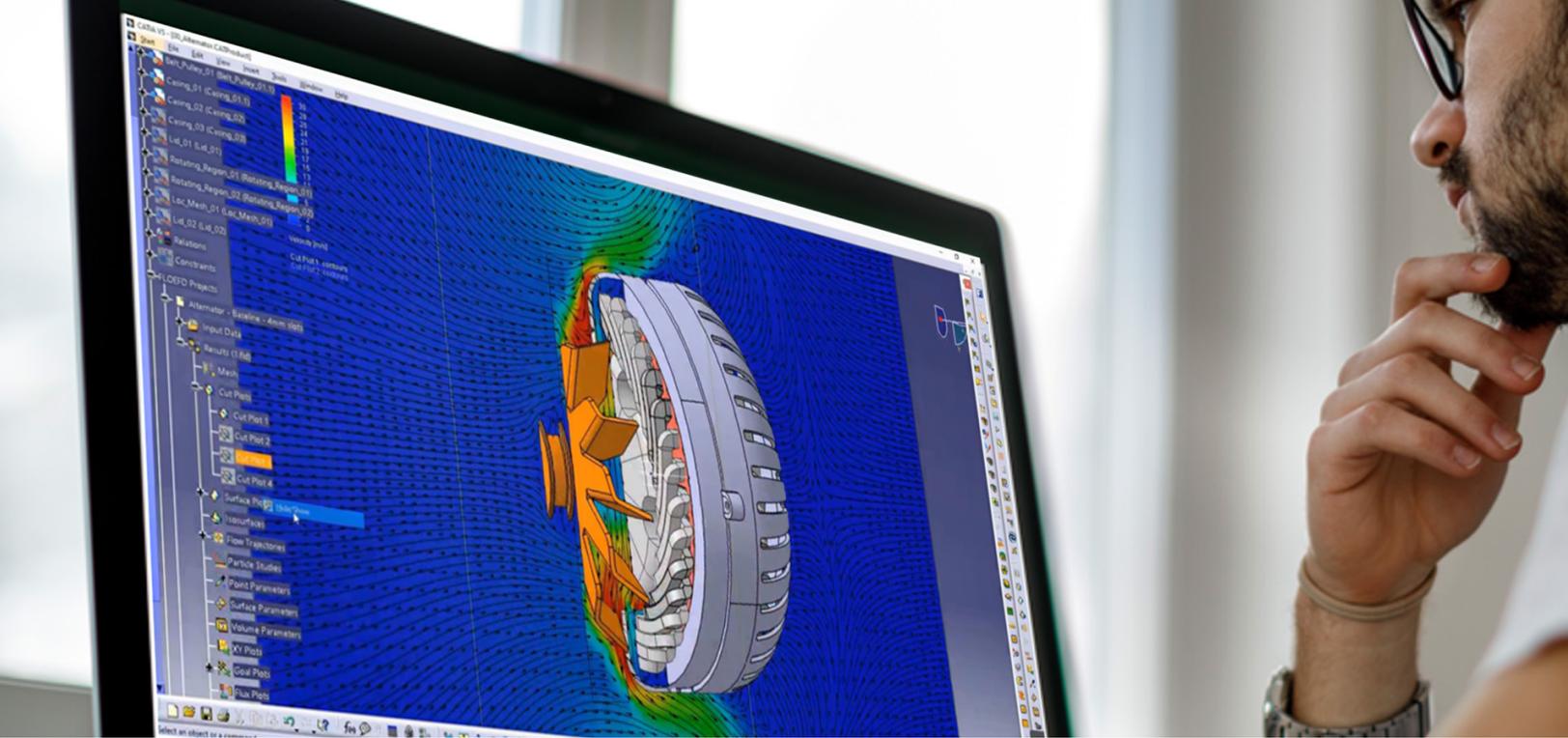
DIGITAL INDUSTRIES SOFTWARE

Simcenter FLOEFD for CATIA V5

CAD-embedded frontloading computational fluid dynamics (CFD) software

Simcenter™ FLOEFD™ for CATIA V5 is a powerful CFD analysis tool that is fully embedded in CATIA V5. It enables engineers to frontload simulation by moving CFD simulation early into the design process; thus, enabling design engineers to examine and evaluate design options earlier to obtain optimized product performance and reliability.

Simcenter FLOEFD features intelligent automation at its core to make front-loading of CFD a reality:

- An intuitive user experience – short learning curve
- Use of native CATIA CAD data – no translation or fluid body creation
- Automatic recognition of geometry changes – geometry and simulation data are synchronized
- Fast automated mesher – fast and easy SmartCell™ meshing

- Unique solver – getting accurate results fast for highly complex geometry
- Powerful parametric study and design comparison functionality for easier what-if analysis

Easy-to-use, fast and accurate, Simcenter FLOEFD can be easily inserted into your current design flow without any disruption to your existing process and reduce your overall simulation time by as much as 75 percent.

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Simcenter FLOEFD for CATIA V5

"**Simcenter FLOEFD helps us to understand and optimize headlamps. Even very complex geometries and test conditions can be investigated with a minimum of effort. New features such as Monte-Carlo radiation and the LED module are especially helpful in speeding the development of very complex products.**"
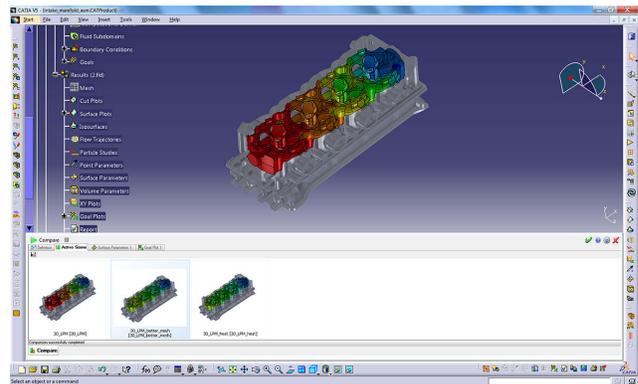
Automotive lighting
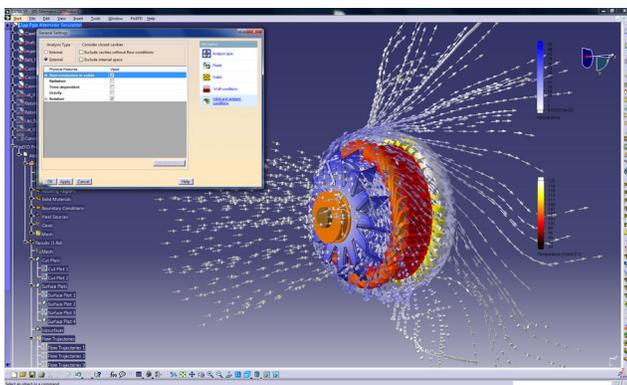
Fast and robust automated meshing technology
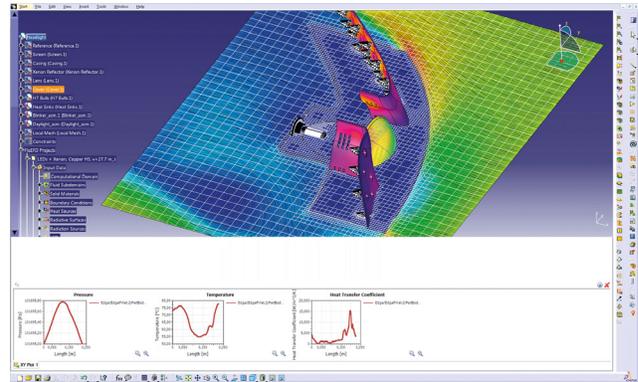
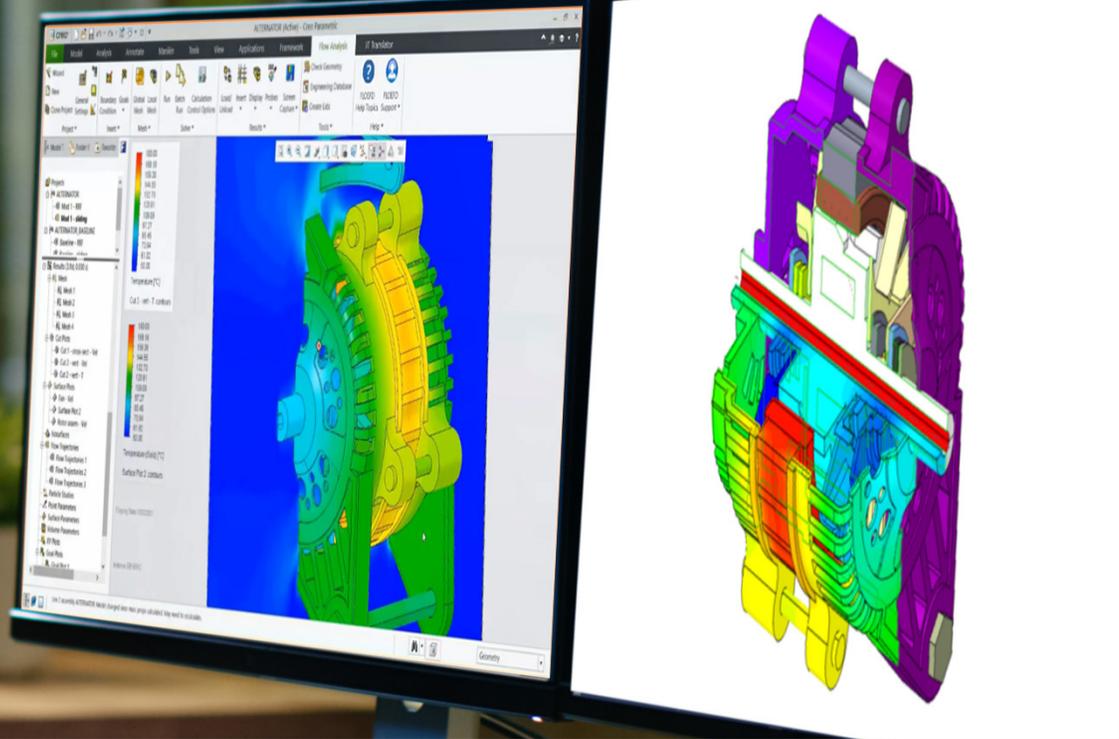

Tight CAD-integrated CFD simulation
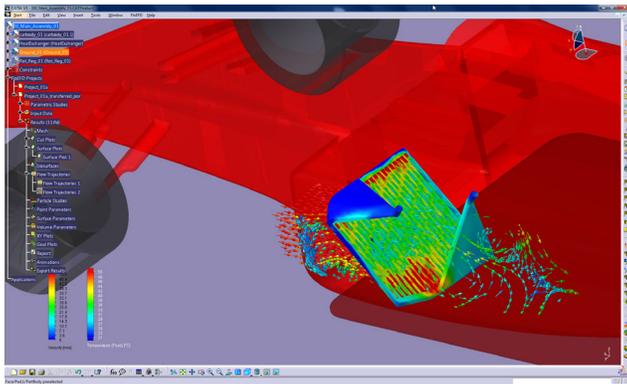
Parametric studies and design comparison

Intuitive user experience

If you use CATIA V5 take a closer look at Simcenter FLOEFD – the only fluid-flow and heat transfer simulation tool that fits into your design process without requiring you to change the way you design products.

