SIEMENS
Ingenuity for life

Überblick von NX Nastran Multistep Nonlinear Solutions 401 und 402

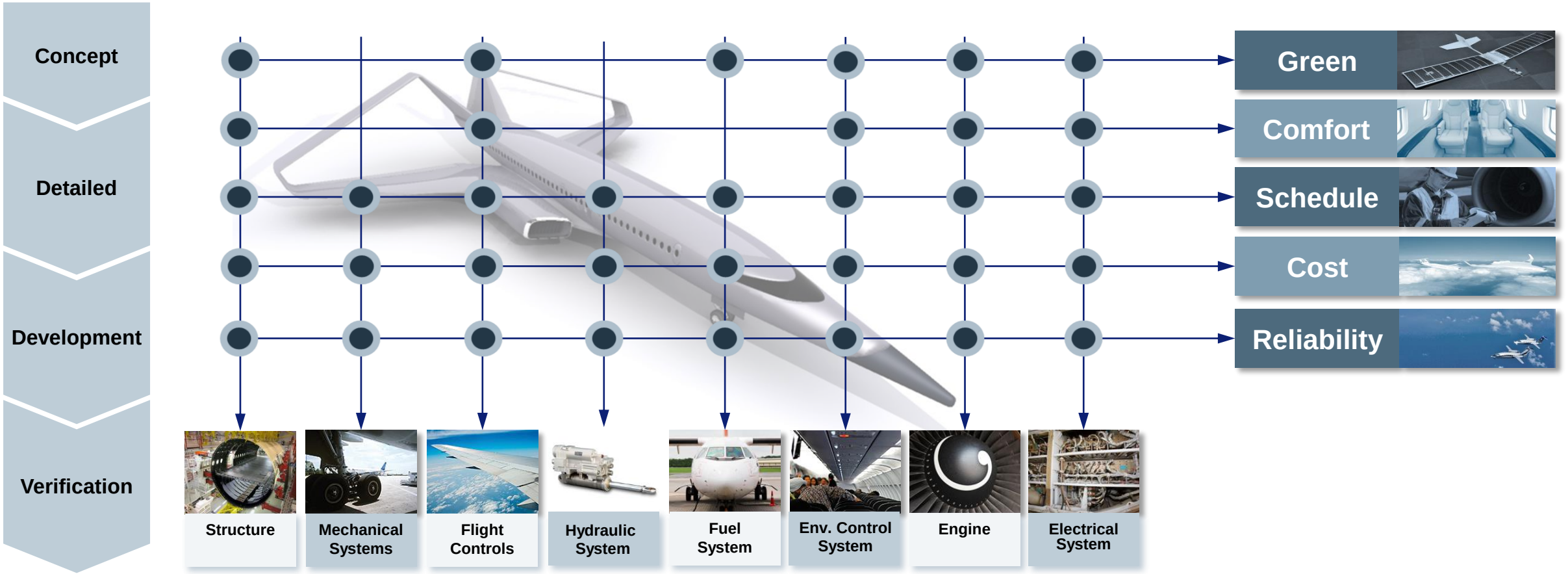
Martin.Kuessner@siemens.com
Global Simcenter Portfolio Development
Linz, 5.10.2018

Simulation impacts design with Simcenter 3D: Smartphone

A smartphone combines all of the capabilities of every product shown on the front page of that Radio Shack ad from 1991 in one single product.

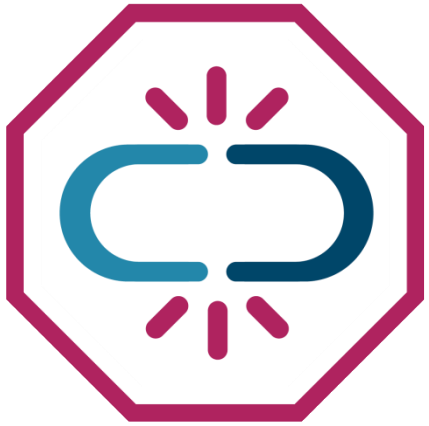
An smartphone explains the concepts of innovation, complexity, risk and intersections.

Innovation happens at “intersections”

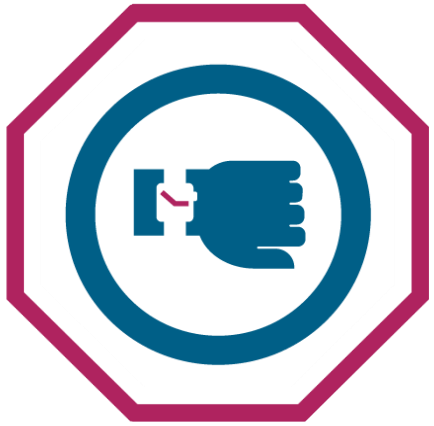


Manage complexity to drive Innovation and contain risks

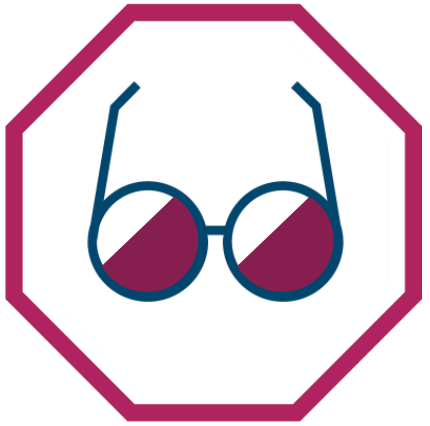
Issues faced by simulation departments and how to fix those



