Appendix P

Multi-Physics Simulation Technology in NX

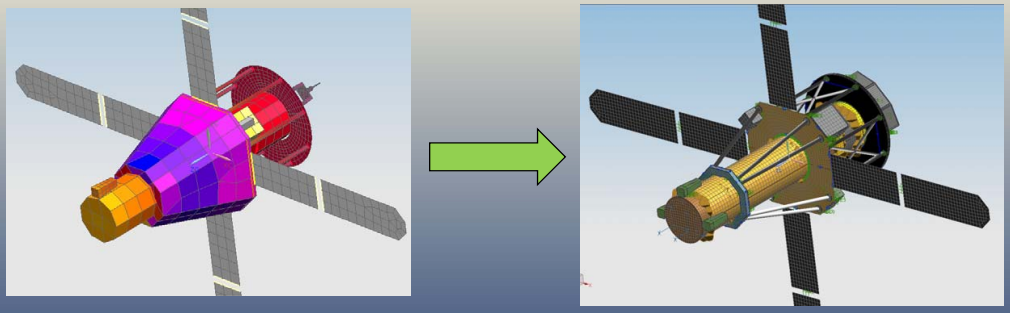
Christian Ruel
(Maya Htt, Canada)

Abstract

As engineers increasingly rely on simulation models within the framework of a collaborative environment, demands for effective solution systems that bridge the gap between multi-disciplinary fields such as thermal, flow, structural and electrical fields are becoming more and more frequent. To solve numerically these complex and coupled fields simultaneously, a comprehensive matrix that includes all the terms in all physical fields should be resolved. However, it is not only extremely difficult and challenging computationally, but also infeasible as typically different physical fields have different behavior that requires different meshing to be modeled correctly. MAYA has developed and maintained concurrent solve of thermal and flow fields which has helped solve efficiently and accurately coupled thermal and flow applications. To enable thermal and structural interaction, MAYA has developed various tools for mapping thermal results to structural models and, more recently, developed a multi-physics application that allows sequential coupling of NX Thermal and NX Nastran allowing the simulation of thermally induced large deformations on a structure and, in turn, their effects on the way heat transfer takes place.

Multi-Physics Simulation Technology in NX

European Workshop on Thermal & ECLS Software – Nov 2011



Christian Ruel
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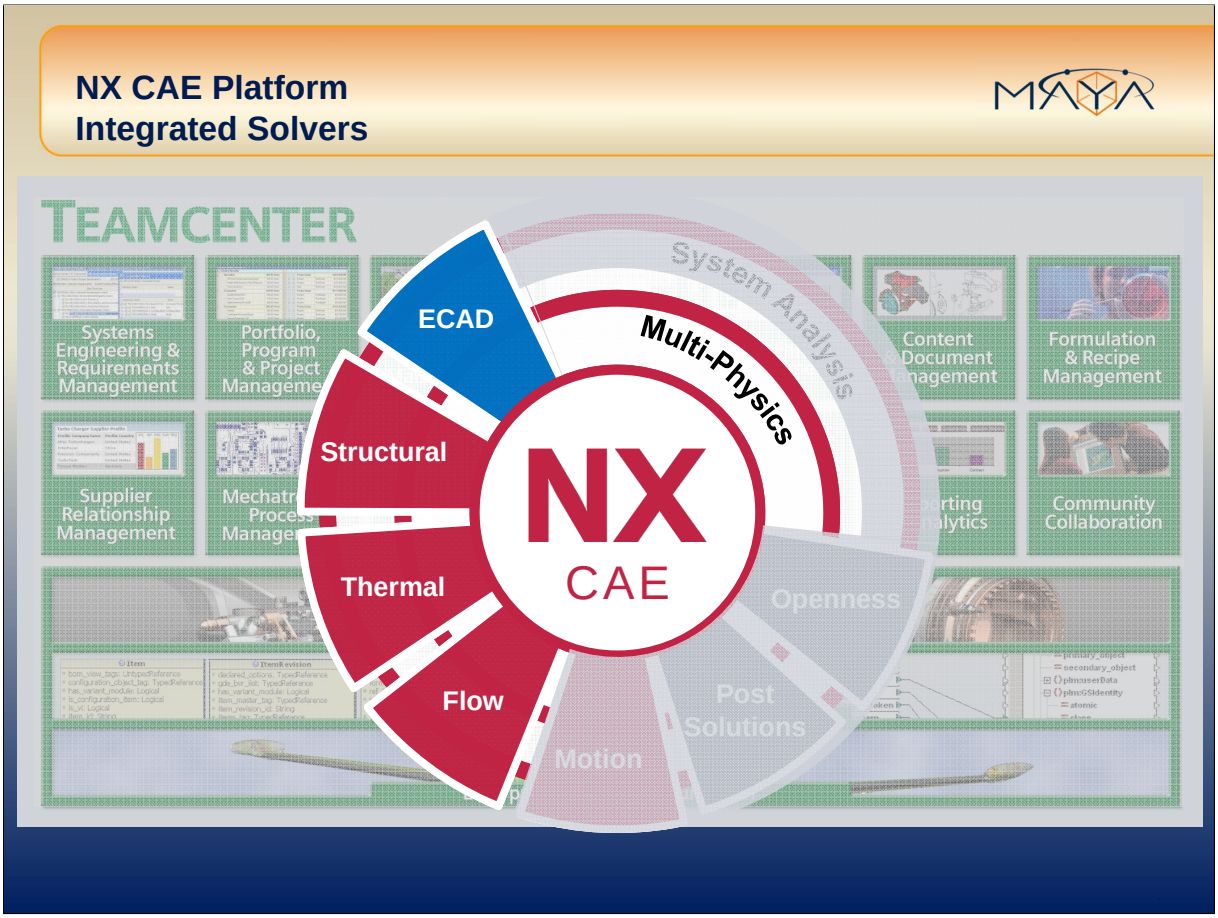
Page 1

NX Simulation

Unmatched breadth and depth of integrated CAE solutions

Advanced Meshing	Linear Structures	Thermal	Flow	Motion and Controls	Assembly Management
Multi-CAD Geometry Editing	Nonlinear Structures	Electronics Systems Cooling	FE Correlation and Update	Durability	Knowledge Automation
Multi-Solver Support	Response Dynamics	Space Systems Thermal	Laminate Composites	Optimization	Integrated Data Management

Nastran
Ansys
Abaqus
LS-Dyna
Recurdyn
Adams


NX CAE Platform
Integrated Solvers
TEAMCENTER
Systems Engineering & Requirements Management
Portfolio, Program & Project Management
Content & Document Management
Formulation & Recipe Management
Supplier Relationship Management
Community Collaboration
System Analysis
ECAD
Multi-Physics
Structural
Thermal
Flow
NX
CAE
Openness
Post Solutions
Motion

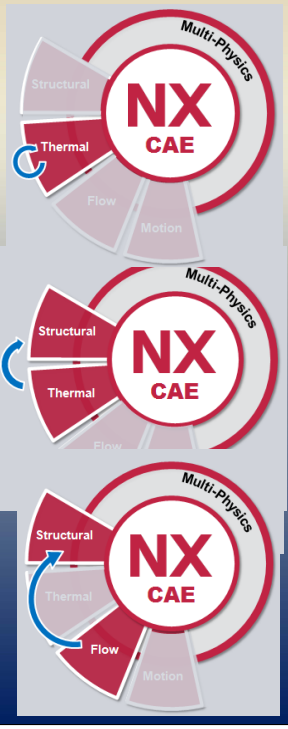

Thermal / Flow Solutions
NX
SPACE SYSTEMS THERMAL
NX
ELECTRONIC SYSTEMS COOLING
NX
ADVANCED FLOW
NX
ADVANCED THERMAL
NX
FLOW
NX
THERMAL