Simcenter FLOEFD for PTC Creo

Fully CAD-embedded computational fluid dynamics (CFD) software

Simcenter™ FLOEFD™ for Creo is an easy-to-use yet powerful Computational Fluid Dynamics (CFD) analysis tool that is fully embedded in Creo. It enables engineers to frontload simulation by moving CFD simulation early into the design process; thus, enabling design engineers to examine and evaluate design options earlier to obtain optimized product performance and reliability.

Simcenter FLOEFD is easy to use and features unique intelligent technologies that make it fast and accurate:

- Use of native Creo CAD data – no translation or fluid body creation

- Automatic recognition of geometry changes – geometry and simulation data are synchronized

- Fast automated mesher – fast and easy SmartCell™ meshing

- Unique solver – provides accurate results fast for highly complex geometry

- Powerful parametric study and design comparison functionality for easier what-if analysis

This unique combination has helped thousands of engineers reduce their overall simulation time by as much as 75 percent.

Simcenter FLOEFD for Creo – the best front-loading CFD solution for engineers using PTC Creo.

"CAD-embedded CFD makes it possible to determine simulation results nearly as fast as we can change the design. The result is that we were able to improve the flow rate of our new CO_2 valve by 15 percent while eliminating about 50 prototypes and reducing time-to-market by four months."
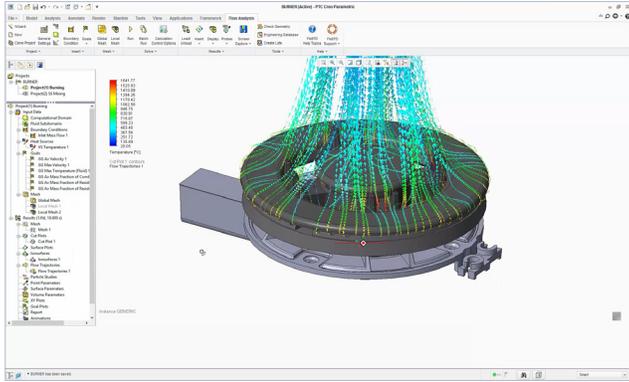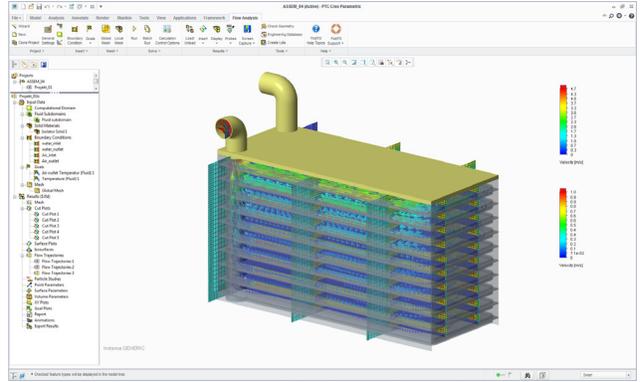
Ventrex

SIEMENS

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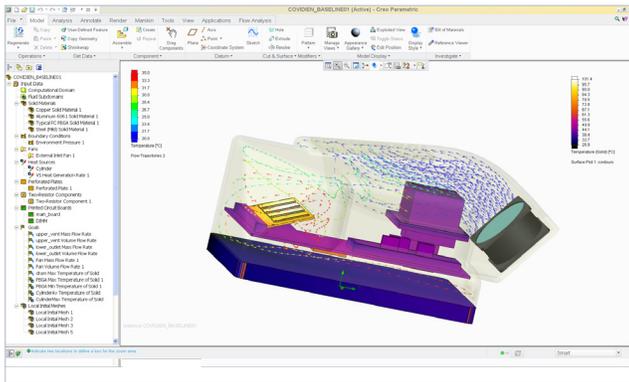
Simcenter FLOEFD for PTC Creo

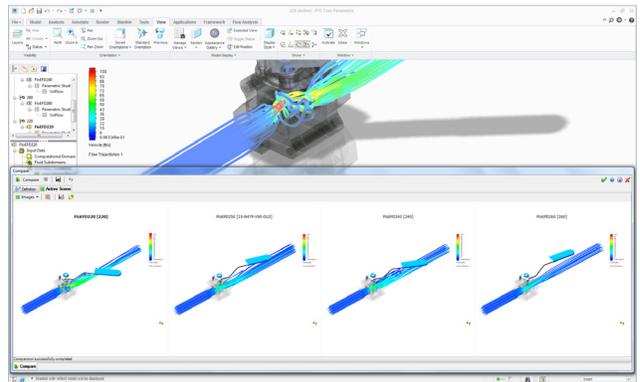### Tightly integrated into PTC Creo

Fast and robust automated meshing technology

Intuitive user experience

Parametric studies and design comparison

If you use Creo, take a closer look at Simcenter FLOEFD – the only fluid-flow and heat transfer simulation tool that fits into your design process without requiring you to change the way you design products.

Simcenter FLOEFD results can also be used as pressure and temperature input for structural simulations with Creo Simulate to increase concept design reliability under real working conditions.

Test drive free on the cloud:
https://trials.sw.siemens.com/en-US/trials/simcenter-floefd-nx

Simcenter Flotherm tools

Design reliable, electronics thermal management solutions faster with the leading electronics cooling simulation software.
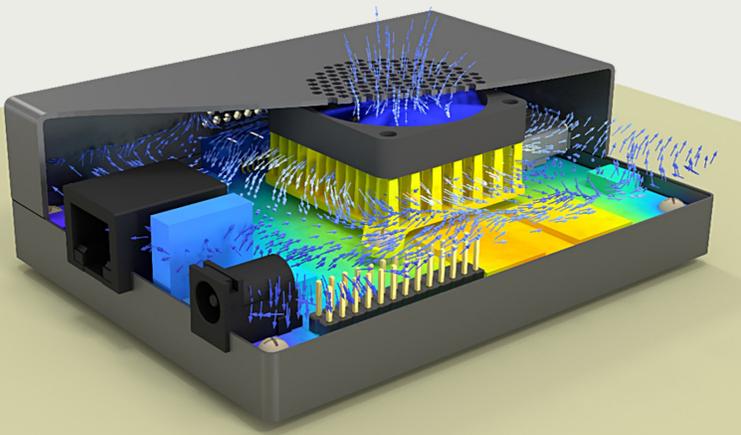
The Simcenter Flotherm™ family of products offers a comprehensive solution in electronics cooling simulation software for thermal design to ensure performance and reliability. Simcenter Flotherm is recognized as a leading technology for accurate and fast thermal analysis, based on over 35 years of constant software development and incorporating user feedback. It enables engineers to develop optimized electronics thermal management solutions for applications in all industries such as semi-conductors, consumer and industrial electronics, communications, through to automotive, defense and aerospace sectors.

There is no one-size fits all approach to electronics cooling CFD simulation. The Simcenter portfolio has a range of accurate CFD, electronics cooling and multi-physics software tools to address any application complexity, to suit different engineering user personas, and help companies shorten thermal analysis workflow. Simcenter tools accelerate your

thermal design process with close EDA and CAD workflow connectivity as part of Siemens Xcelerator. Simcenter also provides unique technology to combine test and simulation to achieve highest modeling accuracy. Simcenter™ Micred™ test hardware offers precise thermal transient measurement of packaged semiconductor components, which is used to automatically calibrate thermal simulation models.

Which electronics cooling user persona do you most identify with?

- Thermal analysts or thermal architects working from early concept layout evaluation, to incorporating complex EDA data from electronic design team changes before final verification

- Thermal engineers working more regularly with complex CAD data received from other engineering groups for enclosures and printed circuit board (PCB) assemblies

- Mechanical and design engineers who work directly in CAD software environment and are either responsible for thermal simulation tasks or simply need earlier results for geometry decision making

- Multiphysics analysts or engineers in research and development (R&D) functions, performing simulation beyond thermal analysis in domains such as structural analysis, acoustics or electromagnetics
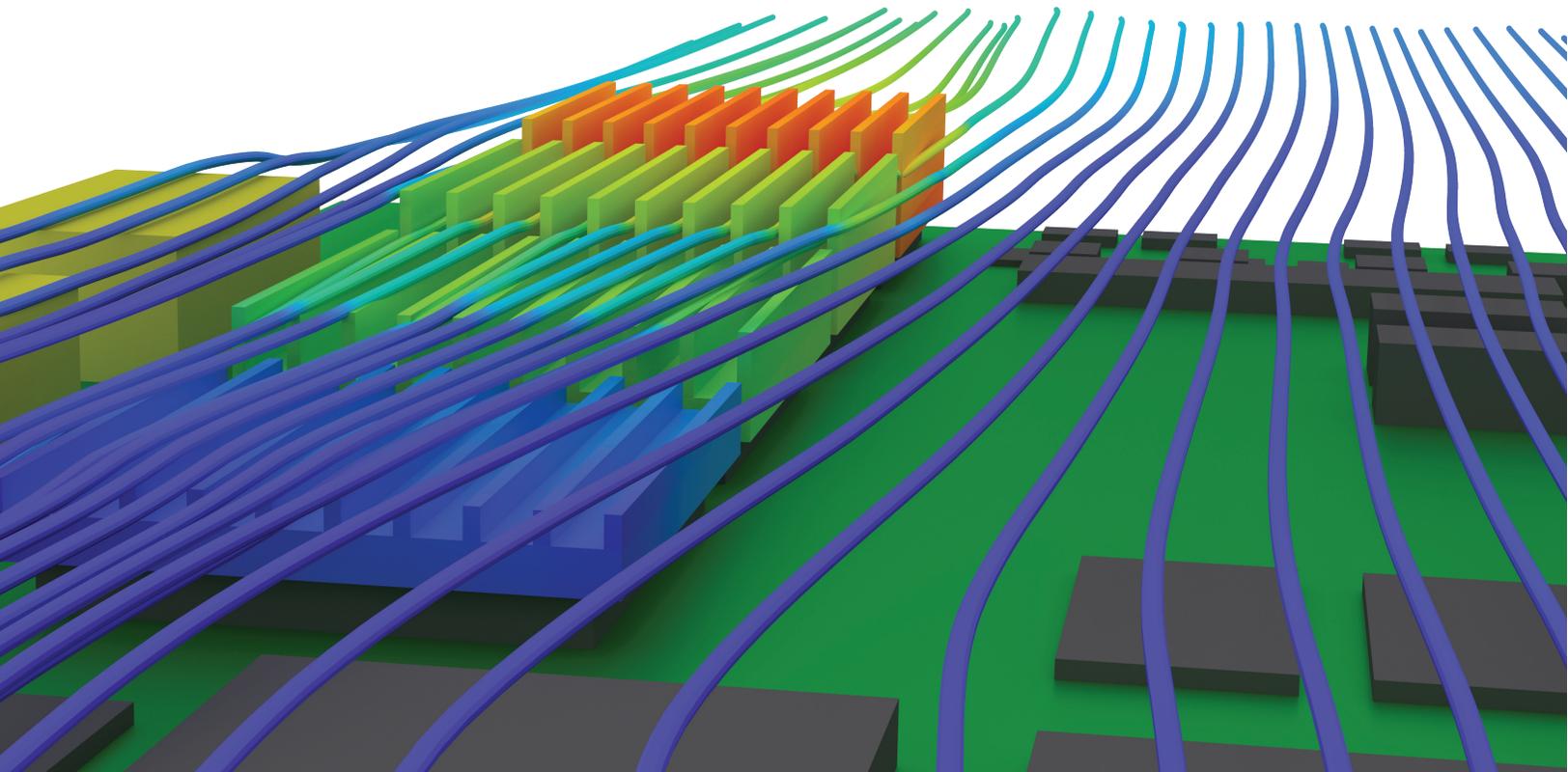
Please consult with Siemens Digital Industries Software to select the best solution to help you design better products faster:

Simcenter Flotherm is the leading electronics cooling software for thermal engineers and analysts who require fast, accurate simulation from early pre-CAD concept exploration through to incorporating increasing EDA complexity and CAD design information as a design progress to final thermal verification.