Disparate tools and inefficient workflows



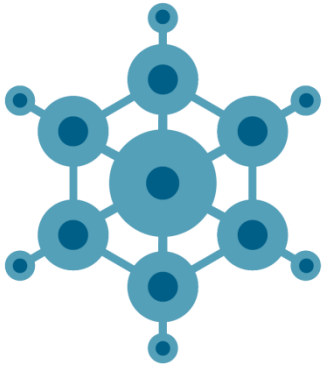
Results out-of-synch with design



Limited visibility and business impact

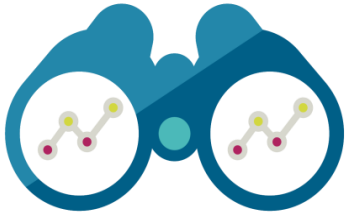
Budget and resource constraints

Issues faced by simulation departments and how to fix those



Integrated environment for streamlined workflows

Timely insight to drive design decisions

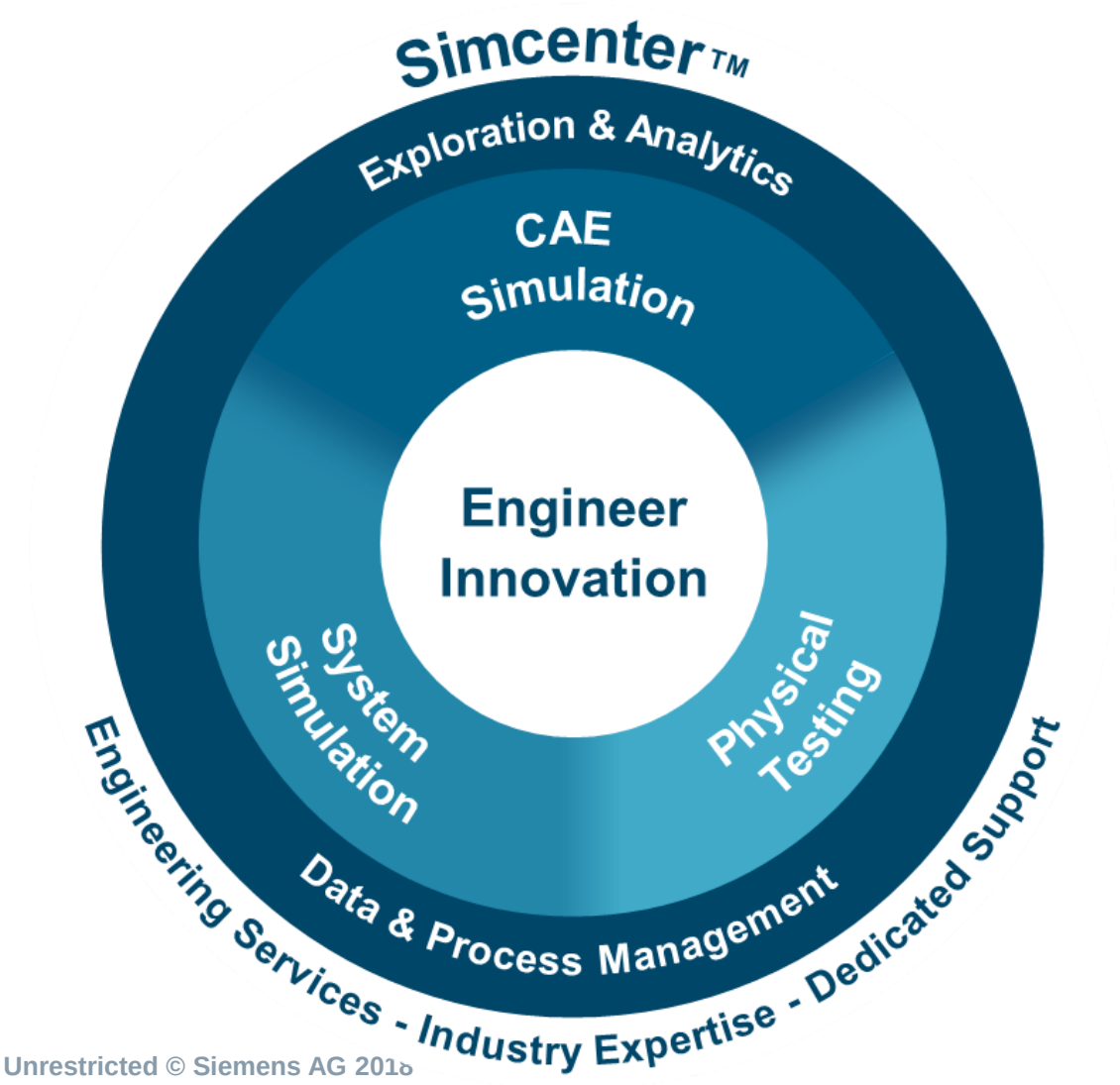


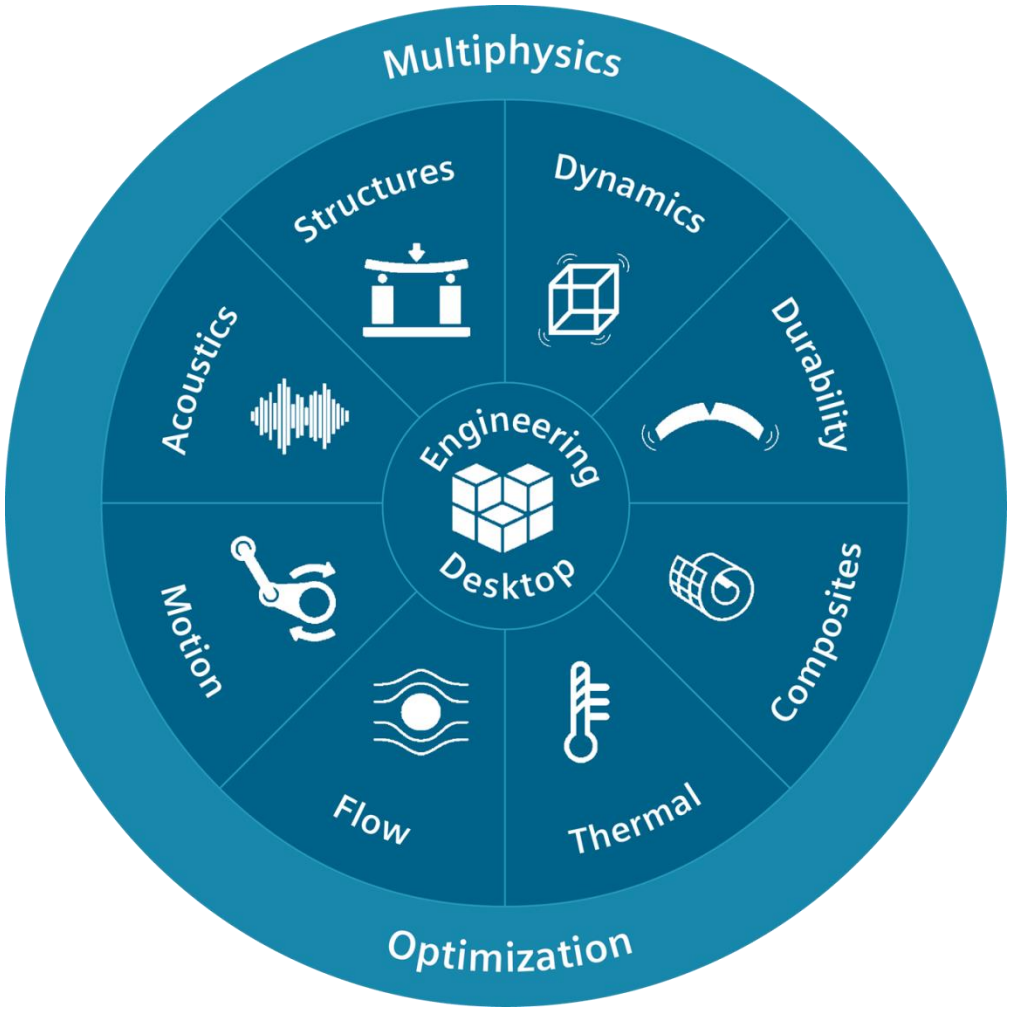
Visible to and used by broader organization

