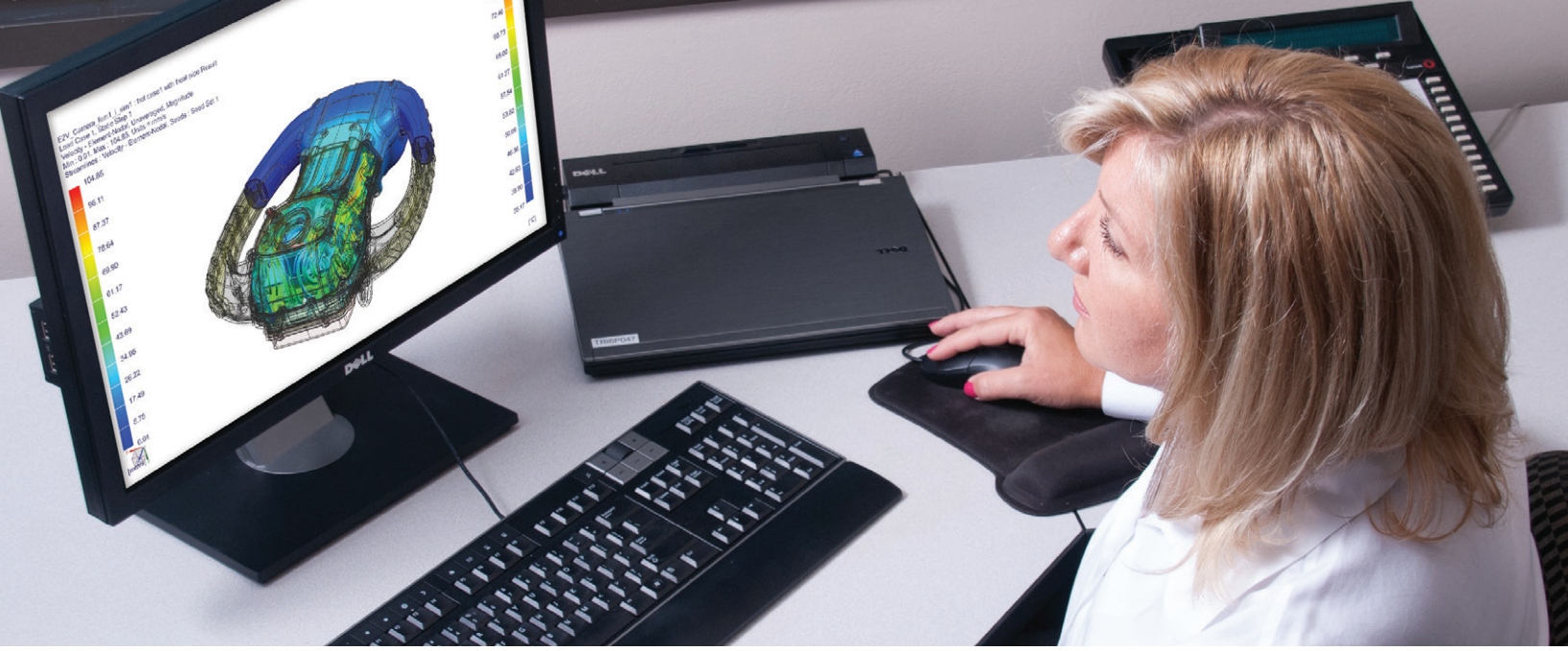


SIEMENS DIGITAL INDUSTRIES SOFTWARE

Simcenter 3D for thermal multiphysics simulation

Facilitating the modeling of nonlinear and transient heat transfer phenomena

Solution benefits

Leverage the Simcenter 3D integrated environment to make quick design changes and provide rapid feedback on thermal performance

Accurately solve the Navier-Stokes equations that describe fluid motion

Perform conjugate heat transfer analysis on complex models using the tight coupling with the Simcenter 3D Flow solver

Use Simcenter Nastran to understand thermoelastic effects with coupled physics analysis

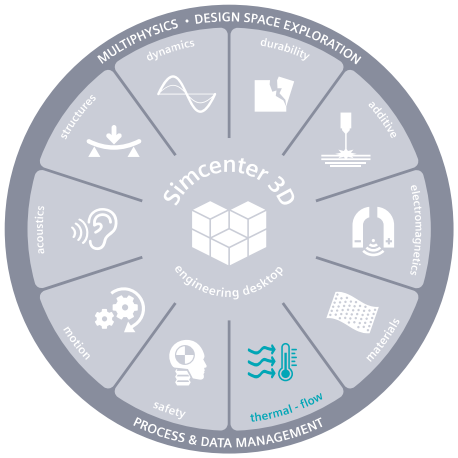
Minimize tedious rework and modeling errors with direct interfaces for ECAD systems