Coupled Physics Modeling

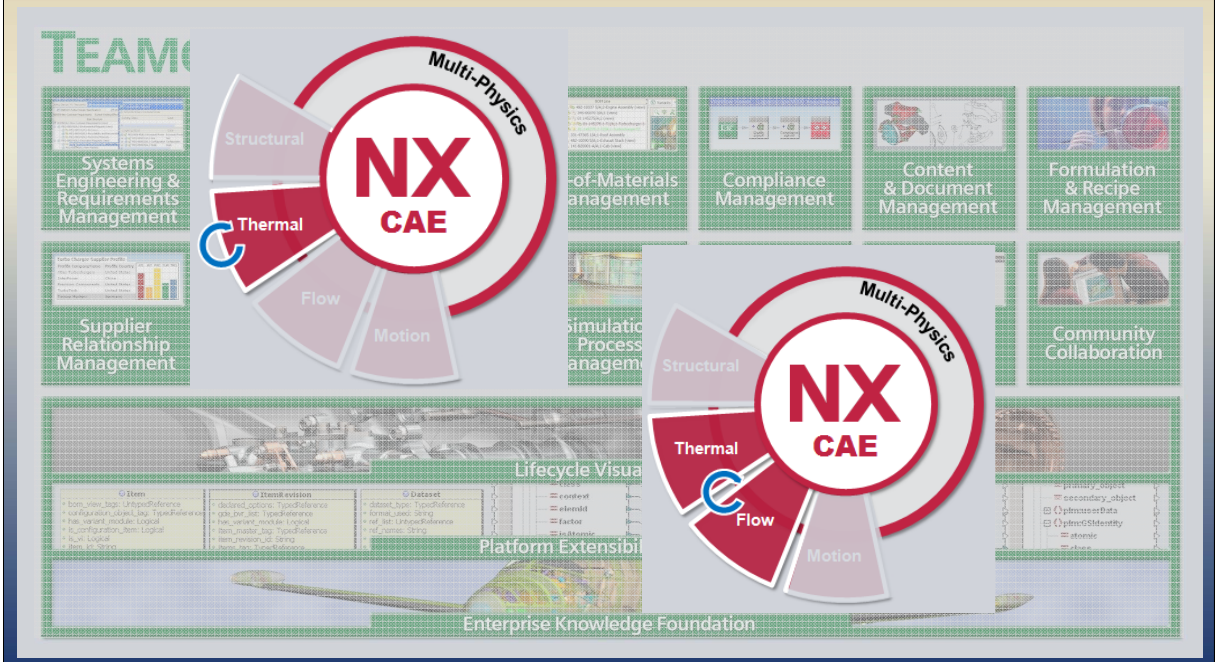
Thermal-Fluid
- NX Thermal incorporates a fully-coupled 1D fluid network solution
- NX Thermal and NX Flow are fully coupled
- Supports dissimilar thermal/fluid mesh at convecting surfaces

Thermal-Structural
- NX Thermal temperature results can be mapped onto dissimilarly-meshed structural model, as thermal pre-loads or spatially varying temperature load
- Bidirectional coupling between NX thermal and NX Nastran: effects of temperatures on the structure and, vice versa, of displacements on the thermal solution

Fluid-Structural
- NX Flow can map temperature and pressure results onto dissimilarly-meshed structural model
- One-way fluid-structural: pressure results from NX Flow used by NX Nastran to compute stresses, deformations



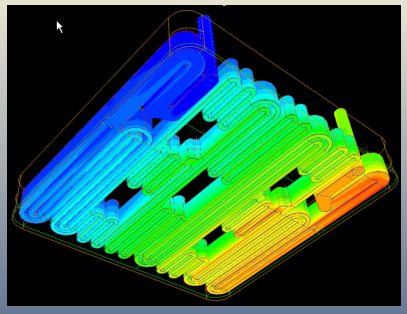
NX CAE Platform
Integrated Thermal-Fluid Solvers



Thermal to 1D-Flow Coupling

Thermal and 1D Flow models are fully coupled

- Forced and natural convection
- Flow and convection resistances are based on known correlations
- Handles all types of conjugate heat transfer
- Mesh can be fully disjoint at the fluid/solid boundaries

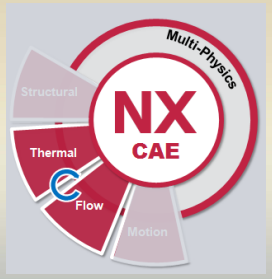


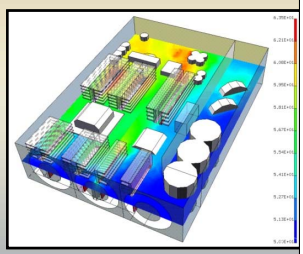
Thermal to CFD Coupling

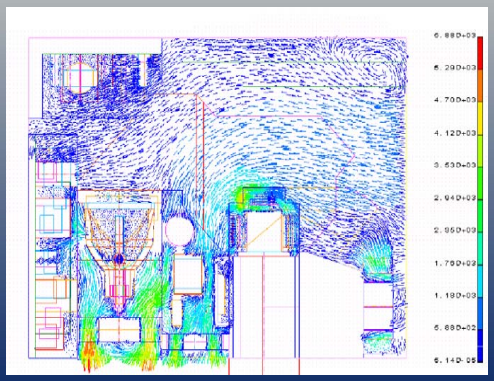
NX Thermal and NX Flow can be fully coupled

- Two separate solvers running concurrently
- Boundary condition exchange frequency can be controlled.
- Meshes can be fully disjoint at fluid/solid interface.

Handles all types of conjugate heat transfer problems.



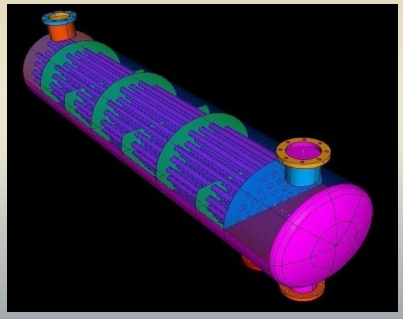


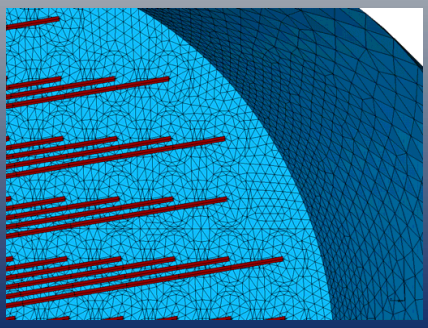


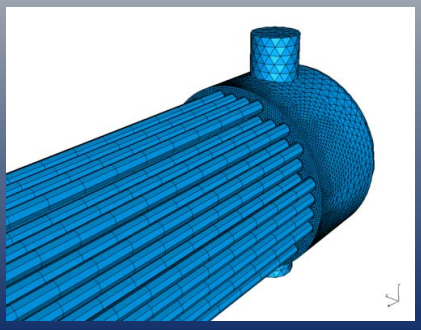
1D to 3D Flow Coupling

1D Flow network can be connected to CFD 3D flow domain

- Boundary conditions at connections are automatically determined: pressure or mass flow
- Conservation of mass and energy at the connections







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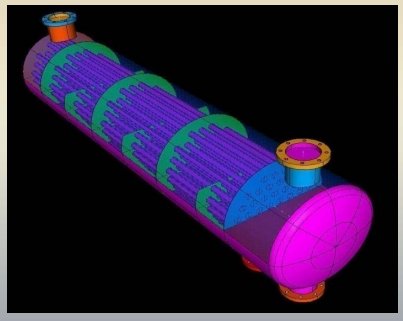
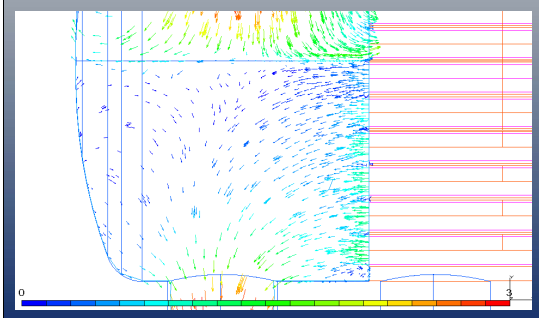
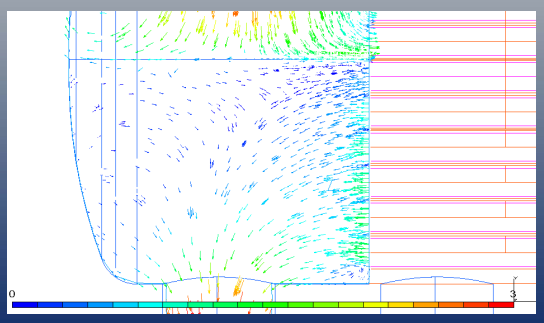