Remove constraints to enable flexible resources

Simcenter 3D

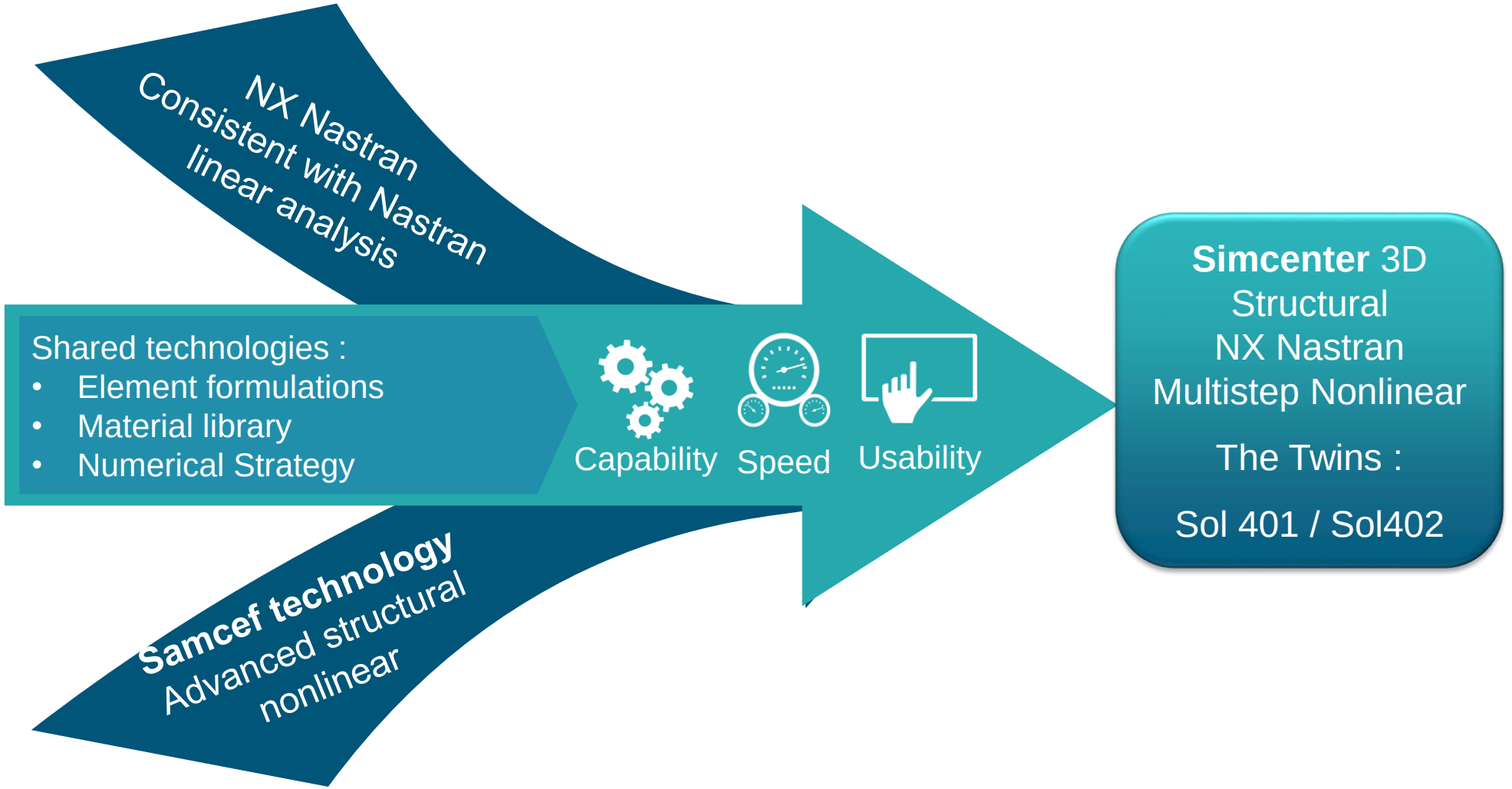
Part of the Simcenter portfolio for Predictive Engineering Analytics





Evolution of the NX Nastran Nonlinear Solutions

"The Twins"



 2018-10-05

NX Nastran Multistep Nonlinear

SIEMENS
Ingenuity for life

NX Nastran Multistep Nonlinear

One License

Two Solutions

SOL 401

- New solution based on Nastran architecture
- Initial targeted for aero-engine applications
- Expanding into general purpose nonlinear

SOL 402

- New solution based on Samcef solver
- Samcef is well known among European aerospace companies
- Embedded in NX Nastran paradigm to provide easy access to PL users