Analyze condensation, humidity and dust particle transport in electronics systems

Predict thermal performance for orbiting vehicles accurately and quickly

Increase collaboration and team productivity with a thermal multiphysics analysis solution that is easily integrated with your design and engineering process

Simcenter™ 3D software offers a complete solution for modeling nonlinear and transient heat transfer phenomena, accounting for conduction, convection, radiation and phase change. Dedicated thermal modeling capabilities are available, such as rapid thermal connection methods, an extensive physical model library and a wide array of thermal loads and boundary conditions. The integrated CFD solution enables fast and accurate fluid flow simulation with tight coupling to the thermal model for conjugate heat transfer analysis of products at all design development phases, limiting costly, time-consuming physical testing cycles. These tools provide flexibility and ease-of-use while addressing complex thermal challenges.



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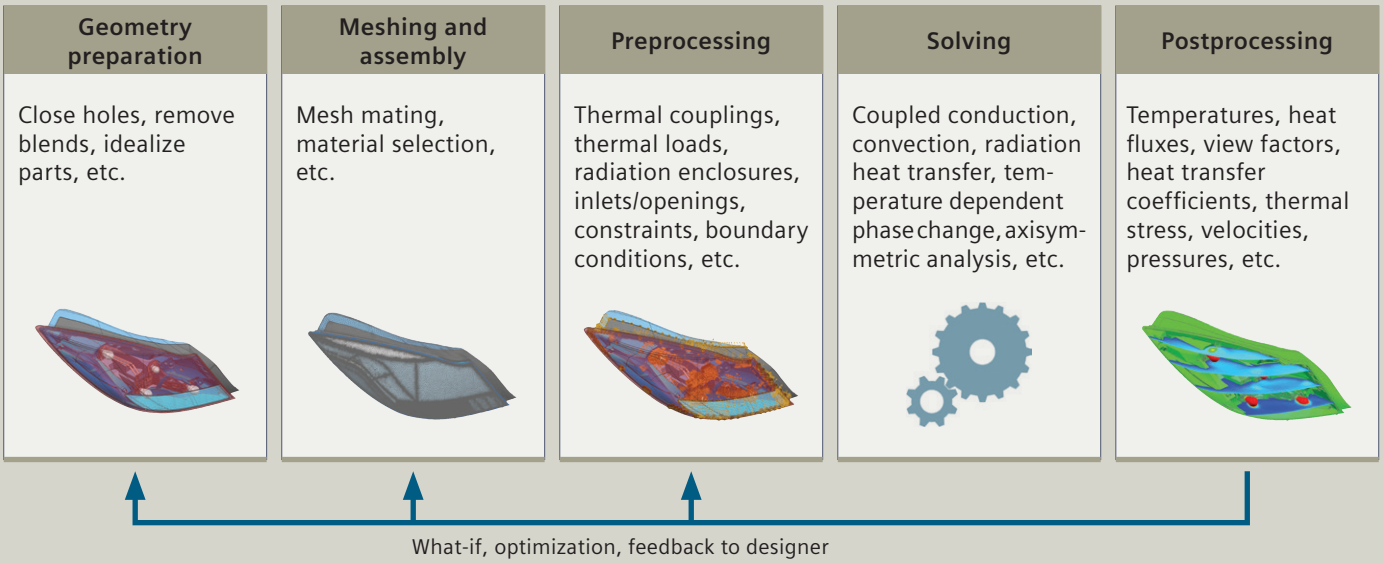
Simcenter 3D for thermal multiphysics simulation



Gain reliable thermal and flow insights

A pioneering tool in computational heat transfer modeling, Siemens Digital Industries Software's Simcenter 3D Thermal Multiphysics has been continuously developed for over three decades. It boasts a complete element, material and physical model library that is linked to enriched, high-fidelity solvers with a broad set of functionalities. This is further enhanced by intuitive pre-/postprocessing functionalities for thermal, flow and multi-physics analysts.

Easily handle thermal exchange between dissimilar interfaces

Using Simcenter 3D, thermal connections can be automatically defined between disjoint components, dissimilar meshes and nonconforming geometry. Moreover, mesh congruence and proximity requirements are eliminated, which enables the user to build and solve large assemblies quickly.

Rapid creation and easy management of fluid domains

Automatic and rapid extraction of the fluid domain using traditional Boolean operations, surface wrapping, or defining immersed bodies helps improve CFD analysis productivity. Simcenter 3D can automatically join dissimilar fluid meshes at interfaces between different parts, which allows the user to quickly investigate many "what-if" simulation scenarios involving complex assemblies. All parts within any design assembly context can be meshed independently. The resulting disjoint fluid faces can be connected to form a single fluid domain at solve time. Individual part changes can be re-integrated quickly within the assembly mesh, thereby avoiding the time-consuming task of remeshing the entire assembly.