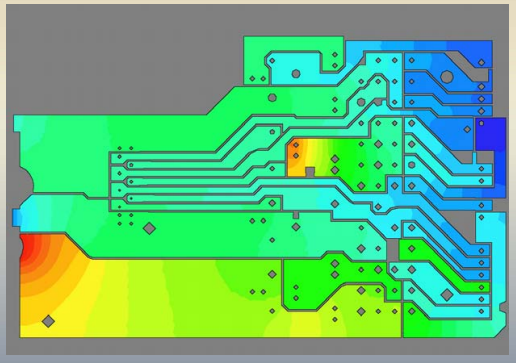




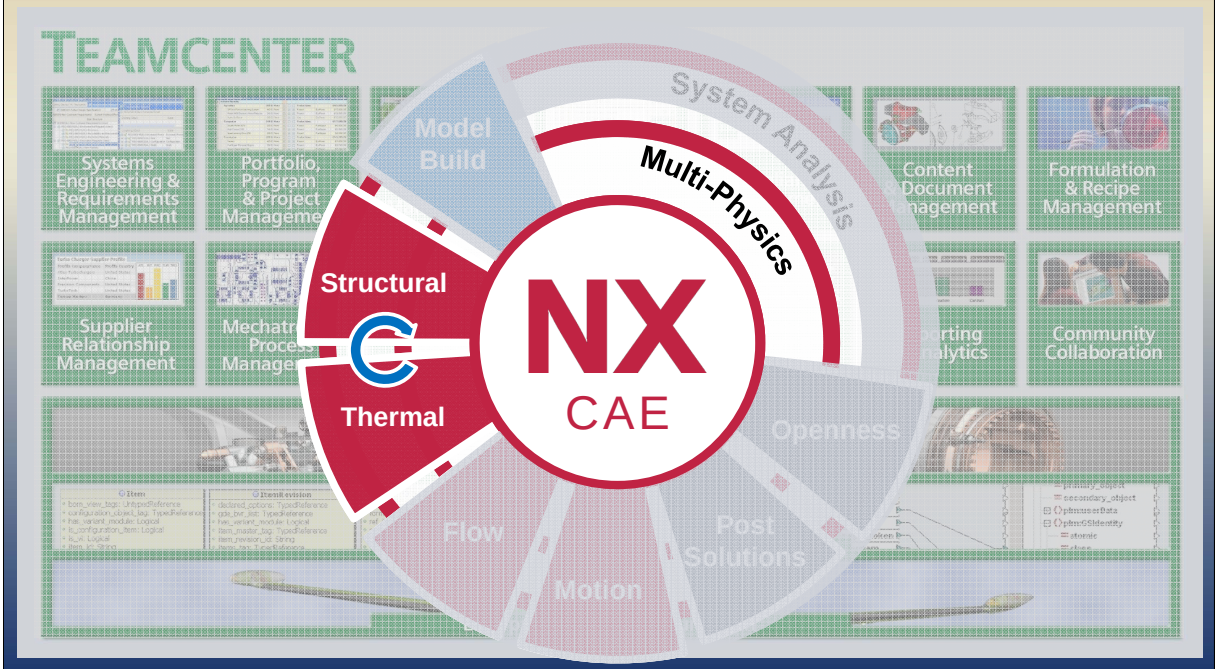
Electrical-Thermal Coupling

Joule Heating

- Electrical network solved based on material electrical resistivity and voltage and current boundary conditions
- Resulting ohmic losses are automatically applied to thermal network



NX CAE Platform
Integrated Thermal-Structural Solvers

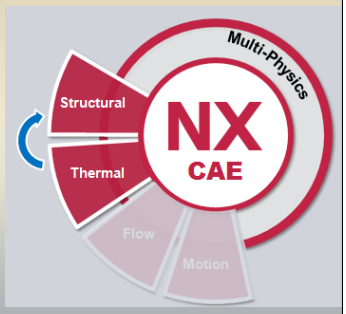


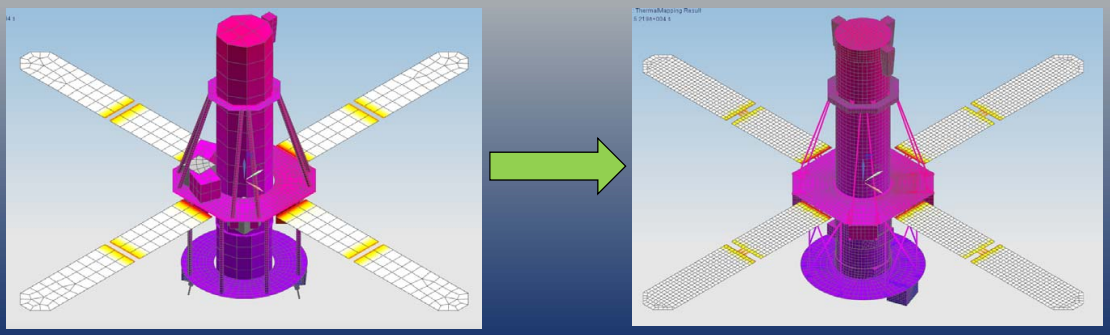
Thermo-Structural Mapping

Temperature results from an NX Thermal model can be mapped onto a structural model

- Models can have different meshes
- User can guide and control the mapping process through target sets and mapping zones.

Geometric proximity is used to find the nearest thermal element for every structural node