Easy transition from linear to nonlinear analysis without leaving Nastran

NX Nastran Multi-step Nonlinear

SIEMENS
Ingenuity for life

Sol401
Multi-Step Nonlinear

- Based on traditional Nastran architecture
- Multiphysics coupling

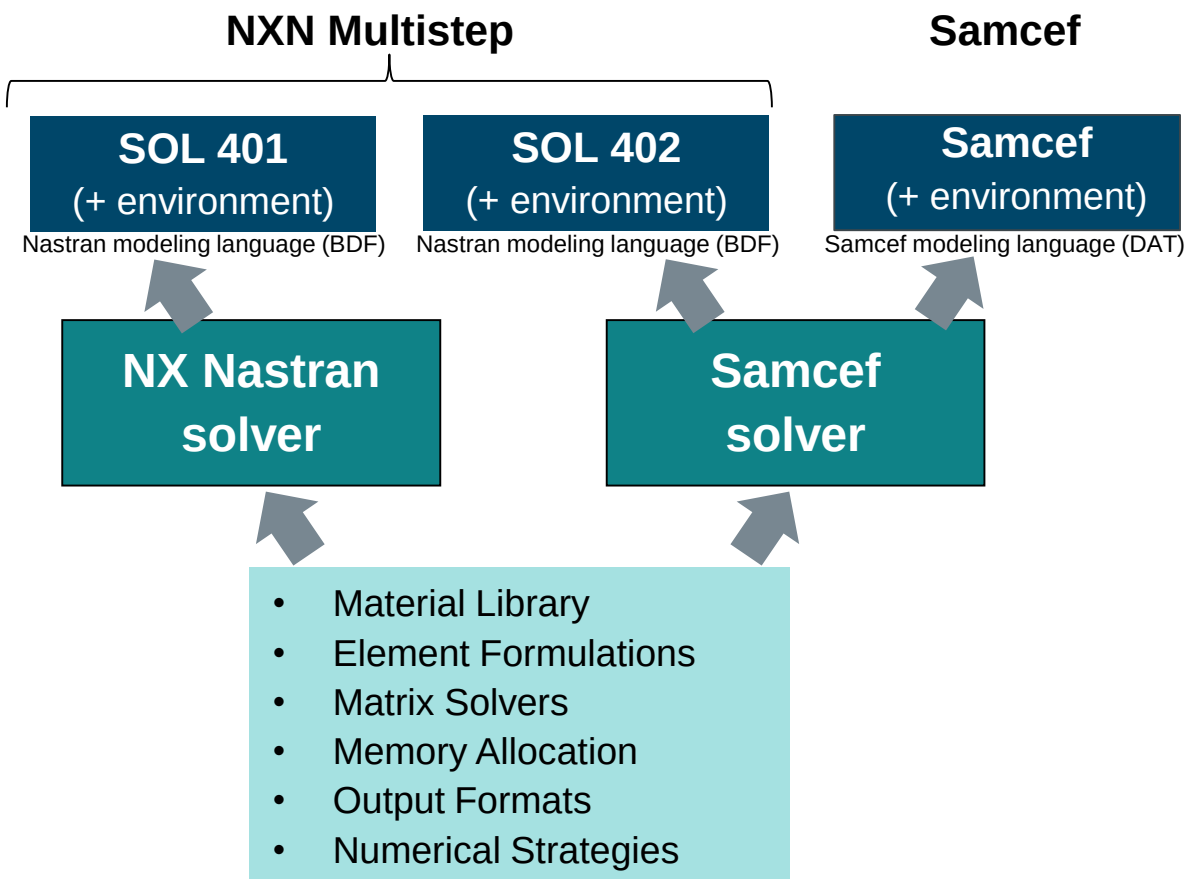
Commonalities

- Mutli-steps solution
- Use many of the same formulation and give nearly the same results
- Use the same Nastran input for easy conversion to one solution to the other
- Large displacement
- Shared Material Models included nonlinear materials

Sol402
Multi-Step Nonlinear Kinematics

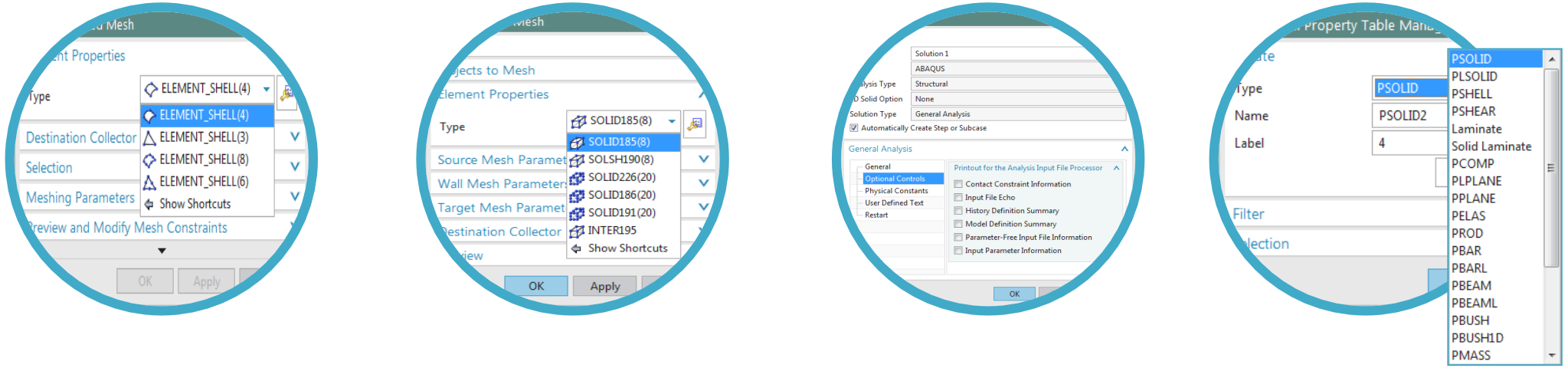
- Based on deep integration of Samcef in Nastran
- Nonlinear mechanism
- Large strain
- Advanced Contact Modeling

Simcenter Nonlinear FE solvers
Family tree



SIEMENS
Ingenuity for life

Unique architecture supports custom environment for each solver



- User interface is tailored for each type of physics being solved
  - Solver-specific terminology used for pre/post