Master complexity and productivity in industry verticals

The capabilities of Simcenter 3D for thermal simulation have been leveraged in vertical applications to satisfy specific industry needs. Simcenter 3D Space Systems Thermal enables the user to model the thermal performance and characteristics of orbiting and interplanetary vehicles. Simcenter 3D Electronics Systems Cooling leverages the flow and thermal solvers as well as the NX™ PCB Exchange capabilities in an integrated multiphysics environment to simulate 3D air flow and thermo-fluid behavior in densely packed, heat-sensitive electronic systems.

Automation and customization to manage a wide range of models

Simcenter 3D for thermal multiphysics provides an extensible solver architecture supporting user subroutines, user plugins, expressions and an open application programming interface (API) to automate and customize the product development workflow according to industry needs.

Providing a platform for multidiscipline simulation

The Simcenter 3D Thermal Multiphysics solution is part of a larger, integrated multidiscipline simulation environment with Simcenter 3D Engineering Desktop at the core for centralized pre-/postprocessing for all Simcenter 3D solutions. This integrated environment helps you to achieve faster CAE processes and streamline multidisciplinary simulation such as thermomechanical analyses based on structural solutions, conjugate heat transfer problems that are coupled with flow solutions, and coupled thermal-flow-structural problems where all three physics are intricately tied together.

Industry applications

Thermal multiphysics applications in Simcenter 3D include simulation and analysis for a range of heat transfer and fluid flow problems in aerospace, automotive, electronics, power generation, process and other industries.

Automotive and transportation

Simcenter 3D helps tackle a variety of analysis scenarios, such as under-hood thermal analysis (including porous blockage models), powertrain thermal management and thermal response and temperatures in automotive lighting systems. Further automotive applications include thermal management in automotive lighting systems, cabin comfort and humidity analysis, gas mixture modeling of exhaust and pollutant species transport. Simcenter 3D offers a complete solution for the thermal design of electric vehicles, including batteries and enclosures.

Aerospace and defense

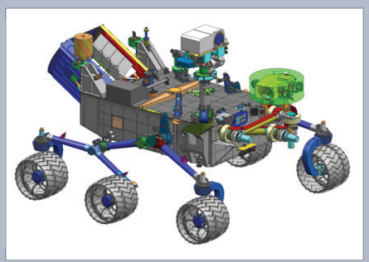
Simcenter 3D includes the ability to model the thermal response from a single component to a global aircraft system. Transporting humidity along with film condensation modeling,can be used to obtain estimates of passenger comfort. The aero-engine turbine, compressor and entire engine may be modeled for a thermal analysis or a coupled thermomechanical analysis with Simcenter Nastran® software. Thermal dissipation from electrical components can be modeled using the nonlinear Joule heating capability. Aerothermal or ablation analysis is an area of strength.

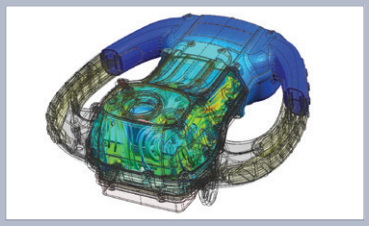
Electronics and consumer goods

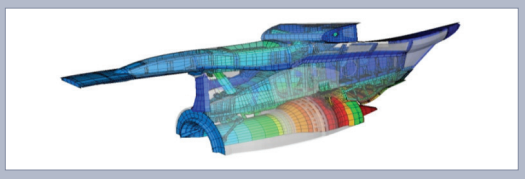
Simcenter 3D can be leveraged to meet the design requirements of compact and complex electronics systems. Examples include identifying recirculation zones and hot spots, predicting thermal response based on spatially varying and orthotropic conductivity and capacitance, and determining cooling strategies and heat sink modeling. Humidity and film condensation on electronics components can be readily simulated.

Industrial machinery

Simcenter 3D can be used to simulate a broad category of applications such as laser ablation and cutting, welding thermal response, mold-cooling analyses and phase change thermal analysis. Flow in rotating machinery can be modeled using the rotating frame of reference method with convection to both 2D axisymmetric and 3D meshes supported. In the cold-chain industry, Simcenter 3D can be used for performing predictive modeling of the quality of frozen and temperature-sensitive materials during shipping and handling. Two-phase flow conditions, with constituents having significantly different densities and viscosities, are also supported.