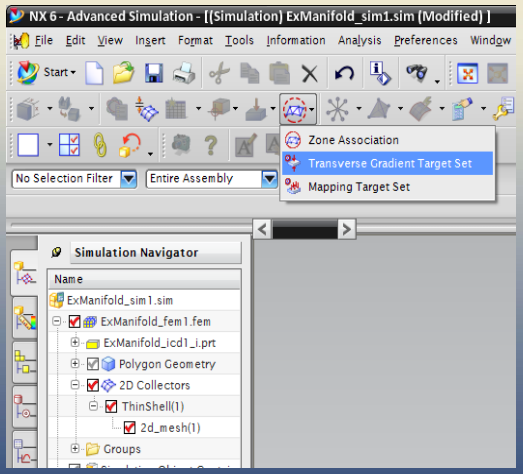


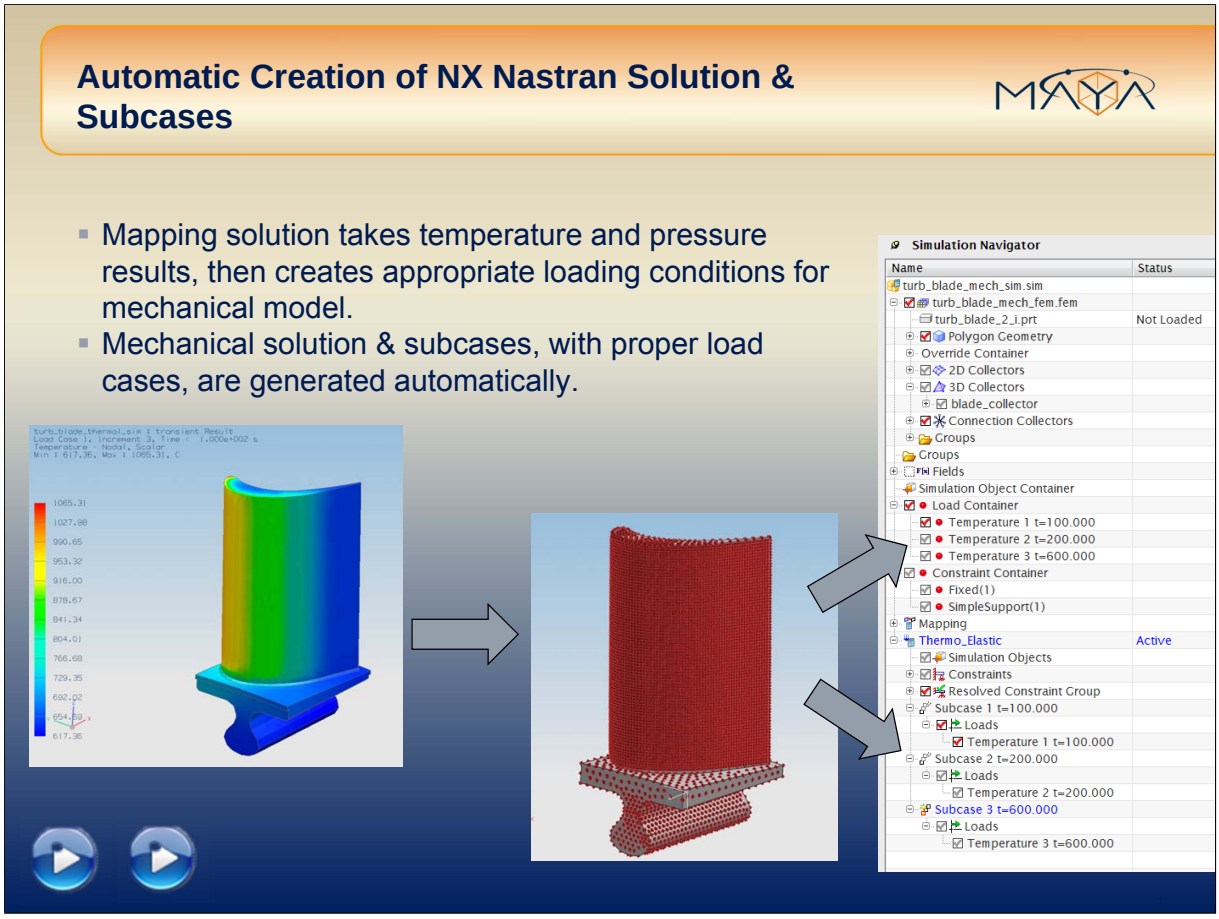


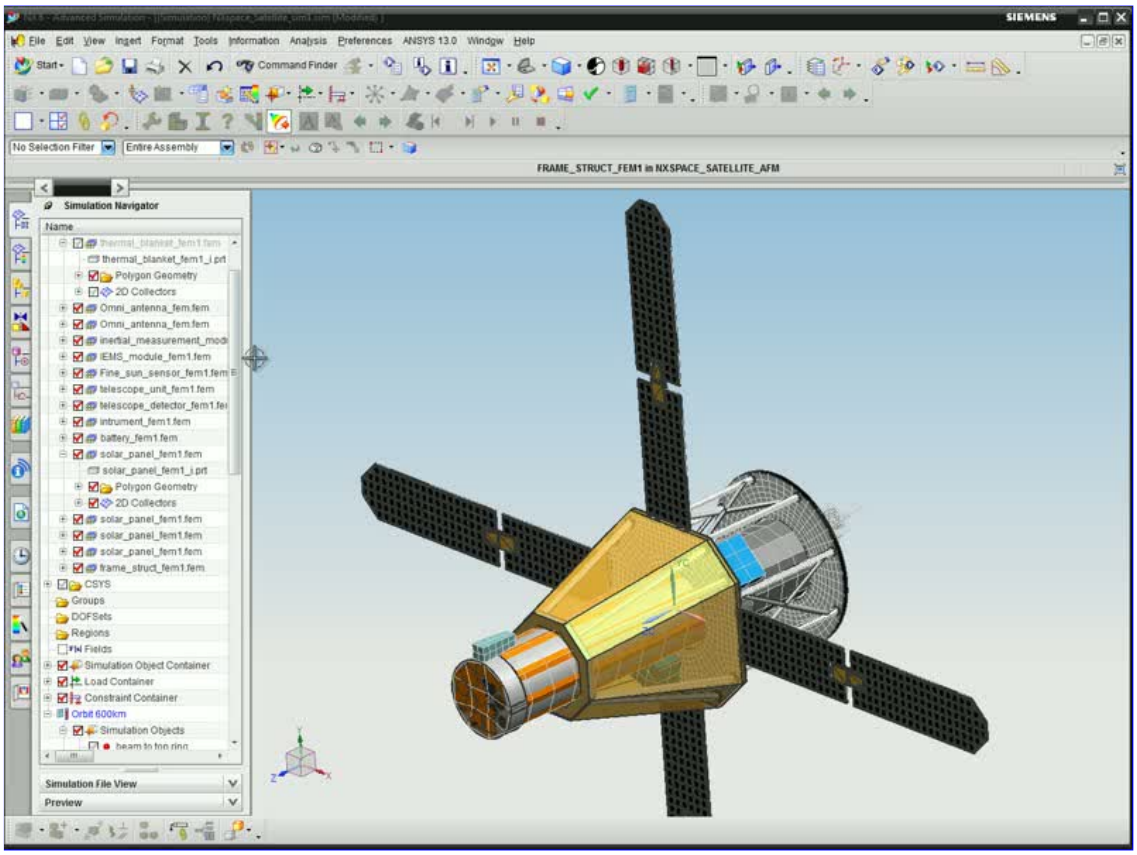
Temperature Mapping Control

User defined constraints can be used to better control the mapping process

- Zone association forces the mapping between specific sets of elements
- Transverse gradient sets identifies element pairs between which a transverse gradient should be calculated
- Exclude element sets specify thermal elements to ignore during mapping, e.g. for multi-layer insulation (MLI)







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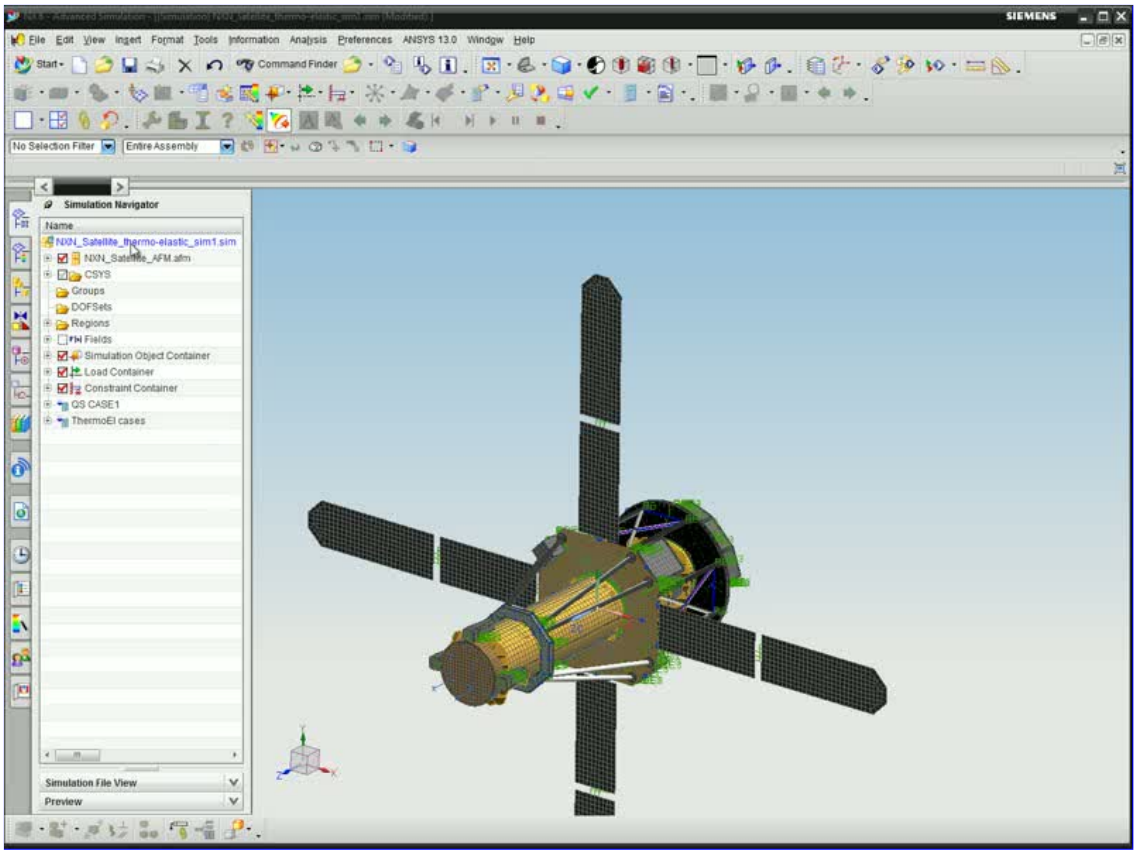