Simcenter FLOEFD, the CAD-embedded CFD simulation software for NX and Solid Edge and also CATIA and Creo that is suitable for designers, mechanical engineers to analysts. Select Simcenter Flotherm technologies are built into several

Simcenter FLOEFD modules that are focused on electronics thermal applications. Simcenter FLOEFD also has structural analysis modules to support thermo-mechanical analysis and modal frequency analysis of electronics within the CAD environment.

Simcenter STAR-CCM+ provides a multiphysics analysis platform centered around advanced computational fluid dynamics and Simcenter 3D is a multiphysics analysis environment with a structural FEA analysis focus, plus acoustics and electromagnetic analysis strengths. These tools and other Simcenter solutions complement Simcenter Flotherm tools that are used in many organizations.

Simcenter Flotherm

Improve electronics thermal management for reliability with fast, accurate electronics cooling CFD simulation from initial pre-CAD exploration to final verification.

Simcenter Flotherm is designed around over 35+ years of development and user feedback to be a leading electronic cooling simulation software solution for electronics thermal analysis that shortens development at IC, package, PCB and enclosure level through to large systems such as datacenters.

Accelerate electronics thermal design workflow

Simcenter Flotherm integrates with the electronics development workflow as a tool for thermal engineers to perform simulation and provide timely accurate results and feedback to other engineering functions. It supports thermal management simulation-based decision making from early-stage a rchitecture to final thermal design verification. This helps to shorten development times and reduce risks of reliability issues or any late-stage re-spins.

Innovative SmartPart technology, extensive libraries, EDA and MCAD data handling, a tailored and stable solver technology, state-of-the art compact thermal modeling techniques, automatic model calibration

through to parametric analysis and optimization functionality are all example capabilities that help engineers to shorten the thermal analysis process.

Leverage accurate, fast thermal analysis

Leverage instantaneous and reliable cartesian gridding that suits large complex electronics models with 1000's of components, materials and powers. Simcenter Flotherm meshing and solver technology has been designed from the outset to handle different length scales from sub-micron to meters. Furthermore, intelligent SmartPart-based, object associated gridding eliminates the need for re-gridding as locations and orientations of objects are changed. This enables you to go faster and stay focused on simulation results and design space exploration.

Reduce model creation time with intelligent SmartParts

Use a thermal engineering-oriented interface, intelligent modeling and libraries to quickly construct models for fast, accurate studies to support early thermal architecture decision making. Build models quickly using SmartParts libraries of electronics specific components such as heatsinks, fans, enclosures, heat pipes and more.

Incorporate EDA and mechanical design data complexity

Enhance your model complexity and fidelity as EDA and mechanical design teams progress during development. You can import and preprocess CAD data. You can import complex ECAD data for board routing and component layout information and modeling from all major EDA software file formats like ODB++ in a straightforward manner. Use
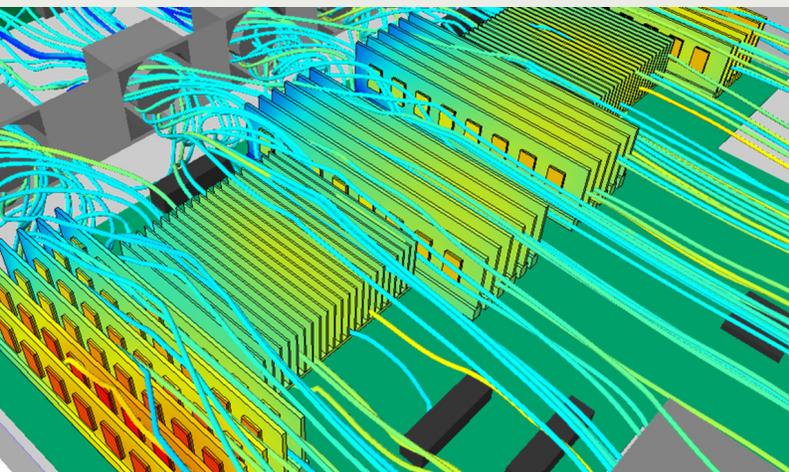
Using Simcenter fluids and thermal solutions

Simcenter Flotherm EDA Bridge for quick processing and options for modeling fidelity appropriate to the design stage.

Optimize electronics thermal management
Use the Simcenter Flotherm interface to explore simulation results intuitively and quickly. Leverage automation or scripting to streamline and standardize repeated simulation preprocessing and postprocessing tasks such as finding maximum temperatures, creating plots or generating reports for design reviews. Using Simcenter Flotherm helps you evaluate more designs within project timelines. Explore the design space with built-in parametric studies, perform design of experiments studies or employ response surface-based optimization to look at design tradeoffs to select the best design faster.

Solution benefits
- Accelerate electronics thermal design workflow
- Leverage accurate, fast thermal analysis
- Reduce model creation time with intelligent SmartParts
- Incorporate EDA and mechanical design data complexity
- Optimize electronics thermal management
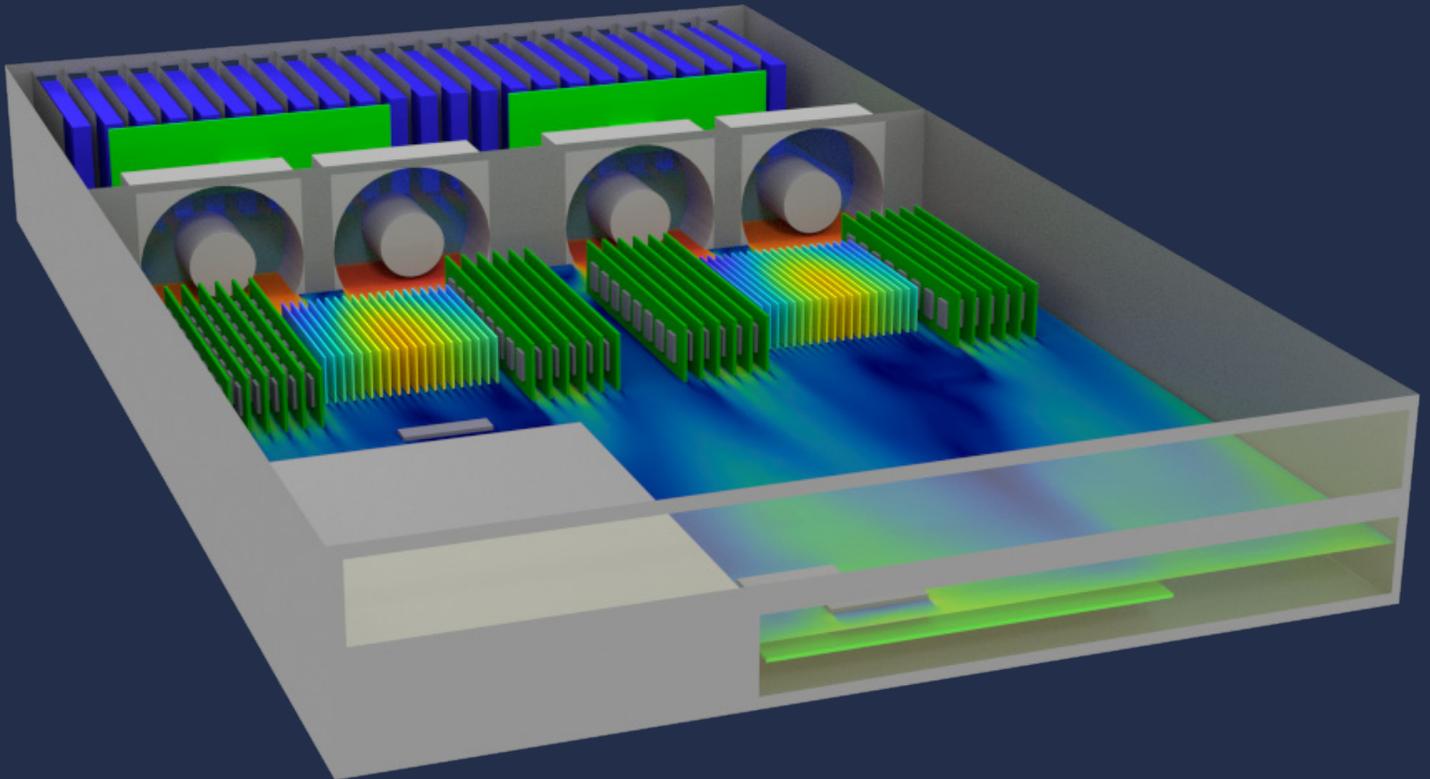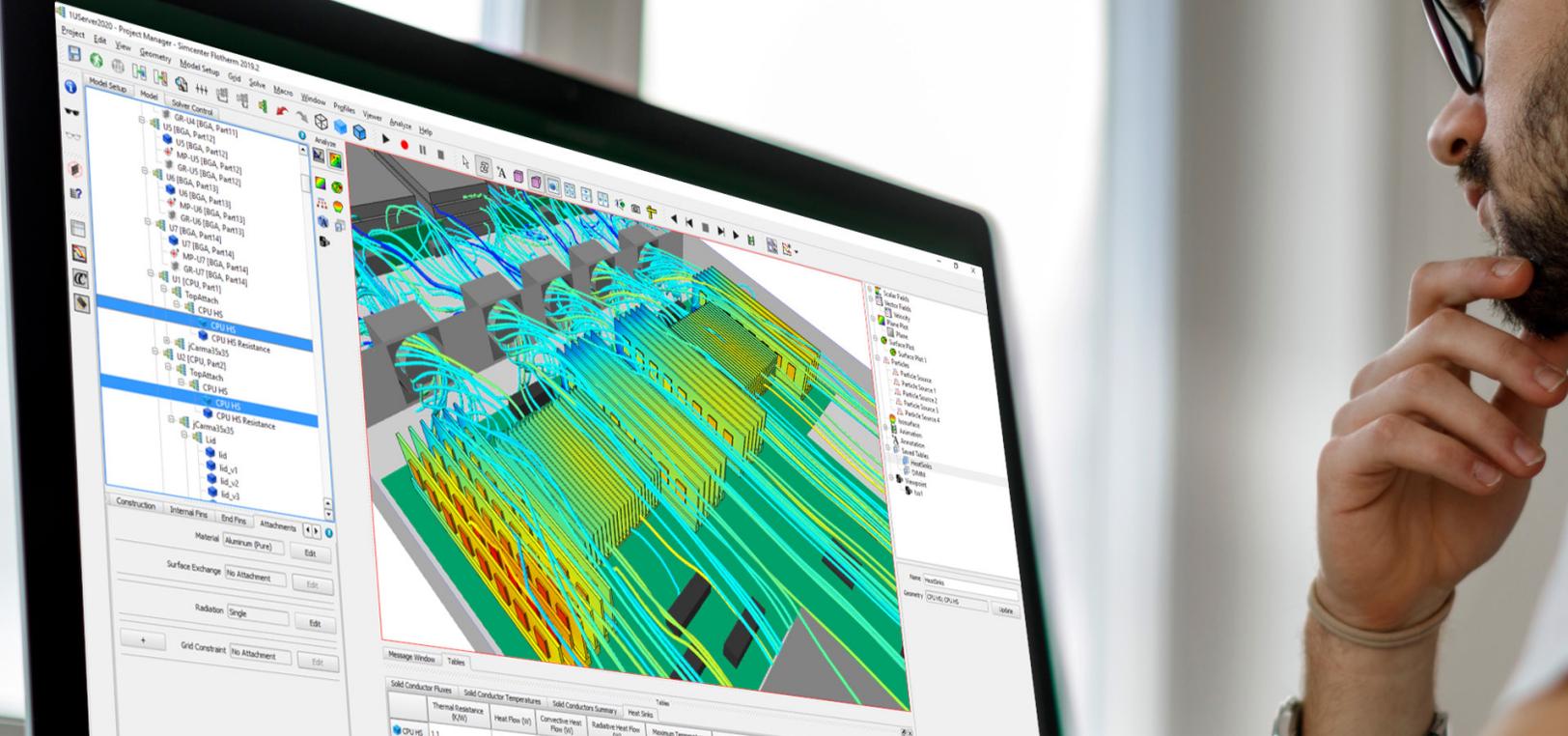
DIGITAL INDUSTRIES SOFTWARE