Whole engine thermomechanical

Spacecraft thermal performance

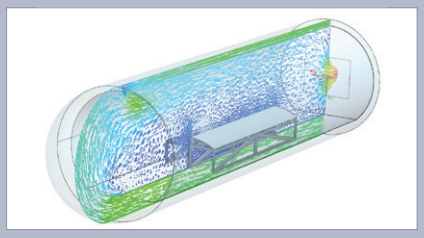
Electronics cooling

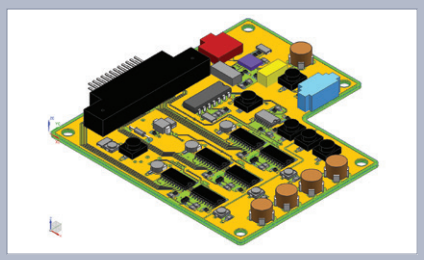
Orbital heating

Powertrain thermal management

Cabin comfort

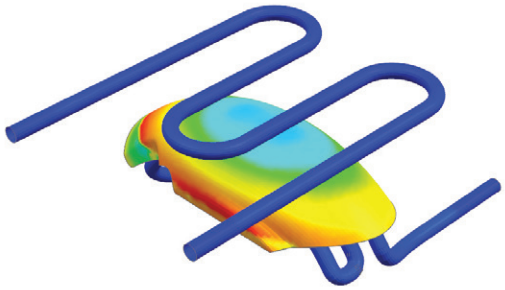
Cold chain

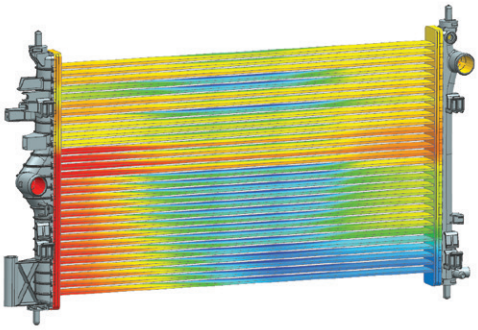


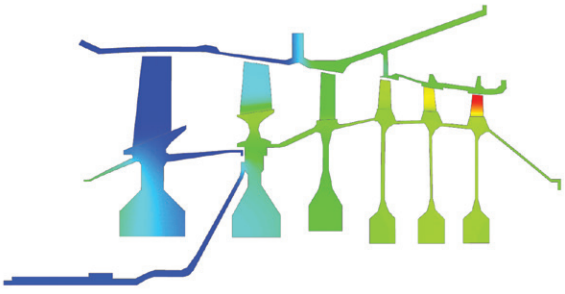


Simcenter 3D Thermal Multiphysics
Thermal

Simcenter 3D Thermal provides heat transfer solutions and can simulate conduction, convection and radiation phenomena for complex products and large assemblies. A wide range of methods are available for sophisticated radiation analysis, advanced optical properties, radiative and electrical heating models, one-dimensional hydraulic network modeling and advanced material models such as phase change, charring and ablation. Thermal control devices and articulation may also be modeled. The Simcenter 3D Thermal solver is based on a finite-element, finite-volume formulation to simulate heat transfer phenomena accurately and efficiently.





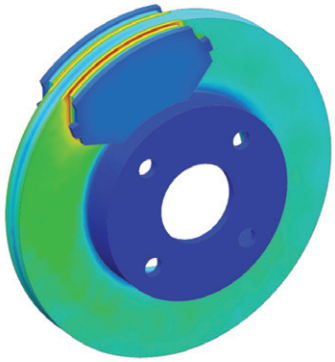


Module benefits

- Solve complex heat transfer phenomena with a comprehensive set of modeling tools
- Leverage open architecture to integrate user subroutines and grant greater control over the solution
- Use parallelized thermal solver and view factor calculations (with GPU support) to increase solution efficiency and reduce total run time
- Use Simcenter Nastran software to understand thermomechanical effects of coupled physics analysis
- Deliver full assembly finite element method (FEM) support to model complex systems