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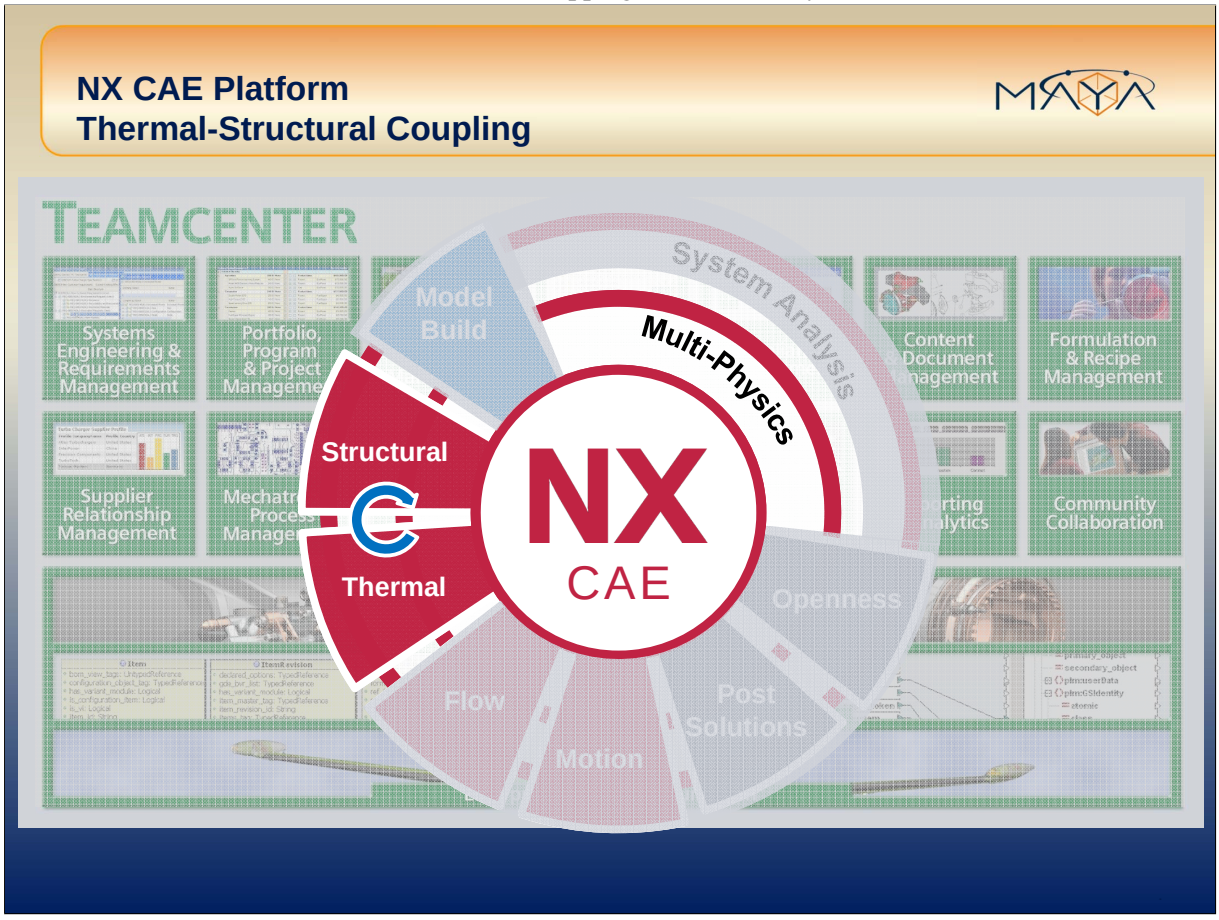
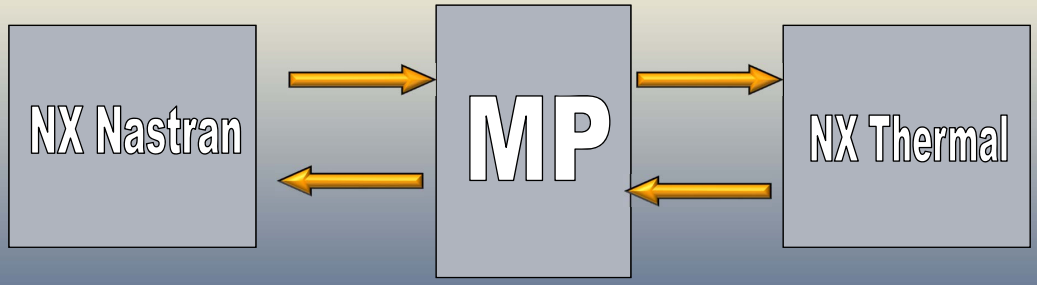


Thermal-Structural Coupling

- Bidirectional coupling between thermal and structural solutions
- Based on NX Advanced Thermal and NX Nastran Solution 101 (linear statics including linear contact)
- Two-way couplings, offers capability to analyze a variety of cases:
  - Thermal loads on structural model
  - Varying gap conductance on thermal model
  - Contact pressures
  - Changes to radiation enclosures
- Steady-steady, or transient-steady (quasi-static) problems to be supported

Thermal-Structural Coupling
NX Multi-physics (MP) Application

- MP is designed as a middleware which connects NX Thermal and NX NASTRAN



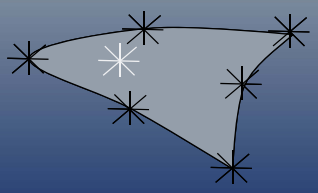
Thermal-Mechanical Coupling
Solution Data Passed between Solvers

- Solution data is passed from solvers to MP, MP maps the data onto the target solver's mesh
- Solution data from NX Nastran
  - Nodal displacements
  - Gap distances
  - Contact pressures
- Solution data from NX Thermal
  - Temperatures
  - Temperature gradients through shells
- MP manages the solve, monitors 'coupled' convergence and coupled iterations. Information passed to solvers includes:
  - Begin, end time intervals
  - Case labels for Nastran
  - Output options

MP Mapping - Supporting Different Meshes

MP gets information about the solver meshes in the mesh setup stage
- Meshes are sent through API's from the solver
- Validation
- Similarity check (proximity)
- Identity check (same mesh?)

Mapping associations performed during solve time
- Associate a node on the target mesh to an element in the source mesh
- Provides data structure for quick interpolation of solution data



Convergence Monitoring
MP vs. Solver Responsibilities

Loose Coupling (transient only):

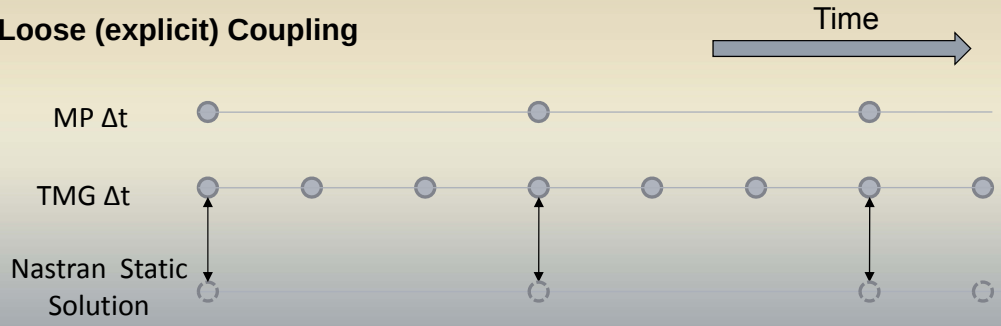
- No coupled convergence check, only one exchange of data per coupling time step

Tight Coupling:

- Solvers are responsible to compute their individual solutions to the convergence criteria specified in their input decks
- Solvers report their convergence status to MP at the end of each solve they do. MP input file has setting to determine subsequent action (CONTINUE or STOP)
- "Coupled" convergence is monitored by MP, checking either a
  - maximum norm convergence criteria, $\max(|\Delta x|)/ \text{mean}\{|x|\}$; or
  - "L^2" criteria, $||\Delta x||_2 / ||x||_2$
- Maximum number of coupled solve iterations per time step also respected