Simcenter Flotherm

Close your thermal design faster, minimize rework and physical prototyping, and free up valuable engineering resources for innovation

Benefits

- Front-loading thermal design prevents late-design re-spins and can eliminate physical prototyping

- Full workflow embedding and supply chain support through drag-and-drop library capability

- Right-by-design cooling solution minimizes product weight and cost

- Use to choose cooling strategy from product conception to final design

- Rapid model creation supported by Smartparts

Summary

Electronics are increasing the complexity of products across all industry sectors, including automotive and transportation, aerospace and defense, electronics and semiconductor and consumer products. While product complexity is increasing, the time and budget for product design is shrinking. Miniaturization is forcing the mechanical and electronic design flows to converge, increasing power densities. This makes it harder than ever to efficiently remove heat, which causes performance and reliability problems, and can cause safety concerns. Front-loading electronics cooling specific thermal design software is helping companies develop products that are light, thin, silent and lower in cost.
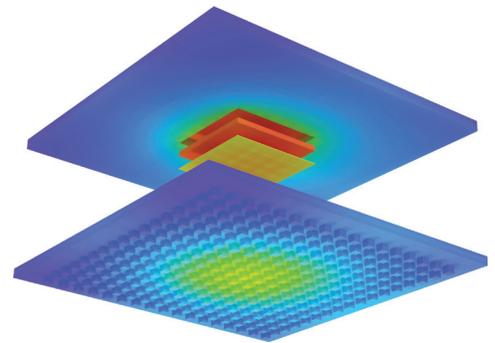
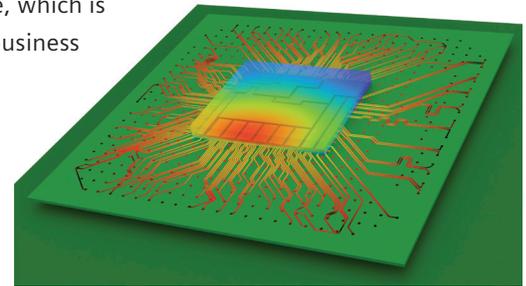Exploded view of ball grid array package showing surface temperatures on objects.

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Benefits *continued*

- Fast and robust meshing and solution supports fully automated design space exploration and design optimization

- Japanese and Simplified Chinese is supported in the user interface

- Unique Flexx licensing option gives access to run either Simcenter Flotherm or Simcenter Flotherm XT software

Simcenter Flotherm offers the solution

A complete set of Smartparts™ software, intelligent multi-level model creation macros providing detailed and compact representations in a single object, is provided. Smartparts combines geometry definition, material attributes and grid settings supporting easy model creation, and re-use across different projects. Supported Smartparts cover everything from semiconductor dies to enclosures.

Simcenter™ Flotherm™ software, which is part of the Siemens Xcelerator business platform of software, hardware and services, has a Windows File Explorer style project manager with drag-and-drop functionality and library system. Model sharing across the electronics supply chain is supported through

Traces on package substrate showing voltage.

hundreds of Smartparts-based objects and attributes available in an installed library including fans, components, heatsinks, materials, thermal interface materials and more. The CAD-style, mouse-driven, Drawing Board delivers simple draw, drag-and-drop and object snap operations to rapidly create and manipulate parametrically defined models.

Modeling electronics assemblies

At the heart of electronics products are populated printed circuit boards (PCBs). Using Simcenter Flotherm provides a wide range of PCB modeling levels to maximize solution speed and accuracy as data becomes available across the development workflow.

Simple block models use an analytical approach to calculate the effective PCB thermal conductivity in early design before the details of the board or layout are clear. In late design the Simcenter Flotherm image-based processing of metal distribution efficiently captures the local effect of copper variation across and through the board.
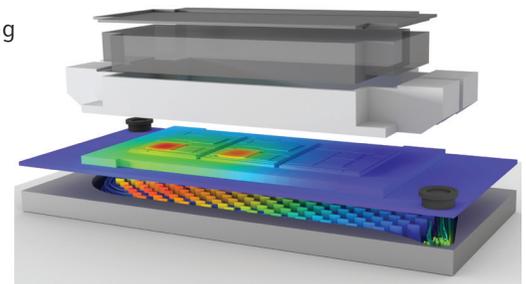
Exploded view liquid-cooled IGBT module showing object temperatures and flow.

Modeling chip packages

Simcenter Flotherm supports the widest range of component thermal models. This enables fast evaluation of architectural choices and design space exploration during conceptual design using simple block and 2-Resistor models. Detailed, 2- Resistor and DELPHI thermal resistor models can be created with Simcenter Flotherm Pack software-as-a-service.

Responses of the actual part in different environments can be measured with Simcenter T3STER™ hardware and Simcenter POWERTESTER™ hardware. RC ladder models derived from these measurements can be used directly in Simcenter Flotherm for use in transient simulations to investigate transient effects and evaluate temperature control strategies. Detailed thermal models can be calibrated against the measurement data, tuning model parameters to match provides the response of the actual part, to provide greater than 99 percent model accuracy in both space and time.

Simcenter Flotherm also supports the creation of boundary condition independent reduced order models (BCI ROMs) and SPICE sub-circuit thermal netlist export. BCI ROMs provide very fast simulation for a long duration power verses time profiles such as a drive cycle for battery electric vehicle.

Conduction, convection, radiation, phase change and solar loading

Electronics cooling applications require full conjugate heat transfer as the norm, not as a special case, along with the ability to account for solar loading and thermal radiation between the large numbers of objects that typically make up an electronics system.

Multiphysics simulations are supported, capturing Joule heating in electrical conductors such as power supply nets and power planes, and even in bond wires in power packages. Multiphysics modeling also captures the latent heat effect of packaged phase change materials (PCMs).

Active thermal management strategies

Modern electronics products rely on advanced, software-based thermal management strategies, which are supported through temperature-dependent component powers. Simcenter Flotherm also supports transient frequency-based power control based on monitored temperature and transient thermostatic control.

Working with MCAD data

Simcenter Flotherm is used to import, heal and simplify mechanical CAD data through the MCAD Bridge module, importing data from NX™ software and Solid Edge® software, Creo Parametric, SOLIDWORKS and CATIA V5. The MCAD Bridge module offers intelligent voxelization as an efficient way of dealing with MCAD data of any complexity and quality.

Working with ECAD (EDA) data

The Simcenter Flotherm EDA Bridge module has direct interfaces to Siemens' BoardStation and Xpedition™ software, Cadence Allegro and Zuken CR5000. Import of IDF and ODB++ files are supported, providing support for Siemens' PADS™ software and other EDA software. Using the EDA Bridge module components can be swapped for thermal models from the library, and components can be filtered on import based on size, power and power density, with thermal power lists imported and exported as .csv files. Joule heating power due to DC IR drop in power and ground planes, etc. can be imported from HyperLynx™ software.

Workflow integration

Simcenter Flotherm supports external model creation, manipulation, execution and postprocessing through FloXML, and record-ing and replaying interactive operations with FloSCRIPT. ECXML supports thermal model interchange with tools from other vendors. Simcenter Flotherm imports thermal models in JEDEC JEP30-T100 format.
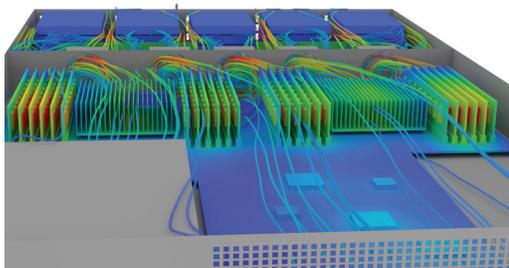
1U server with velocity colored streamlines and surface temperatures.

Fast, robust meshing and solution

The Simcenter Flotherm Cartesian-based Instamesh technology delivers instantaneous and totally robust meshing, with multicore parallel solvers on Windows and Linux capable of handling the level of complexity and number of discrete objects found in modern electronics products.