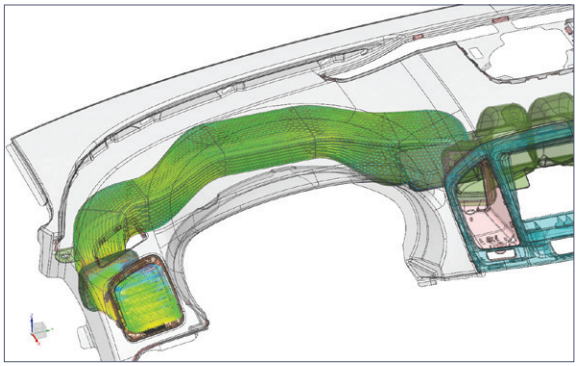
Key features

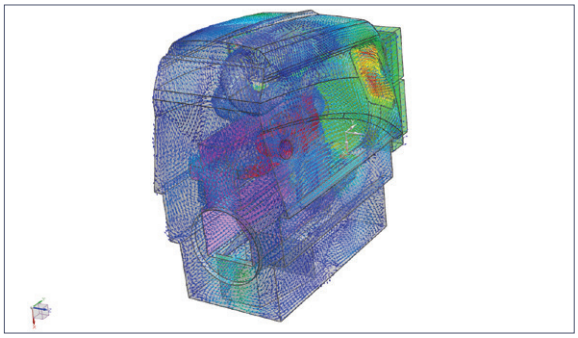
- Fully coupled conduction, radiation and convection heat transfer simulation to steady-state and transient problems
- Axisymmetric modeling, streamlined 2D-3D modeling and nonlinear thermal properties
- Thermally connect disjoint and dissimilar mesh faces and edges
- Live results post-processing & solver parameters control during solve
- Advanced radiation methods such as deterministic and Monte Carlo ray tracing and nongray multiband radiative heat transfer
- Dedicated turbomachinery-specific boundary conditions combining ducts and streams
- Seamlessly submit simulations to powerful remote machines using the integrated Simcenter 3D Remote Simulation capability

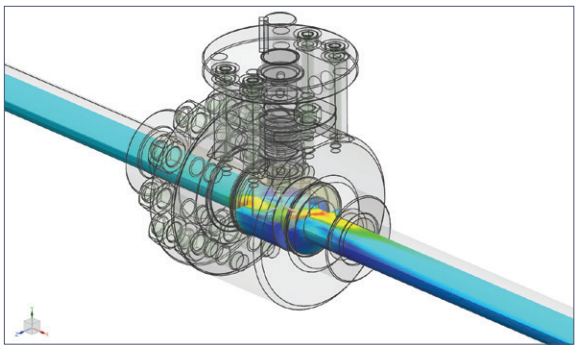


Simcenter 3D
Flow

Simcenter 3D Flow is a computational fluid dynamic (CFD) solution that provides sophisticated tools to model and simulate fluid flow for complex parts and assemblies. Simcenter 3D Flow combines the power and accuracy of the well-established control-volume formulation with cell-vertex formulation to discretize and efficiently solve the fluid motion described by the Navier-Stokes equations. The capabilities encompass internal or external fluid flow, including compressible and highspeed flows, non-Newtonian fluids, tracking of heavy particles and multiple rotating frames of reference.





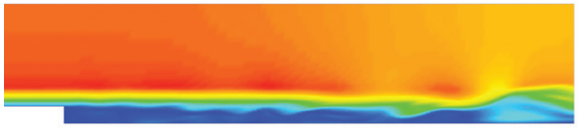


Module benefits

- Reduce costly physical prototypes by simulating fluid flow in a virtual environment
- Streamline processes that require a multidisciplinary simulation approach
- Save time and avoid errors due to transfer of data and results for multiphysics simulation
- Readily track the interface between two fluids in a sloshing problem
- Efficient and accurate rotating machinery simulation
- Couple 1D hydraulic networks with 3D flow models to simulate complex systems

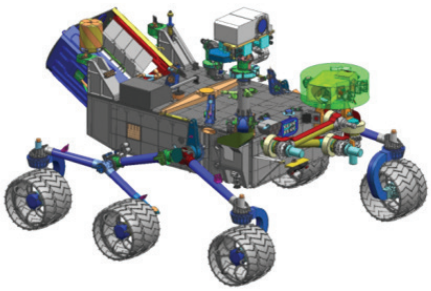
Key features

- Simulate internal- or external-flow problems in turbulent, laminar and mixed flows
- Account for forced, natural and mixed convection
- Connect dissimilar fluid meshes at interfaces between complex assemblies
- Immersed Boundary Method available for fast and easy CFD workflow
- Live results post-processing & solver parameters control during solve
- Industry-standard turbulence models such as RNG k-epsilon, Realizable k-epsilon, SST, k-omega and LES are supported
- Multi-species filling and emptying
- One and two-way fluid-structure interaction with Simcenter Nastran
- Seamlessly submit simulations to powerful remote machines using the integrated Simcenter 3D Remote Simulation capability



Simcenter 3D
Space Systems Thermal

Simcenter 3D Space Systems Thermal is the vertical application that provides a comprehensive set of tools to perform orbital thermal analyses in the Simcenter 3D environment. Simcenter 3D Space Systems Thermal helps resolve engineering challenges early in the design process and is a valuable tool for predicting and understanding thermal physics for space-bound, orbiting and interplanetary vehicles.