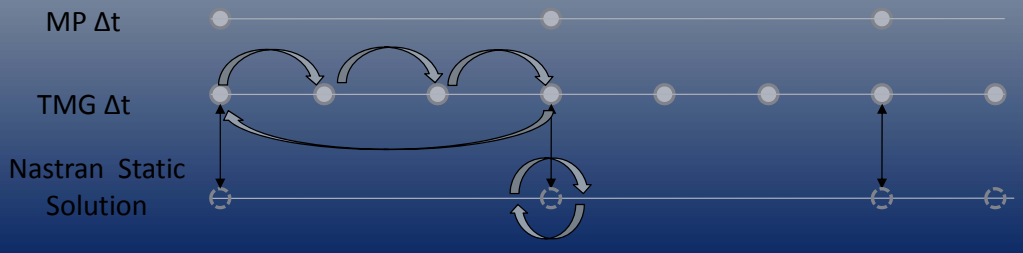
Transient Thermal/Quasi-static Mechanical

Loose (explicit) Coupling



Tight (implicit) coupling

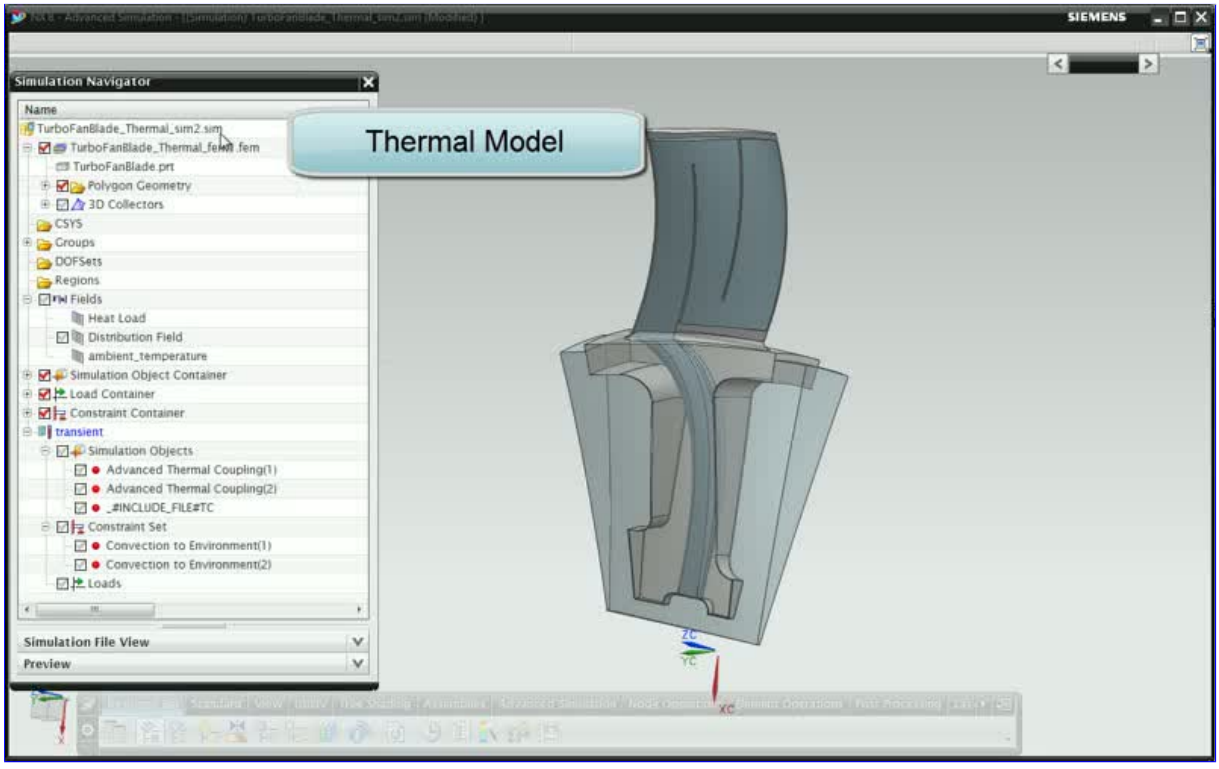
- Solvers need to support implicit coupling modes



Thermal-Structural Coupling Options

Steady-state thermal-mechanical
- Iterates between thermal and mechanical solution until a converged solution is reached

Transient thermal / Quasi-static mechanical
- Assumes dynamic response of mechanical system is much faster than the thermal transient
- Solvers communicate with MP at 'coupling time points' defined in MP input file
- Coupling intervals are a subset of the NX Thermal transient run
- Coupling time points correspond to a specific case in the Nastran deck
- Loosely coupled (explicit) coupling: no MP iterations over a timestep
- Tightly coupled (implicit) coupling: MP iterates over timestep