Mesh settings are associated with the geometry preserving resolution if objects are moved within the model or added to the library for future use and sharing.

Postprocessing

Comprehensive postprocessing capabilities provide plane, surface and iso-surface plots, complemented by callouts on plots to annotate simulation result values. Patented BottleNeck (BN) and ShortCut (SC) numbers help identify aspects of the design that can be exploited to improve cooling. Capture index

for hot and cold aisles for data center applications. Results can be shared across and beyond your organization with the free Simcenter Flotherm Viewer.
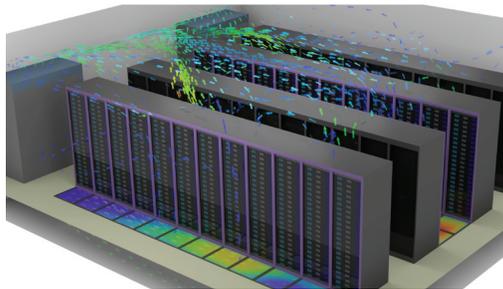
Conventional data center data halls showing complex air flow within aisles.

Design space exploration and optimization

The Command Center module supplied with Simcenter Flotherm includes design-of-experiment (DoE) and response surface optimization (RSO), with a correlation matrix to identify which input parameter combinations have the greatest effect on the selected output variables such as component temperatures. Simcenter Flotherm is also accessible through the HEEDS™ software for multidisciplinary optimization.

Free 30-day cloud-based trial

Not convinced? Try Simcenter Flotherm for yourself with a free 30-day, cloud-based trial where you can become proficient in driving the software, and work through a series of self-paced tutorials to explore the full range of features available in Simcenter Flotherm.

Notes:

MCAD Bridge module and model calibration each require an additional license.

Simcenter Flotherm Pack software-as-a-service is licensed separately.
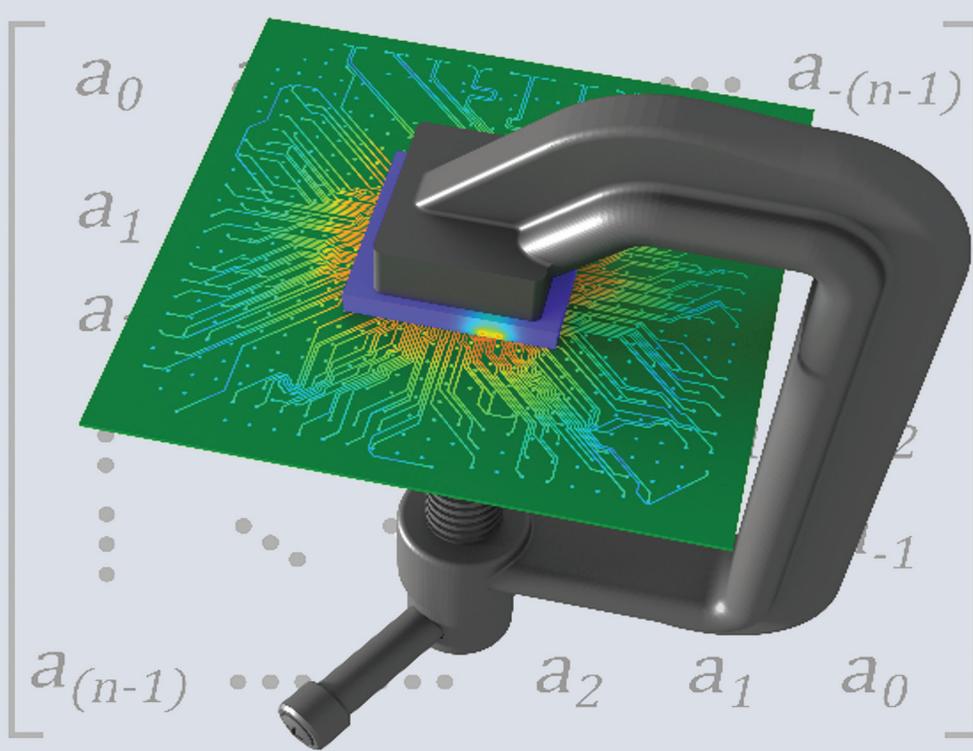
DIGITAL INDUSTRIES SOFTWARE

Simcenter Flotherm BCI-ROM technology

Boundary-condition-independent reduced-order models accelerate
electronics thermal design

Benefits

- Up to 40,000 times faster than solving
  the full 3D detailed model*

- No loss of effective accuracy versus full
  3D detailed model

- Valid for all thermal environments –
  user defines range of heat transfer
  coefficients

- Makes possible transient simulations over
  very long durations, such as automotive
  drive cycles

- Supports multiple heat sources

Summary

Transient simulations can present a significant challenge in electronics thermal
design. Modern electronics design requires consideration of multiple transient
power loads, various power control strategies and a wide range of expected
operating conditions that all impact performance and reliability.

Even with state of the art 3D computational fluid dynamics (CFD) solvers for
thermal analysis, it is too time intensive to explore all possibilities. Time pres-
sures in competitive electronics development can prevent full thermal evalua-
tion of the design space which can introduce risks to reliability.

Accurately predicting temperature is an essential analysis task to confirm that
temperature specifications for components are not exceeded for a product.
Careful design consideration must be given to maximum temperature limits,
temperature gradients in space, temperature rates of change and temperature
cycling that all impact reliability through a variety of damage mechanisms.
Accurately predicting temperature in space and time is key.

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Benefits *continued*

- Generate BCI-ROMs as matrices type, electrothermal models for circuit simulation (VHDL-AMS format), for system simulation (FMU format) and even Embeddable BCI-ROMs for 3D CFD use****

- Highest accuracy is achievable by starting from a detailed model that is calibrated to thermal transient test data**

Simcenter™ Flotherm™ software has the capability to extract a boundary-condition-independent (BCI) reduced-order model (ROM). These BCI-ROMs maintain predictive accuracy in all situations and can be solved orders of magnitude faster than CFD, providing a huge increase in productivity.
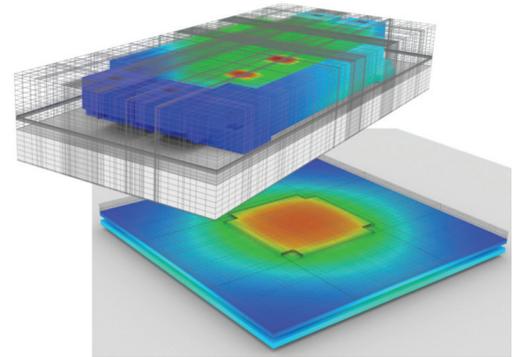
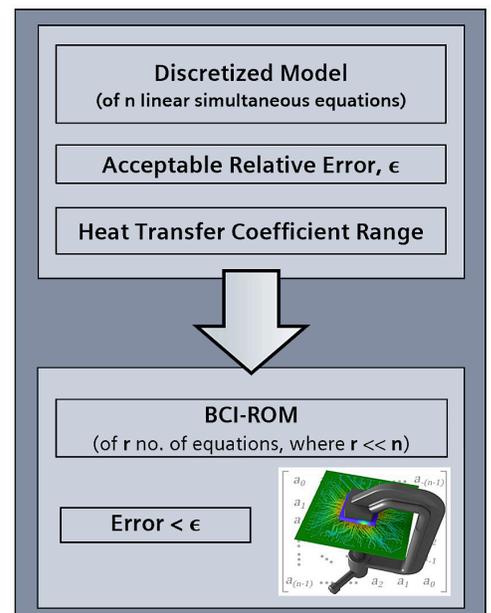BCI-ROMs of component, subsystem or system geometries preserve 3D detailed model accuracy.

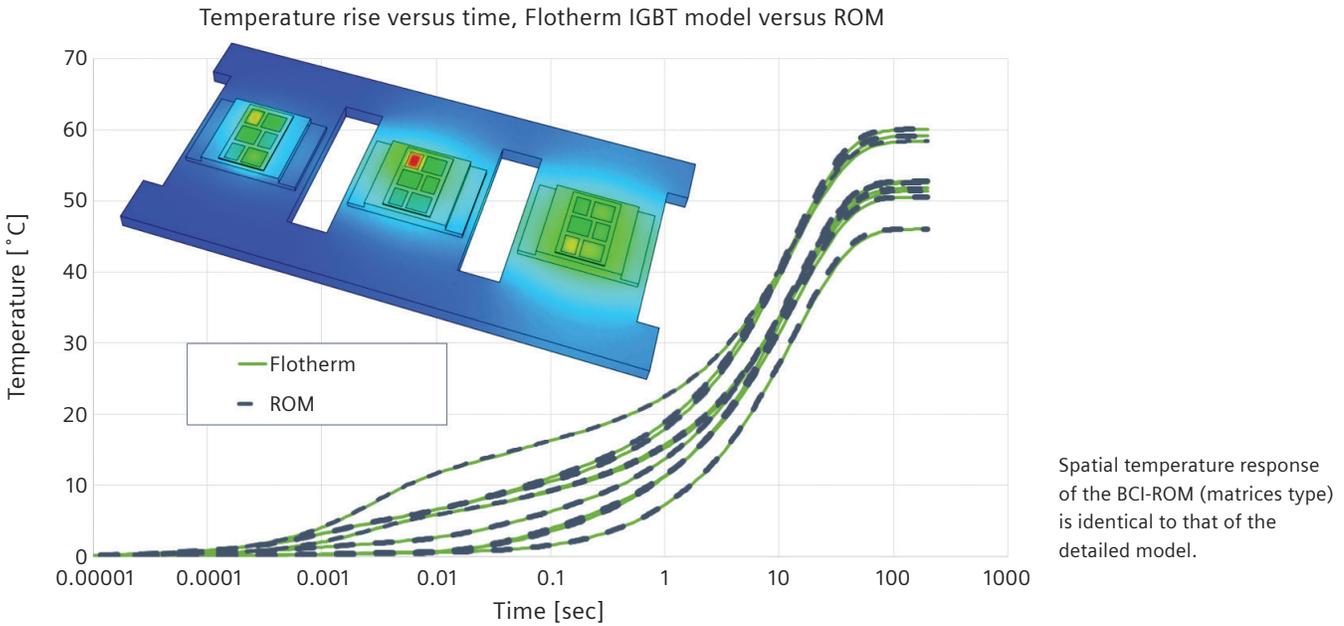**Simcenter Flotherm Reduced Order Modeling Technology**

The BCI-ROM method provides an alternative to extracting thermal resistor – thermal capacitor based dynamic compact thermal models, which have limited partitioning of the surface area and are typically only possible for single heat source packages. Simcenter Flotherm's BCI-ROM technology allows linear conduction application models with any number of heat sources to be solved up to 40,000 times faster with the same accuracy as the full 3D conduction model.