 2018-10-05

Direct Matrix Abstraction Program (DMAP) in NX Nastran

SIEMENS
Ingenuity for life

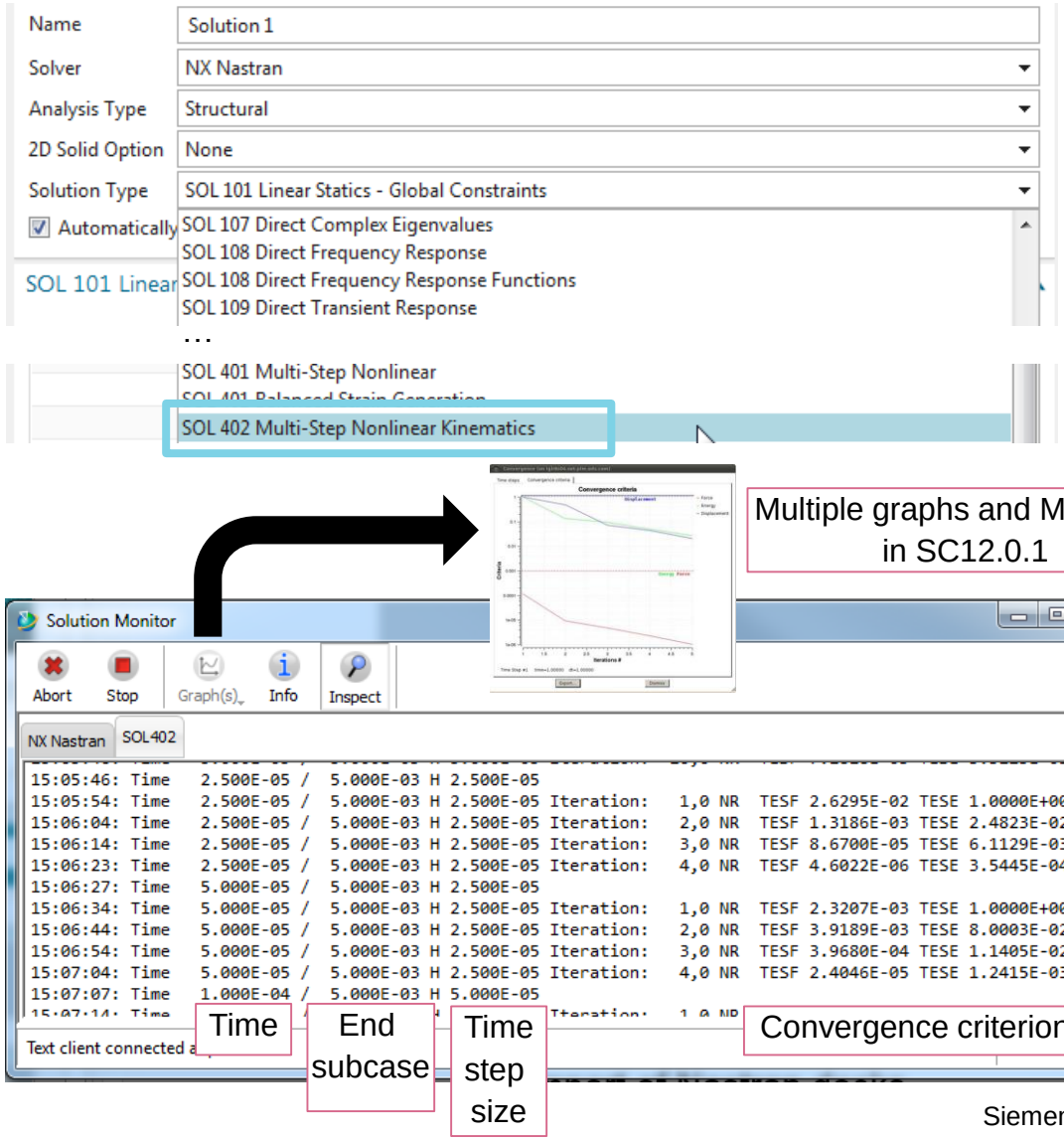
NX Nastran Direct Matrix Abstraction Program (DMAP) is a high-level language with its own compiler and grammatical rules.

- A DMAP program consists of a series of functional blocks called “modules,” each of which has a unique name and a specific function. Modules are executed sequentially; branching and looping operations are performed by DMAP control statements. Modules communicate through the NX
- Nastran Executive System (NES) via logical collections of data called “data blocks” and “parameters.”
- Data blocks come in two distinct forms: “matrices” that obey the rules of matrix algebra, and “tables” that represent a convenient collection of data items.

NX Nastran SOL402
Simcenter environment

SOL402 is available as an **NX Nastran solution** in structural analysis type, and benefits from following capabilities:

- Import of Nastran decks
- Mesh definition in the FEM file
- Boundary conditions in the SIM file
- Solver syntax preview
- Export and solve
- HPC : DMP and SMP
- Solver monitor with abort and stop
- Post-processing



Nonlinear materials
Hyperelastic Materials (SOL 402)