Module benefits

- Predict thermal performance for orbiting vehicles accurately and quickly
- Increase collaboration and team productivity with a thermal analysis solution that is easily integrated with your design and engineering process
- Maximize process efficiency with a highly automated solution that requires no additional input files and carries out the analysis in a single pass

Key features

- Model orbital heating for all planets of the solar system
- Transient view factor recalculations with articulating geometries such as sun-tracking solar panels and directional antennas
- Support for advanced thermo-optical properties, including angle and spectral dependencies
- Accurate modeling of solar radiation that accounts for atmospheric effects such as turbidity, and ground reflection and shadowing
- Multilayer shell formulation for modeling multilayer insulation, composite panels and thermal protection systems
- View simulation results in the Orbit Visualizer for a clear view of the evolution of thermal characteristics over the course of the orbits
- Seamlessly submit simulations to powerful remote machines using the integrated Simcenter 3D Remote Simulation capability

Simcenter 3D
Electronic Systems Cooling

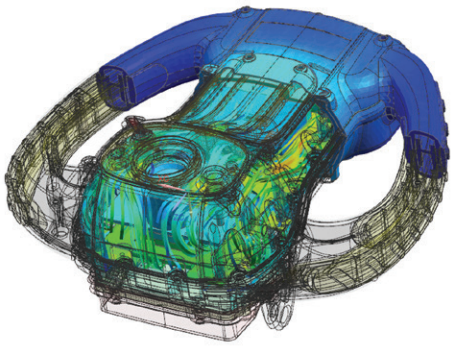
Simcenter 3D Electronic Systems Cooling software is an industry-specific vertical application that leverages Simcenter 3D Thermal Multiphysics solvers as well as NX™ software and the NX PCB Exchange module capabilities in an integrated multiphysics environment. This enables you to simulate 3D airflow and thermofluid behavior in densely packed, heat-sensitive electronic systems.

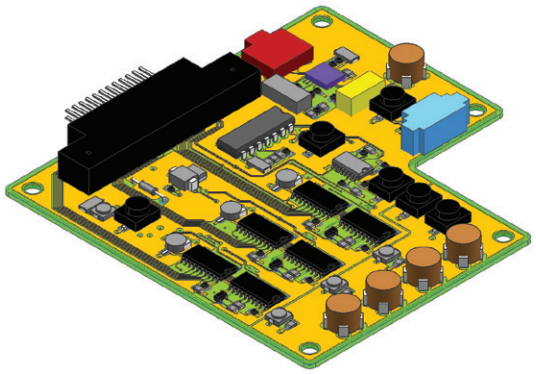
Module benefits

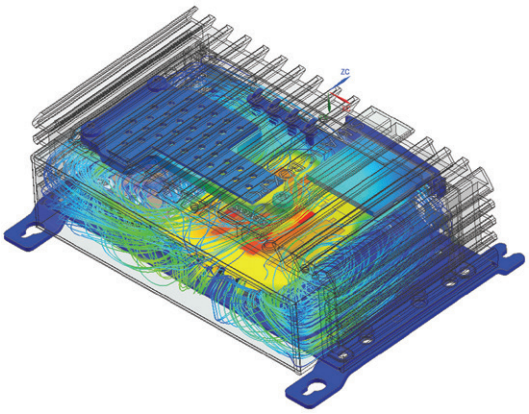
- Simulate 3D airflow and thermal behavior in electronic systems
- Minimize tedious rework and modeling errors with direct interfaces to electrical computer-aided design (ECAD) systems
- Transport condensation, humidity and dust particles in electronics systems

Key features

- With NX PCB Exchange, fully three-dimensional board designs can be obtained from the leading printed circuit board (PCB) and flexible printed circuit (FPC) layout software packages from companies such as Expedition, Zuken, Cadence and Altium
- Model the electrical network along with Joule heating with temperature-dependent resistivity
- The immersed boundary method provides a faster, more convenient worklow for fluid mesh generation
- A catalog of fan curves is available out-of-the-box (OOTB), which can be extended with additional manufacturer data



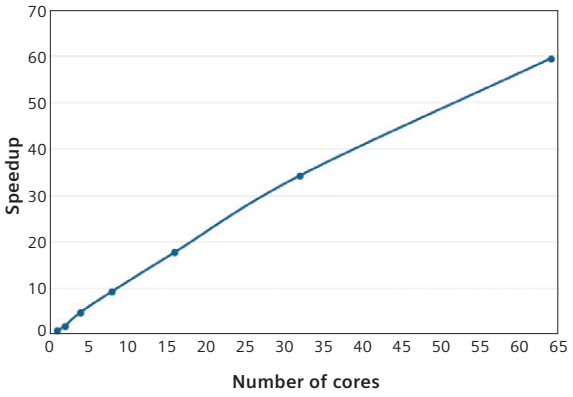




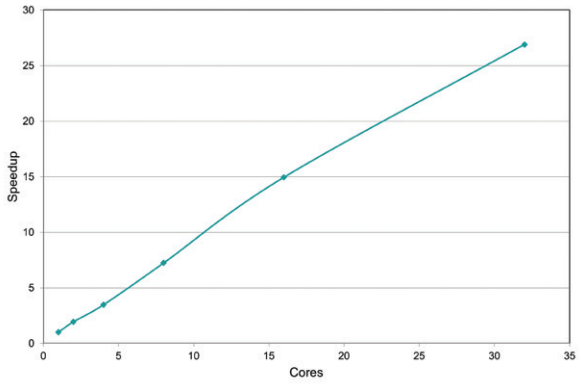
Simcenter 3D
Thermal Multiphysics HPC

Simcenter 3D Thermal Multiphysics high-performance computing (HPC) leverages hardware systems configured as a multiprocessor desktop or a multi-node cluster. One license of Simcenter 3D Thermal/Flow DMP together with the prerequisite licenses can be used to produce a solve over as many processors as available.