The BCI-ROM technology is an extension of the fast novel thermal analysis simulation tool for integrated circuits (FANTASTIC) method pioneered by Professor Lorenzo Codecasa from Politecnico di Milano, Italy. His publications generally describe the method and apply it to several validation examples***.
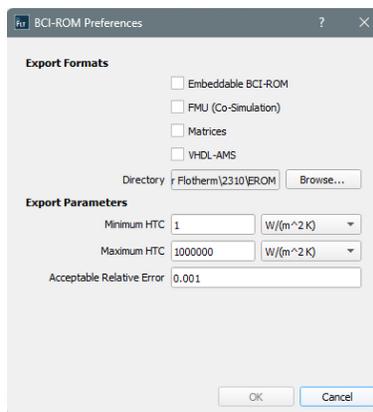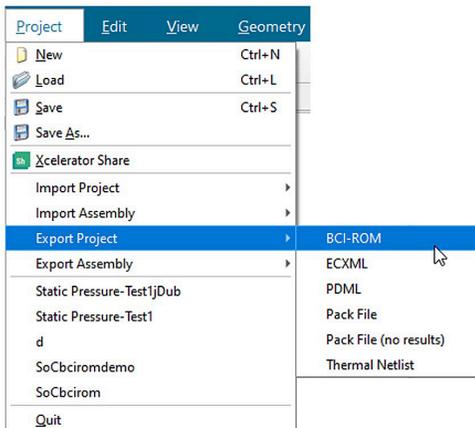
Simcenter Flotherm BCI-ROM export as matrices, VHDL-AMS or FMU format or as an Embeddable BCI-ROM.

Temperature rise versus time, Flotherm IGBT model versus ROM

Spatial temperature response of the BCI-ROM (matrices type) is identical to that of the detailed model.
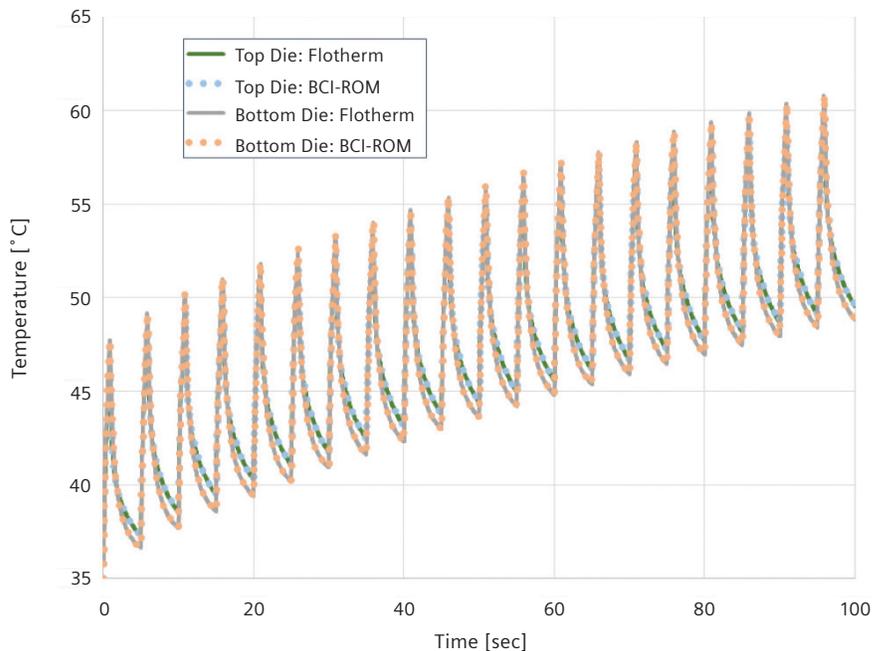
Accuracy is mathematically assured by the FANTASTIC method. The required accuracy is set by the user as the acceptable relative error when the BCI-ROM is extracted. The heat transfer coefficient range is also set by the user on extraction.

BCI-ROMs can be exported in the following formats:

- **Matrices** for solution in tools such as Matlab, GNU Octave, or using the command line standalone solver included with Simcenter Flotherm.
- **VHDL-AMS** for electrothermal modeling in circuit simulation tools such as PartQuest Explore or Xpedition AMS
- **FMU** for use in system simulation by tools that support FMI (Functional Mockup Interface) such as Simcenter Amesim™ software and Simcenter Flomaster™ software
- **Embeddable BCI-ROM** for use in a 3D thermal CFD simulation. Close accuracy of a detailed package thermal model while protecting IP sensitive internal details.****

Any transient powering profile of an arbitrary number of heat sources, or temporal or spatial change in environmental conditions can be simulated, fully accounting for changes in the heat flow paths within the 3D structure. Hours of real time can be simulated in just a matter of minutes.

BCI-ROM (matrices format) response to complex powering profiles is identical to the detailed model.

Power electronics (electrification) applications

System simulation tools, such as Simcenter Amesim, are often used to model complete vehicle including systems for the battery, motors and drivetrain, and power control units (including inverters) alongside linked cooling and control systems. Such modeling is to evaluate vehicle performance and efficiency (for range prediction) using virtual drive cycles. By generating a power module BCI-ROM in FMU format, that preserves 3D Simcenter Flotherm model accuracy, it can be embedded in a system simulation model so the junction temperature of crucial power semiconductors, including IGBTs or SiC MOSFETs, can be evaluated more precisely.

Such simulations can be useful to:

- Predict if maximum temperature rates of change or maximum temperatures exceeded
- Assess reliability through understanding of temperature cycling, or to generate data for lifetime testing of power semiconductors (power cycling) by using rainflow counting methods to derive mission profiles for tests

IGBT Junction Temperature · Cold Plate Temperature · Coolant Inlet Temperature
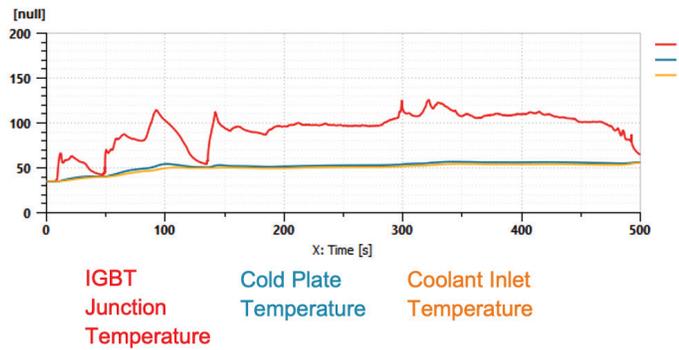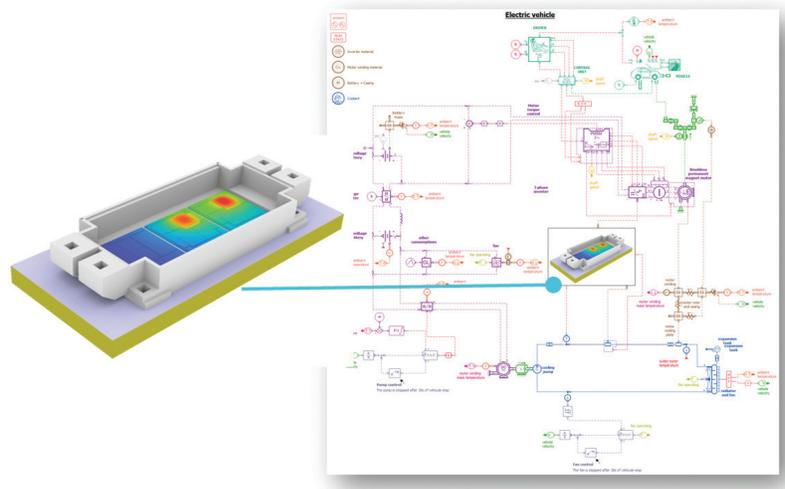
A BCI-ROM (FMU format) of an inverter power module within a Simcenter Amesim electric vehicle model.

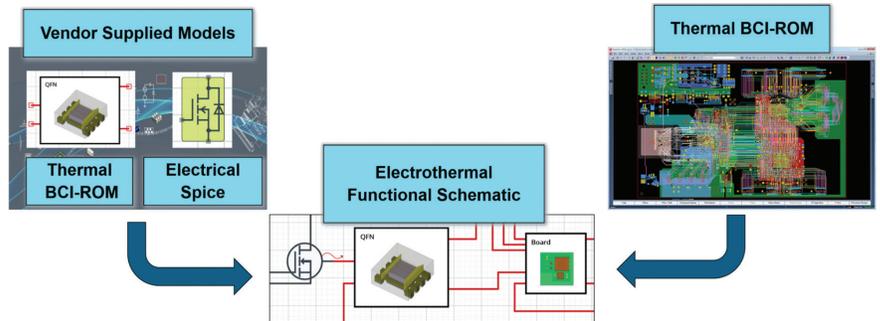## Electro-thermal circuit simulation applications

Digital electronics

Modern digital electronics have complex active power management strategies that can be tested against a wide range of use cases and environmental conditions. Each use case has a unique set of component powers and even a specific power map for each die. The simulation can consider combinations of use cases, for example, using a mobile phone for a phone call, then streaming a video, then using a satnav application with the phone on charge in a car. These use cases put different thermal demands on different parts of the system. By importing the BCI-ROM in VHDL-AMS format, electrothermal simulators such as PartQuest™ Explore and Xpedition™ AMS can consider changes to both the powers and thermal environment, for example due to a change in fan speed.

Control logic can be optimized to ensure that the system cooling solution and active cooling strategy combine to provide the best possible user experience, minimizing the need for performance derating by reducing clock frequency, while maintaining component junction, component case and touch temperatures within allowable limits.

Analog electronics

For electronic circuit designers of systems that are primarily composed of continuous (non-switching) analog electronics devices, BCI-ROMs in VHDL-AMS also provide improved thermal accuracy to enhance circuit simulation.

BCI-ROM technology supporting the electronics supply chain for circuit simulation.
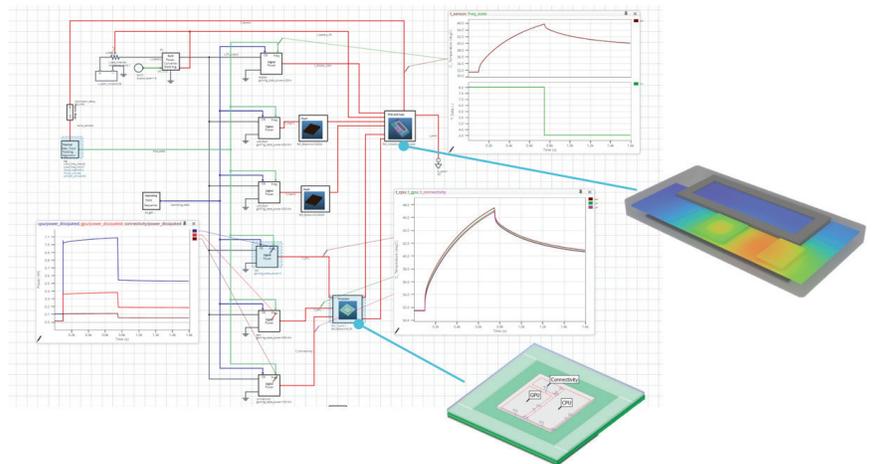

A smart phone circuit simulation in PartQuest Explore with BCI-ROM (VHDL-AMS format) thermal models generated from Simcenter Flotherm.