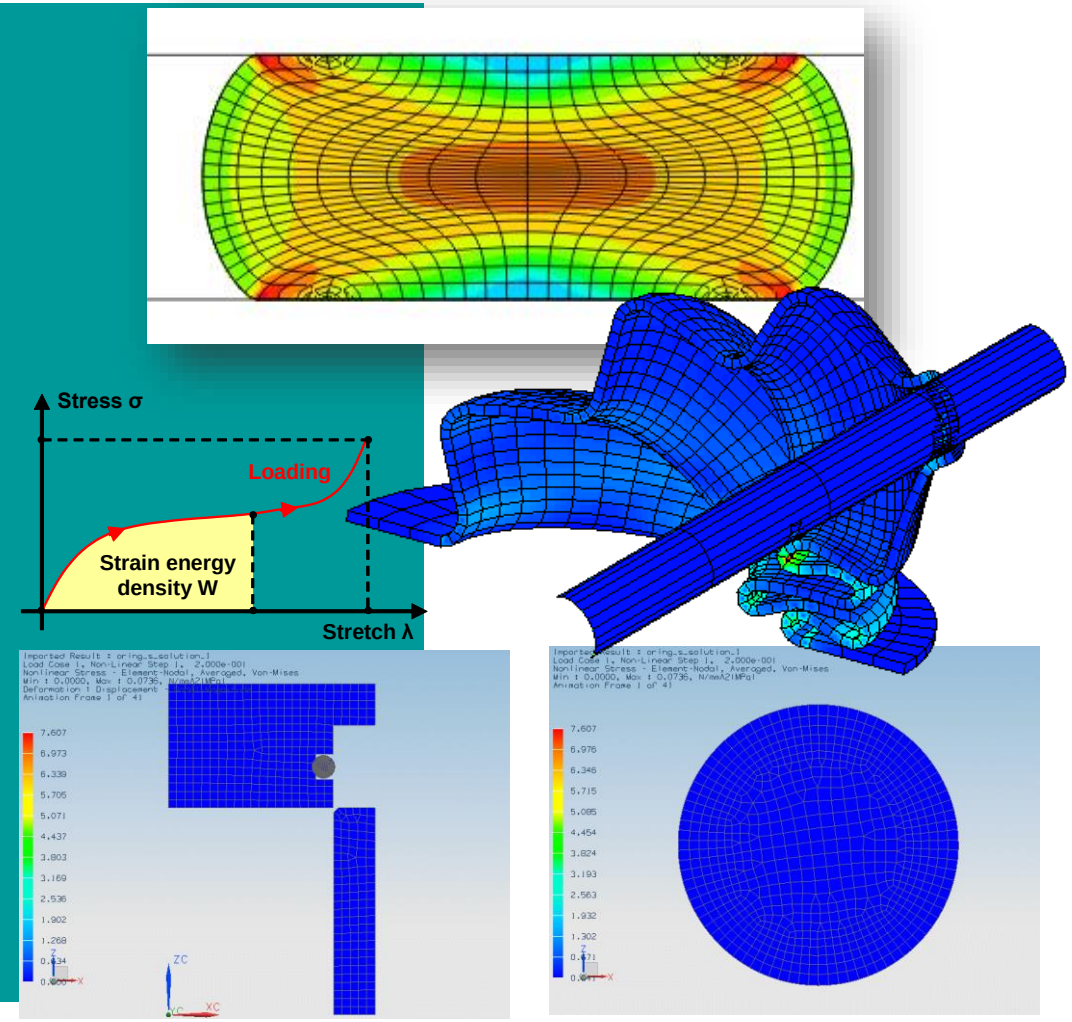
SIEMENS
Ingenuity for life

Typical Elastomeric Material Characteristics

- Nonlinear-elastic load extension behavior.
- Can be subject to large elastic strains (up to 600%)
- Nearly incompressible
- Temperature dependent properties

Implementation

- Large displacement and large strain
- Models
  - Generalized Mooney-Rivlin model
  - Mullins effect with Ogden model
  - Viscoelastic effect with Holzapfel
  - Hyperfoam model



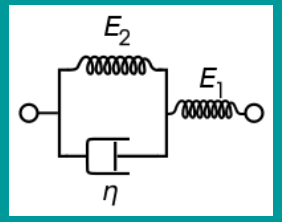
Nonlinear materials
Viscoelastic Materials

Viscoelastic materials :

- Elasticity (like a rubber that stretches instantaneously a s original state once a load is removed
- Viscous behavior (like the gradual deformation)

Implementations :

- Kelvin (Sol402 & Sol401)



- Prony series (402)

$$g(t) = 1 - \sum_i w_i \left(1 - e^{\frac{-t}{\tau_i}}\right)$$

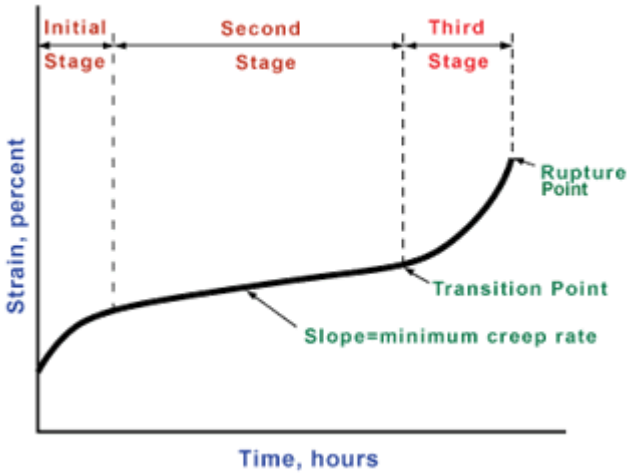
Nonlinear materials
Creep

Creep (or cold flow)

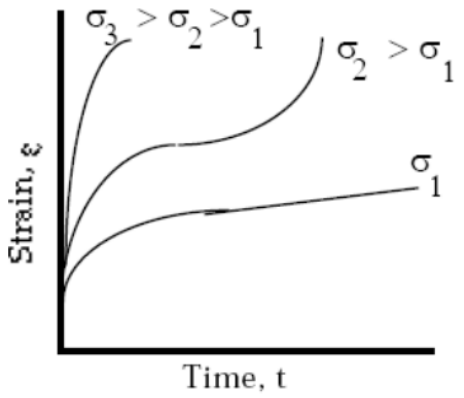
- Permanent deformation after a long term exposure to high levels of stress
- Important for long period of exposure to het

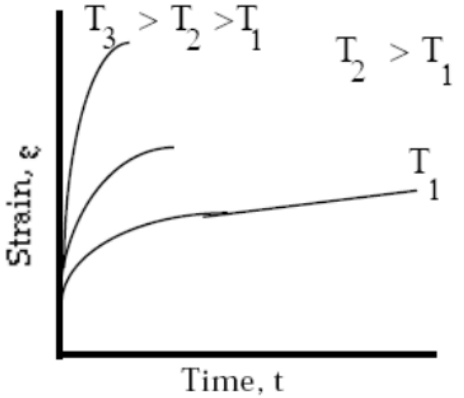
Creep Implementation :

- Baily Norton model (isotropic creep with optional temperature dependency)
- Dedicated time step management



Validated by several industrial cases





Nonlinear materials
Progressive damage of composite material (Sol402)

Several native models available for :

- Interlaminar damage or Interlaminar damage

Intralaminar damage :

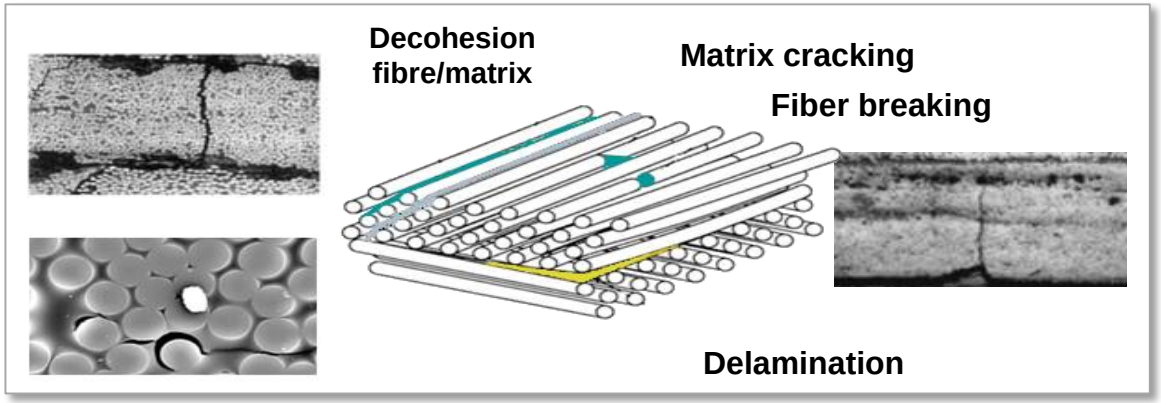
- For Unidirectional or Woven ply
- Different type of damage :
  - Fiber damage
  - Matrix Damage
  - Decohesion between matrix et fiber