Canadarm view factor calculation scaling (~66 million view factors)



CFD analysis: Humidity transport in a chiller



Module benefits

- Leverage the flexibility of solving on a single machine or across a distributed network or cluster
- Maximize the value of your hardware investments and greatly improve your solution

Key features

- Cores may be co-located on a single workstation, distributed over a local area network (LAN), or exist within a standalone computational cluster
- Limitations on the maximum number of cores are eliminated, allowing solve speeds to scale up or down based on the number of available cores, not the number of available licenses
- Domain decomposition techniques are included for solving large-scale thermal models and flow models
- The Simcenter 3D Thermal Multiphysics solver features parallel computation of radiation view factors, radiative heating and a solution for the thermal model
- Enables GPU-based view factor computation and ray tracing for rapid radiative heat transfer computations

Capabilities chart

General capabilities	Specific capabilities	Simcenter 3D Thermal Multiphysics	Simcenter 3D Space Systems Thermal	Simcenter 3D Electronics Systems Cooling	Simcenter 3D Thermal Multiphysics HPC
Solver(s)	DMP thermal parallel processing	+	+	+	•
	DMP flow parallel processing	+		+	•
	Thermal parallel processing	+	+	+	•
	Flow parallel processing	+		+	•
	Multiphysics solve	+	+		
	Multithreading	•	•	•	
	User subroutine	•	•	•	
	User plugin	•	•	•	
File export	cgns	•		•	
	esatan		•		
	INPF	•	•	•	
	Mapping constraint	•	•	•	
	primitive		•		
	Sinda-85		•		
File import	cgns	•		•	
	I-DEAS scratch file	•	•	•	
	INPF	•	•	•	
	NX xml	•	•	•	
	plot3d	•		•	
	primitive		•		
	Universal	•	•	•	
Modeling objects	Ablation charring	•	•		
	Active heater controller	•	•	•	
	Advanced parameters flow	•		•	
	Advanced parameters thermal	•	•	•	
	Axisymmetry source zone (multiphysics only)	•			
	Convection properties	•		•	
	Duct convection correction	•	•		
	Duct head loss	•	•		
	External conditions	•		•	
	External solver	•			
	Fan speed controller	•		•	
	Generic entity	•	•	•	
	Homogeneous gas mixture	•		•	
	Immiscible fluid mixture	•		•	
	Joint	•	•		
	Joint orbital tracker		•		
	Layer	•	•	•	
	Monte Carlo settings	•	•	•	
	Multiphysics thermal output request	•			
	Nongeometric element	•	•	•	

General capabilities	Specific capabilities	Simcenter 3D Thermal Multiphysics	Simcenter 3D Space Systems Thermal	Simcenter 3D Electronics Systems Cooling	Simcenter 3D Thermal Multiphysics HPC
Modeling objects *(continued)*	Non-Newtonian fluid	•		•	
	Orbit		•		
	PCB layer		•	•	
	PCB via		•	•	
	Planar head loss	•		•	
	Reference temperature	•	•	•	
	Rotational periodicity source zone (multiphysics only)	•	•		
	Target temperature	•	•	•	
	Target temperature change	•	•	•	
	Thermal solution parameters (multiphysics only)	•	•		
	Thermal source zone (multiphysics only)	•			
	Thermo optical properties	•	•	•	
	Thermo optical properties advanced	•	•	•	
	Thermo optical properties state	•	•	•	
	Thermostat	•	•	•	
	Tracer fluid	•		•	
Advanced Fluid Modeling required during solve as well	3D Hybrid mesh	•		•	
	Constraint - auto refinement	•		•	
	Constraint - contact prevention	•		•	
	Constraint - local resolution	•		•	
	Boundary layer mesh control	•		•	
	CGNS import / export	•		•	
	PLOT3D import	•		•	
	Sim fluid domain SSSO	•		•	
	Sim fluid domain mesh	•		•	
	Recipe create (output body)	•		•	
	Recipe create (output body + 2D mesh)	•		•	
	Recipe create (output 2D mesh)	•		•	
	Recipe create from 2D element faces	•		•	
	Tet Mesh (with BL mesh control)	•		•	
	WRAP (output body)	•		•	
	WRAP (output body + 2D mesh)	•		•	
	WRAP (output 2D mesh)	•		•	
	WRAP recipe with constraints	•		•	
	WRAP recipe from 2D element faces	•		•	