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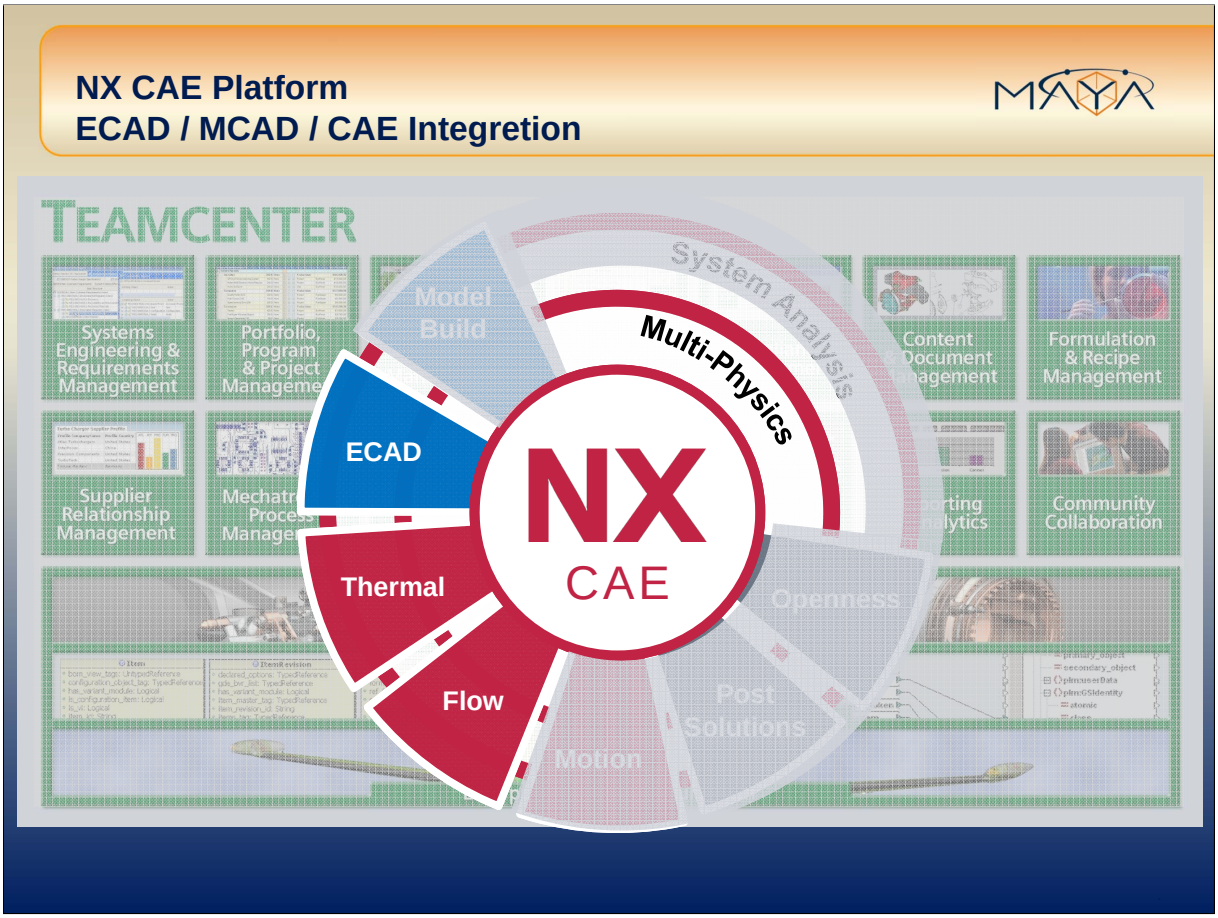
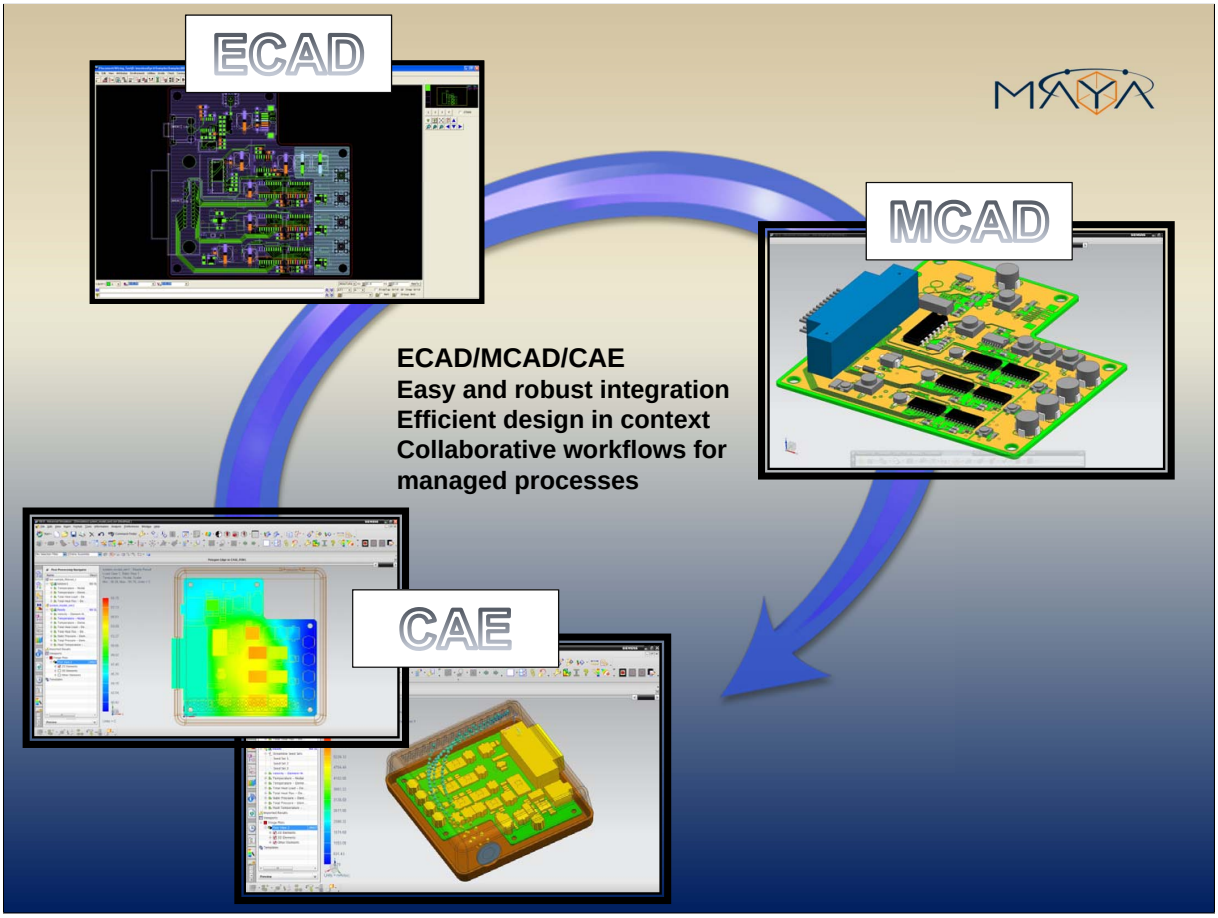
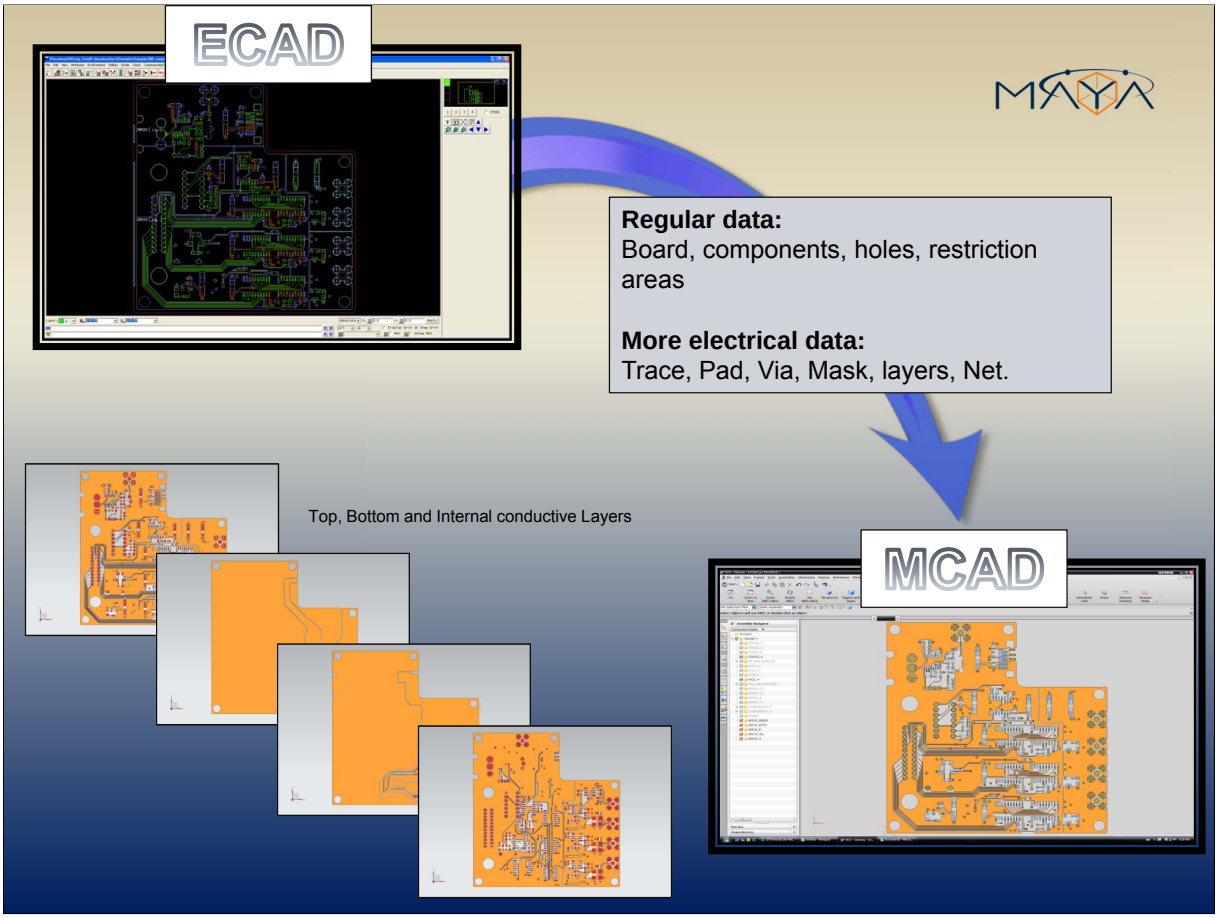
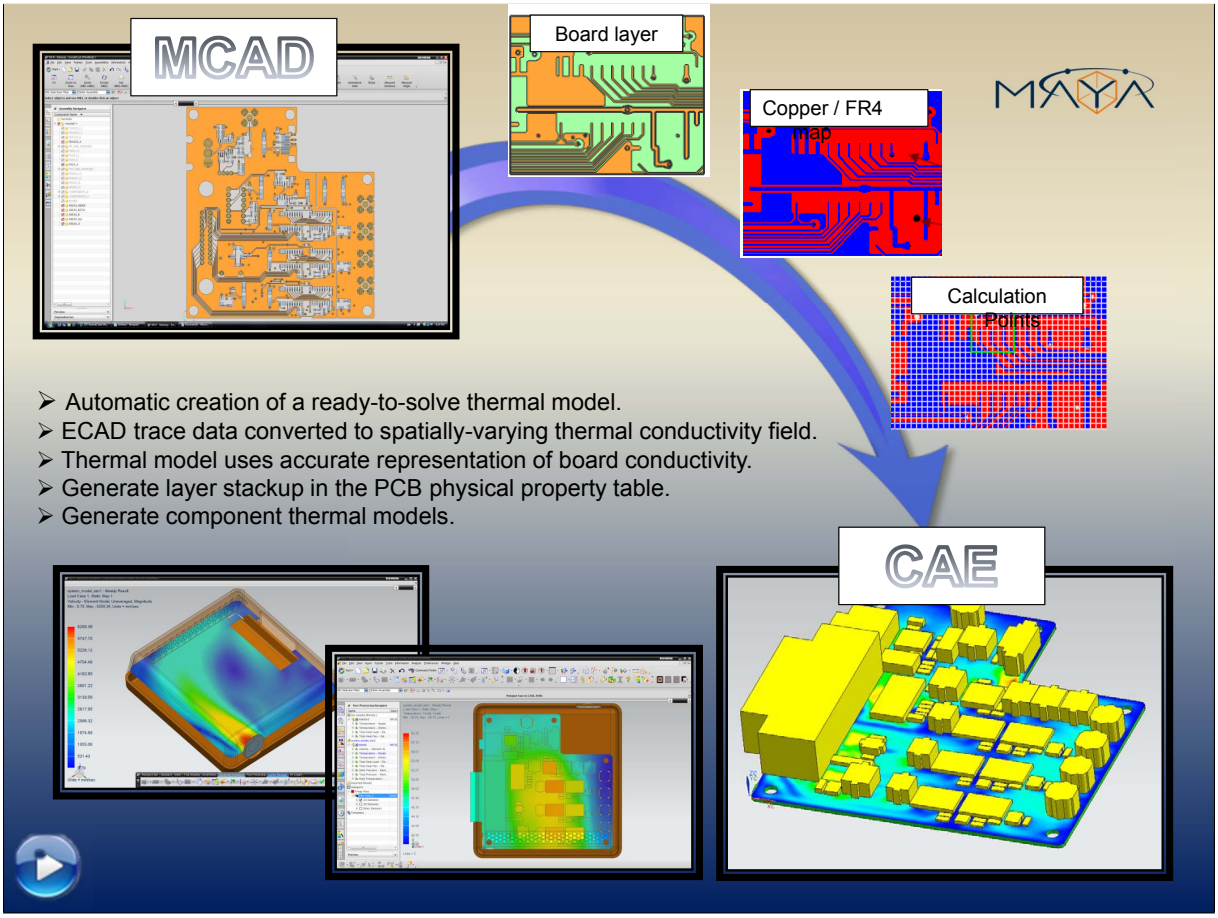
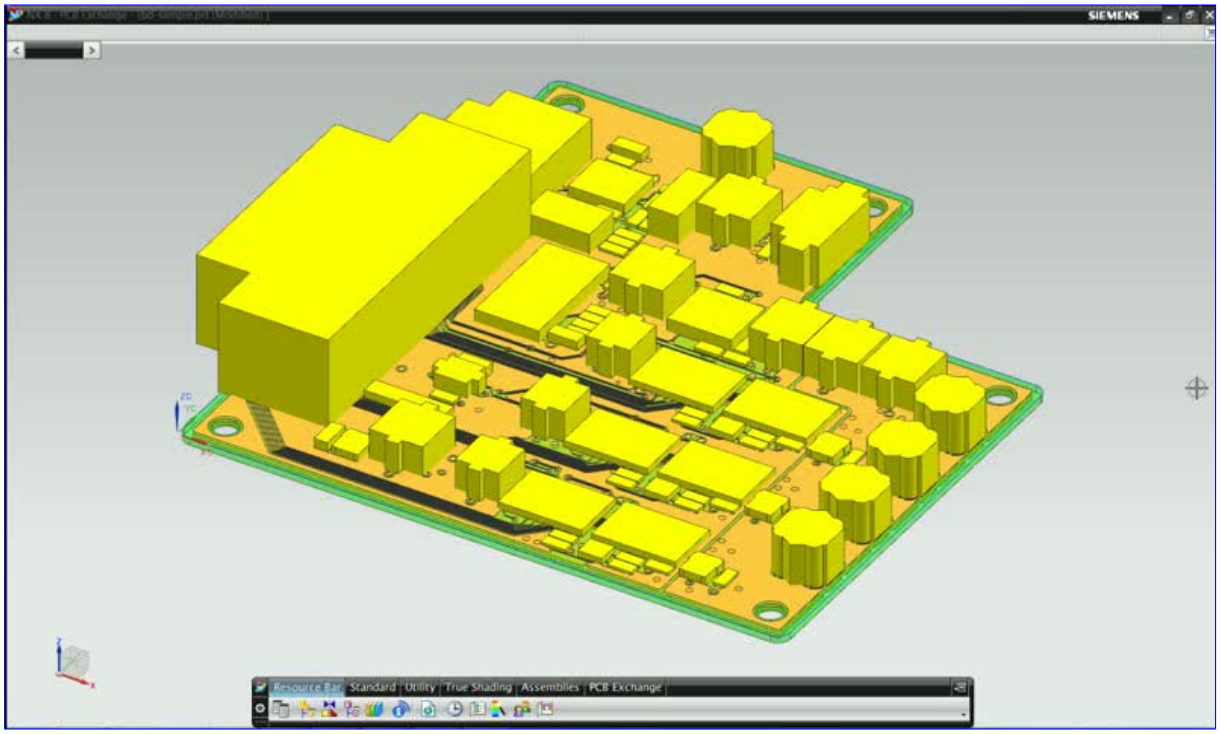