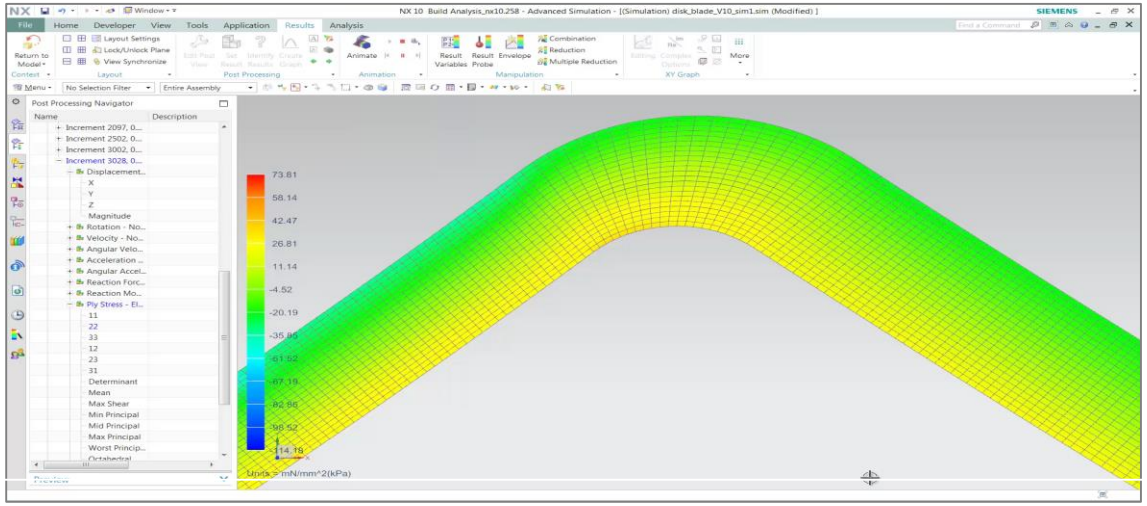
Interlaminar damage :

- Using cohesive element (managed by SC3D)
- Several behavior

Validated by several industrial cases

Accurate Progressive Damage Prediction





User material (MUMAT) or Custom Material Law

User (MUMAT) : Material model user-subroutine

Description

- Allow users to link proprietary material models NX Nastran
- Rate dependent or rate independent

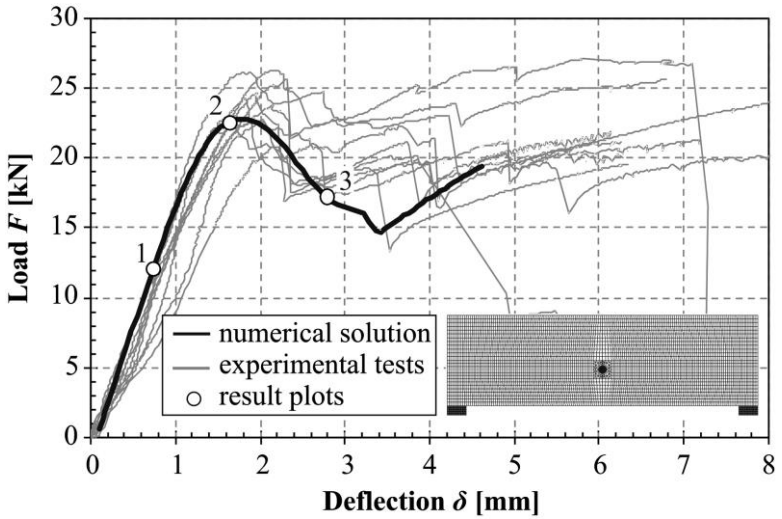
Implementation

- Users link Fortran code of material models to NX Nastran via a DLL
- Supports rate dependent and rate independent materials
- Allows output of state variables

Value

- Users can develop and use proprietary material models
- User can also set up this material from SC3D environment

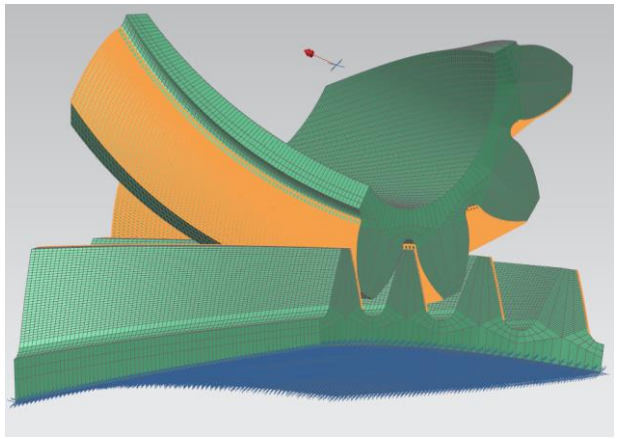
```
User Defined Materials C
=================================================================+
SUBROUTINE NXUMAT(
* IOPER , MODNAME1, MODNAME2, MATID , HOOK , TANSTIFF,
* MATIR , MATIN , NMATI , MUDATAR , MUDATAI , NMUDATA ,
* DFGRDT0 , DFGRDT1 , EPSTOTT1, EPSMT1 , EPSTHT1 , EPSDELM ,
* DELTAT , TIMET1 , TEMPT0 , TEMPT1 , NB , INTVALS ,
* REALVALS, XYZT1 , ROT , NXPARAM , STATEVAR, NSVAR ,
* SIGMA , EPSPL , EPSCR , DTCRPRAT, VOID1 , VOID2 ,
* VOID3 , IRET )C ----------------------------------------------------------------+
C
IMPLICIT NONE
CC
ARGUMENTS DECLARATION
C ---------------------
C
CHARACTER*8 MODNAME1, MODNAME2
C
INTEGER*8 INTVALS(*), IOPER , IRET , MATID , MATIN(*),
& NB , MUDATAI(*), NMATI, NMUDATA, NSVAR ,
& NXPARAM(*)
C
```