General capabilities	Specific capabilities	Simcenter 3D Thermal Multiphysics	Simcenter 3D Space Systems Thermal	Simcenter 3D Electronics Systems Cooling	Simcenter 3D Thermal Multiphysics HPC
Solution attributes and parameters	Fixed turbulent viscosity	•		•	
	Standard K-epsilon	•		•	
	RNG K-epsilon	•		•	
	Realizable K-epsilon	•		•	
	K-Omega turbulence model	•		•	
	LES-Large eddy simulation	•		•	
	Mixing length	•		•	
	Laminar flow	•		•	
	Spalart-Allmaras	•		•	
	Shear stress transport (SST)	•		•	
Loads	Thermal loads (heat load, heat flux,heat generation)	•	•	•	
	Gravity (component, magnitude and direction)	•	•	•	
	Rotation (model subset and whole model	•	•	•	
	Thermal convecting zone	•	•	•	
	Thermal loads (heat load, heat flux,heat generation)	•	•	•	
	Thermal stream	•	•	•	
	Thermal void	•	•	•	
Constraint	Axisymmetry target zone	•	•	•	
	Convection to environment	•	•	•	
	Initial conditions	•	•	•	
	Film cooling	•		•	
	Flow target zone	•		•	
	Mapping	•	•	•	
	Mapping target zet	•	•	•	
	Rotational periodicity target zone	•	•	•	
	Simple environment radiation	•	•	•	
	Symmetry target zone	•	•	•	
	Temperature	•	•	•	
	Thermal target zone	•	•	•	
	Transverse gradient target zone	•	•	•	
Simulation objects	Advanced controls	•	•	•	
	Deactivation set	•	•	•	
	Deactivation set advanced	•	•	•	
	Disjoint fluid mesh pairing	•		•	
	Duct flow boundary condition	•	•	•	
	Flow blockage (porous, isotropic, orthotropic, solid)	•		•	
	Flow boundary condition				
	Bursting membrane	•		•	
	Convective outflow	•		•	
	Flap	•		•	
	Inlet	•		•	
	Internal fan	•		•	
	Opening	•		•	
	Outlet	•		•	
	Recirculation loop	•		•	
	Static pressure	•		•	

General capabilities	Specific capabilities	Simcenter 3D Thermal Multiphysics	Simcenter 3D Space Systems Thermal	Simcenter 3D Electronics Systems Cooling	Simcenter 3D Thermal Multiphysics HPC
Simulation objects *(continued)*	Flow surface (boundary and embedded, with obstructions)	•		•	
	Fluid domain (fluid mesh and surface mesh)	•		•	
	Free molecular heating		•		
	Immersed boundary	•		•	
	Immersed ducts	•	•	•	
	Interface resistance	•	•	•	
	Joule heating (current, electrica lcoupling, voltage)	•	•	•	
	Merge set		•		
	Mixing plane (disjoint and joint)	•		•	
	Moving frame of reference (rotating and translating)	•		•	
	Orbital heating		•		
	Override set - thermal properties	•	•	•	
	Particle injection	•		•	
	PCB component		•	•	
	Periodic boundary condition (rotational and translational)	•		•	
	Printed circuit board		•	•	
	Protective layers	•	•		
	Radiation (all radiation and enclosure radiation)	•	•	•	
	Radiation thermal coupling (gap and object-to-object)	•	•	•	
	Radiative element subdivision	•	•	•	
	Radiative heating	•	•	•	
	Report	•	•	•	
	Screen	•		•	
	Selective results	•		•	
	Solar heating	•	•		
	Solar heating space	•	•		
	Solid motion effects (articulation, spinning)	•	•		
	Supersonic inlet	•		•	
	Symmetry plane	•		•	
	Thermal coupling	•	•	•	
	Thermal coupling – advanced	•	•	•	
	Thermal coupling – convection	•	•	•	
	Thermal coupling – radiation	•	•	•	
	Thermal devices (Peltier cooler, heat pipe)	•	•	•	
	Thermal rotational periodicity	•	•	•	
	Thermal streams junction	•		•	

General capabilities	Specific capabilities	Simcenter 3D Thermal Multiphysics	Simcenter 3D Space Systems Thermal	Simcenter 3D Electronics Systems Cooling	Simcenter 3D Thermal Multiphysics HPC
Catalogs	Advanced parameters	•	•	•	
	Component		•	•	
	Duct convection correction factors	•	•	•	
	Fan catalogs			•	
	Fan curves	•		•	

Legend:

- • = included in module
- \+ = additional product required

Note: Simcenter 3D Engineering Desktop is a minimum prerequisite for all Simcenter 3D products.
Other dependency or prerequisites may apply for individual products.

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