NX CAE Platform
ECAD / MCAD / CAE Integretion
TEAMCENTER
Systems Engineering & Requirements Management
Portfolio, Program & Project Management
Model Build
System Analysis
Content Management
Formulation & Recipe Management
Supplier Relationship Management
Community Collaboration
Multi-Physics
ECAD
Thermal
Flow
NX
CAE
Openness
Post Solutions
Motion


ECAD
MCAD
CAE
ECAD/MCAD/CAE
Easy and robust integration
Efficient design in context
Collaborative workflows for
managed processes


ECAD
Regular data:
Board, components, holes, restriction areas
More electrical data:
Trace, Pad, Via, Mask, layers, Net.
Top, Bottom and Internal conductive Layers
MCAD


MCAD
Board layer
Copper / FR4
map
Calculation Points
➢ Automatic creation of a ready-to-solve thermal model.
➢ ECAD trace data converted to spatially-varying thermal conductivity field.
➢ Thermal model uses accurate representation of board conductivity.
➢ Generate layer stackup in the PCB physical property table.
➢ Generate component thermal models.
CAE



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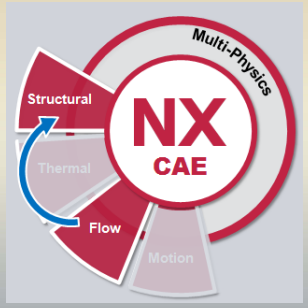
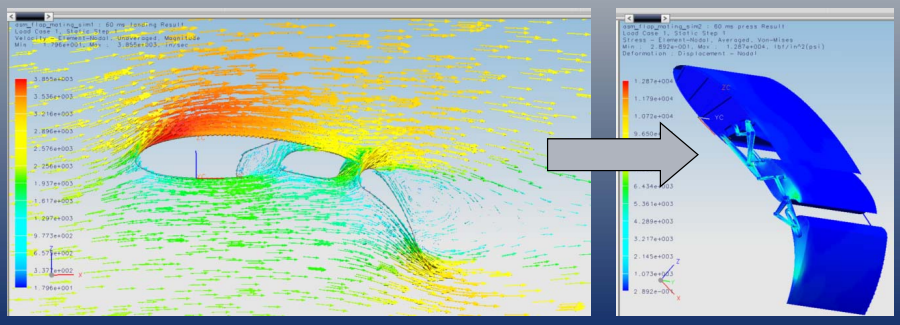
Fluid – Structure Mapping

Structural Solvers Supported

- NX Nastran
- MSC.Nastran
- ANSYS
- ABAQUS
- LS-Dyna

Fully dissimilar and disjoint flow and structural model supported





Thank You

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