Liquid cooled electronics systems applications

For liquid cooled servers in datacenters, rack liquid cooled avionics and other large systems, there are advantages in using fast solving 1D fluid dynamics system simulation tools like Simcenter Flomaster. This is for component sizing, configuration studies and also for long transient simulations being performed to evaluate operational scenarios and the active controls for ensuring efficient cooling. Using BCI-ROMs exported from Simcenter Flotherm in FMU format, it is possible to bring the accuracy of 3D electronics cooling thermal analysis to 1D system modeling environments that support the FMI standard.
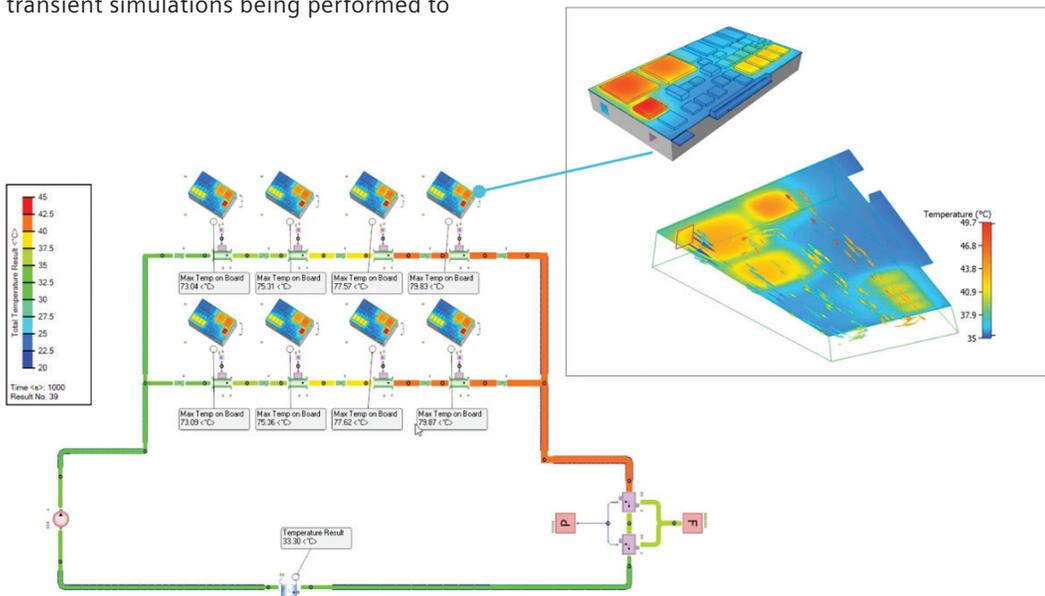

A Simcenter Flomaster 1D CFD system simulation liquid cooling piping network model incorporating cold plate cooled PCBs modeled using imported BCI-ROMs (FMU format).

Embeddable BCI-ROM

Embeddable BCI-ROM technology enables creation of accurate reduced order thermal models of IC Packages that can be used in Simcenter Flotherm 3D CFD electronics cooling simulation while protecting IP sensitive information.

The accuracy of an Embeddable BCI-ROM is very close to the detailed model it is extracted from. Importantly, all internal construction details (dimensions and materials) of a package are not present and they cannot be reverse engineered. This eliminates typical
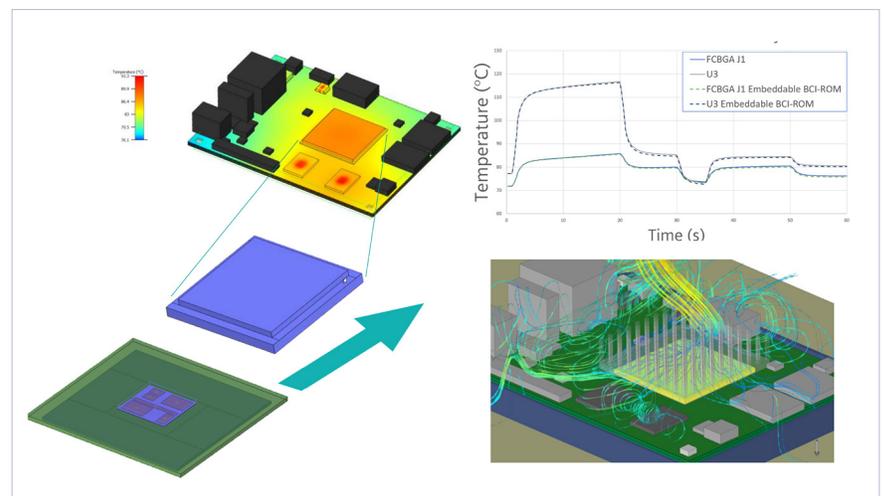
barriers to sharing accurate thermal models from semiconductor OEMs to the entire electronics supply chain.

During Embeddable BCI-ROM extraction from a linear conduction model, thousands of objects in a detailed model are reduced to a single 3D Smart Part object. When imported into Simcenter Flotherm, the Smart Part object geometry envelope consists of faces that interact with solid bodies (for example, board mounting or a heatsink placed on it), with the surrounding airflow, and via radiation heat transfer. When an Embeddable BCI-ROM is created, multiple power sources are set that can then be assigned power in the 3D simulation. In CFD system simulation, results for internal temperature are available for any probe location defined by the Embeddable BCI-ROM author. Results for surface temperatures can also be viewed in the 3D simulation.

Note: The Simcenter Flotherm BCI-ROM module is required to generate Embeddable BCI-ROMs only (author), however the module is not required for import and use models in Simcenter Flotherm.

Embeddable BCI-ROM accuracy compares favorably to detailed thermal models and compact thermal models of 2 Resistor (2R) and
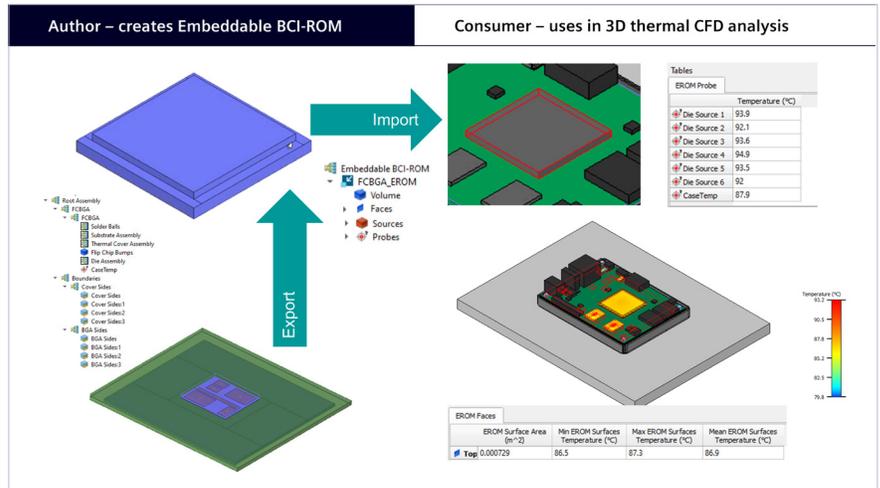
Embeddable BCI-ROM extraction, followed by import and use in Simcenter Flotherm.

DELPHI types. In validation studies, accuracy within 5 percent error compared to the detailed thermal model results is regularly achievable for steady state analysis and average error < 1 percent is possible for many package types. Embeddable BCI-ROM models therefore offer an accuracy level comparable to a standard DELPHI CTM model approach or better. Additional advantages of Embeddable BCI-ROMs over DELPHI and 2R approaches is are modeling packages with multiple powered sources and supporting transient 3D analysis.

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Simcenter Culgi

Engineer novel materials with the desired properties along the complete lifecycle using multiscale computational chemistry simulations.

Simcenter Culgi™ software helps product development and material scientists design new materials with the desired properties along the complete life cycle: inception, process development, logistics and market analysis on a digital platform.

Engineer better materials
Virtual screening of novel materials in an early stage of development is a key enabler of innovation in the chemical and process industries.

Using Simcenter Culgi helps you design new materials with the desired properties along the complete lifecycle from inception, to process development, logistics and market analysis on a digital platform.
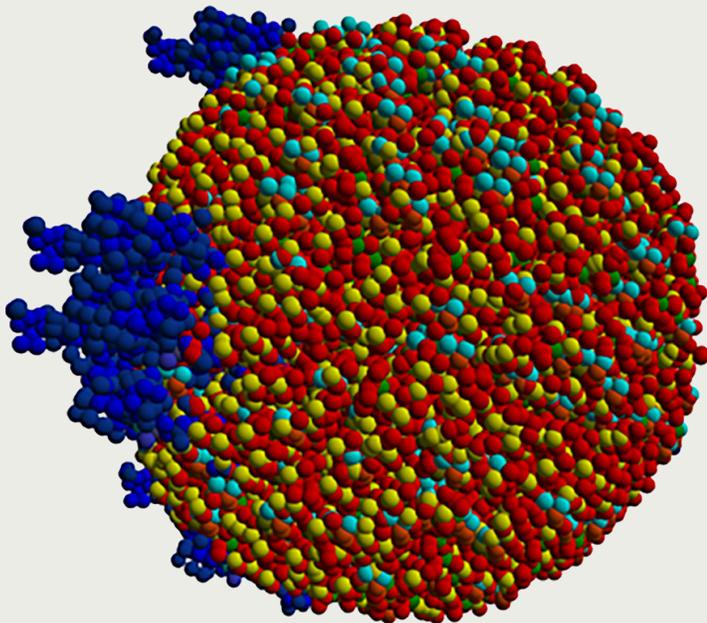
Model complex mixtures
Use Simcenter Culgi to simulate the most complex systems faster and build better products with lower carbon impact.

Simcenter Culgi covers all aspects of multiscale simulations in chemistry, crossing relevant length and time scale so that you can model all properties related to materials and processes, not only on a macroscopic level but all the way down to the molecular level through chemical interactions.

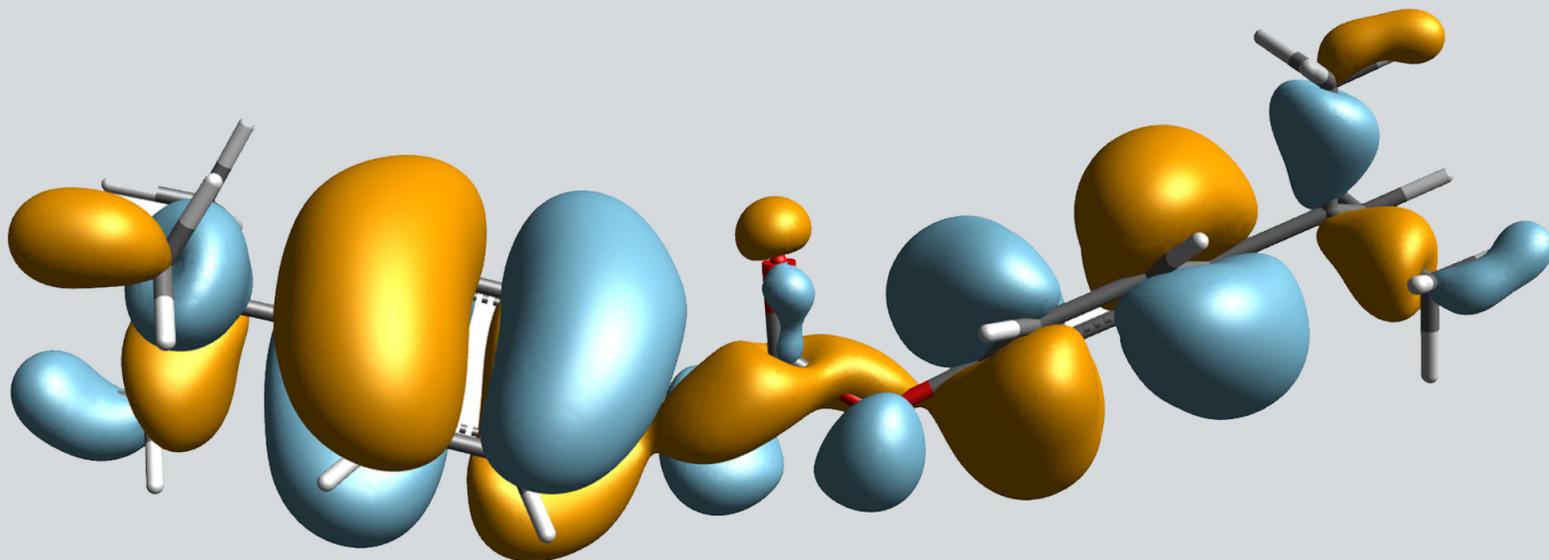### Predict chemical and physical properties
Companies use Simcenter Culgi to accelerate material development in domains such as specialty chemicals, energy storage, pharmaceuticals, personal care and cosmetics.

Examples of applications include:
- Discovering interactions between drug formulations to safely produce medicines
- Screening of green solvents for chemical manufacturing to improve sustainability
- Inventing durable polymer membranes for batteries and fuel cells
- Finding more effective chemical mixtures for oil recovery
- Improving impact strength of materials for automotive components and designing lightweight and temperature resistant composites and adhesives

Solution benefits
- Engineer better materials
- Model complex mixtures
- Predict chemical and physical properties

Simcenter Culgi

Using multiscale computational chemistry simulations to engineer better materials

Benefits
- Engineer better materials
- Model complex mixtures
- Predict chemical and physical properties

Summary

Virtual screening of novel materials in an early stage of development is a key enabler of innovation in the chemical and process industries. Using Simcenter™ Culgi™ software helps product development and material scientists design new materials with the desired properties from inception to process development on a digital platform.

Simcenter Culgi helps you cover all aspects of multiscale simulations in chemistry so scientists can model all properties related to materials and processes on a macroscopic level and down to the molecular level.

Companies can leverage the product to accelerate material development in domains such as specialty chemicals, energy storage, pharmaceuticals, personal care and cosmetics.

Capabilities

Using Simcenter Culgi helps product development and material scientists design new materials with the desired properties along the complete life cycle: inception and process development on a digital platform. Simcenter Culgi is part of the Siemens Xcelerator business platform of software, hardware and services.
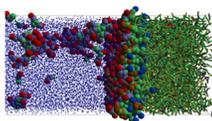
SIEMENS

Formulations

With its multiscale chemistry simulation, you can use this tool to accurately model formulation properties.

Use the complete suite of tools that enable the simulation of complex mixtures at all scales to predict chemical and physical properties for real-life applications from design to production.

Multiphase systems

You can leverage Simcenter Culgi with its powerful coarse-grained implementation for multiphase modeling.

Take advantage of automated parameterization and coarse-graining applications. Develop complex models of dozens of different molecules.

Leverage the interface's versatility to quickly create complex multiphase systems and address their quality and performance.

Gain insights into the stability of various systems, from a simple micro-emulsion to the most complex liposome configuration.

Polymers
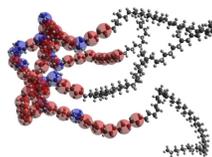
Simcenter Culgi contains all of the required tools you need to easily and automatically design a digital twin of any type of polymer formulation through multiscale modeling.

Calculate polymer properties on various scales from crystallization and reactions on the atomistic level to the morphology of phase-separated polymer blends.

Optimize formulations using a design of computations, where a large set of polymer combinations is automatically screened on the desired properties using high-performance computing.

Solutions
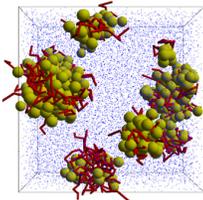
Changing regulations and novel discoveries usually force engineers to redevelop formulations, especially in the personal care industry. Properly assessing the stability, efficiency and toxicity of a new solution is a complex and expensive task.

Leverage this solution and the complete platform to quickly develop and test novel formulations.

Use automated parameterization and a molecular generator to design and model innovative solutions to react to change and explore the chemical space.

Multiscale modeling

Enable materials innovation in today's fast-paced environment by accessing Simcenter Culgi computational chemistry software, covering the entire hierarchy of material scales.

This solution includes all aspects of computational chemistry from quantum to molecular and coarse-grained modeling to informatics and thermodynamics. Run realistic models for simulations through scripted workflows that facilitate a data flow of parameters from quantum models to the continuum level.

This, combined with a comprehensive computational library, ensures that physical parameters are derived with accuracy and enables materials innovation across all lengths and time scales.

Coarse-grained simulations
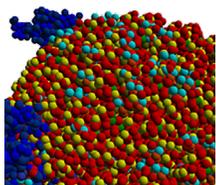
With an integrated automatic mapper and parameterization algorithm, you can apply the solution to model solutions for nano- and micro-structured chemical systems.

Without having to design the coarse-grained model, you can quickly screen for novel formulations or materials to reduce research and development (R&D) costs and accelerate innovation. You can use Simcenter Culgi computational chemistry solution to cover all common coarse-grained modeling tools ranging from Brownian to dissipative particle dynamics (DPD). You can also leverage model reactive and charged systems without needing extensive force-field development, further enhancing the R&D processes.

Mesoscopic modeling
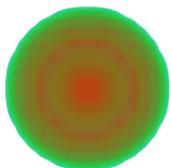
With its unrivaled mesoscopic modeling package, Simcenter Culgi offers you a unique way to model complex polymer systems.

Using phase-field models, optimize or discover novel formulations for blends and formulations.

You can use the graphical programming environment to create and study complex molecular architectures to understand how they diffuse and distribute within its systems to improve production.

Molecular dynamics
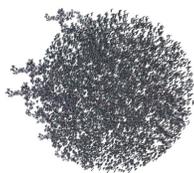
Leverage this solution to design your own workflow or force field by levering the extensive suite of molecular dynamics algorithms available.

Either by importing previously made simulations or developing your own, you can design and develop novel materials, including polymers, chemicals, formulations and so on. Leverage molecular dynamics packages to automatically develop your own force fields. Tailor the solution to your specific needs with high accuracy.

Quantum chemistry
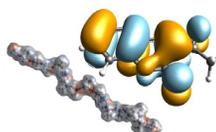
Use this product to design novel molecules in record time by using powerful quantum chemical solutions.

Coupled with ab initio methods, Simcenter Culgi provides you with a complete quantum chemistry platform to understand the underlying interaction of your systems while developing innovative materials. It includes the NWChem package to model the quantum behavior of solids and molecules to give you insight into the nanoscale of systems and understand properties related to the electronic material structure.

Applications
You can access Simcenter Culgi to address various applications in many industrial fields and domains. Below are some example application cases.

Electronics and semiconductors – Nanochip manufacturing

Design more reliable and innovative nanochips

Real Model → Computed Model (Simcenter Culgi)
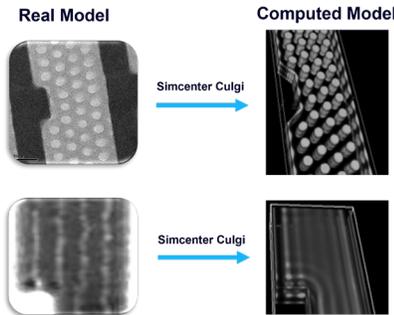
Challenge
As circuits for nanochips continue to shrink, they become more prone to defects, making them less reliable and deteriorating their performance

Solution
Adopt this solution to investigate self-assembly of the polymers during the nanochip molding

Benefits
• Understand and mitigate defects early
• Optimize design before molding
• Decrease defect rate by 20 percent

Consumer products and retail – Food packaging

Accelerate innovative package development with a digital twin

Challenge
Create new, environmentally friendly packaging without mold and leakage while fulfilling food regulations is complex and costly task
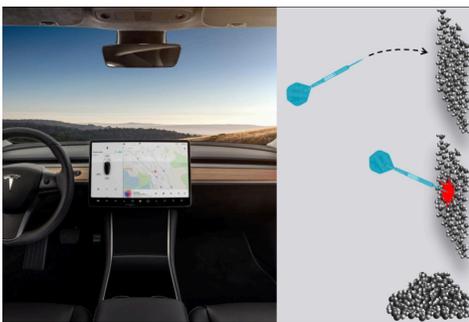
Solution
Apply Simcenter Culgi digital twin to develop innovative packaging that has the required properties and respect for food regulations

Benefits
• Cut time and cost with a digital twin
• Faster development of innovative, new packaging
• Approved by food regulators (REACH)

Automotive and transportation – Dashboard robustness

Ensure safety and efficiency of vehicles

Challenge
Plastic materials with high stiffness often have low resistance against cracking and impact. Dashboards and bumpers should be both stiff and tough

Solution
Identify new polymer formulations by using the product to explore the design space and scan for optimal rigidity and durability properties

Benefits
• Increase experimental testing efficiency
• Accelerate the design of new materials and processes
• Deliver safer and more efficient vehicles

Supported platforms
• 64-bit, Windows and Linux, serial and parallel

Siemens Digital Industries Software helps organizations of all sizes digitally transform using software, hardware and services from the Siemens Xcelerator business platform. Siemens' software and the comprehensive digital twin enable companies to optimize their design, engineering and manufacturing processes to turn today's ideas into the sustainable products of the future. From chips to entire systems, from product to process, across all industries, Siemens Digital Industries Software – Accelerating transformation.

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