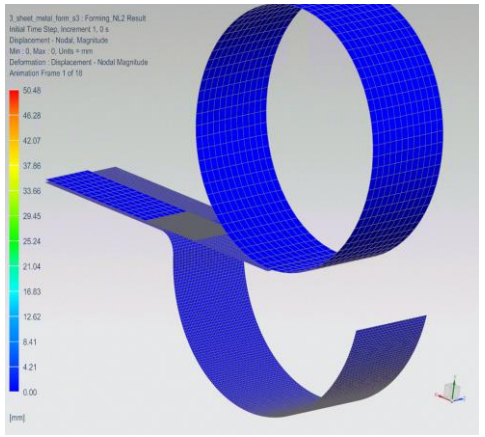


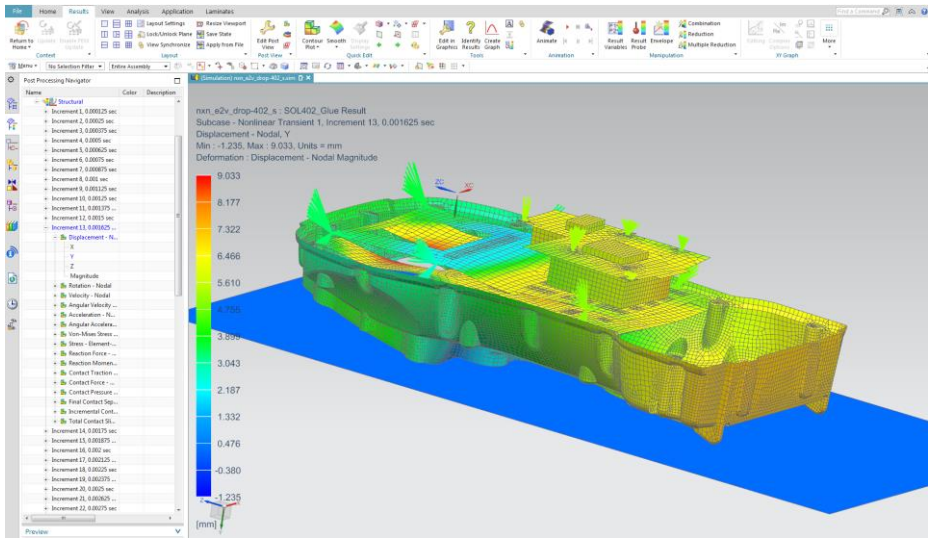
NX Nastran SOL40x
Contact modeling

Capture the real behavior of your structure with contact between parts:

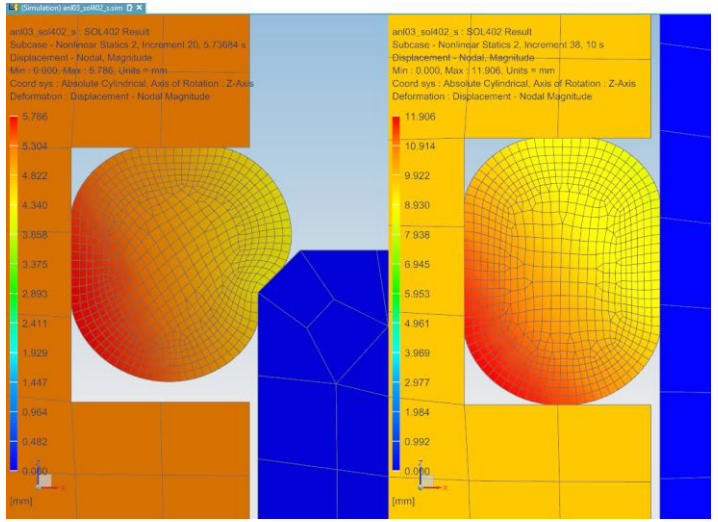
- Several contact algorithm and options
- Support all the possible nonlinearities (material & geometric)
- Update of the contact condition during the run (large displacement)
- Explicit definition of the contact for Node to Face





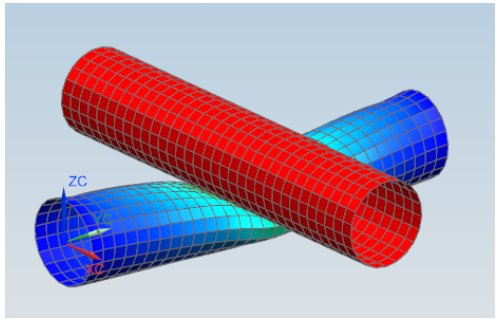


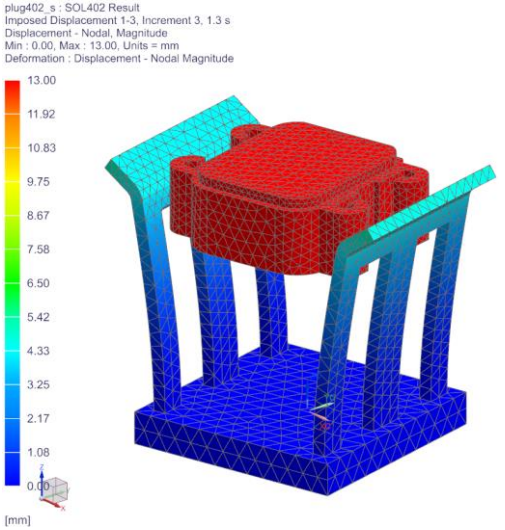
- Friction
  - Constant, infinite, function of temperature, velocity or time
- Large sliding
- Gap and offset control
  - Ignore, eliminate, override initial distance
- Flexible or Rigid targets
- Geometry smoothing option
- Activation/deactivation of contact condition
- Stabilization options
- …

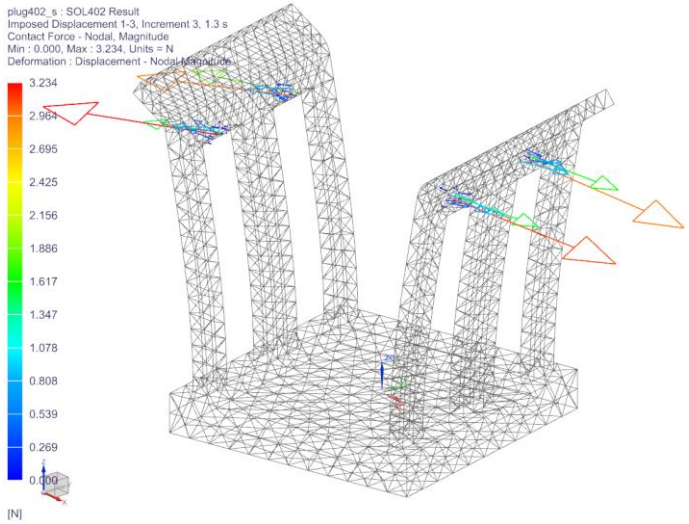


Outputs

- Contact pressures
- Contact forces
- Normal distance
- Sliding





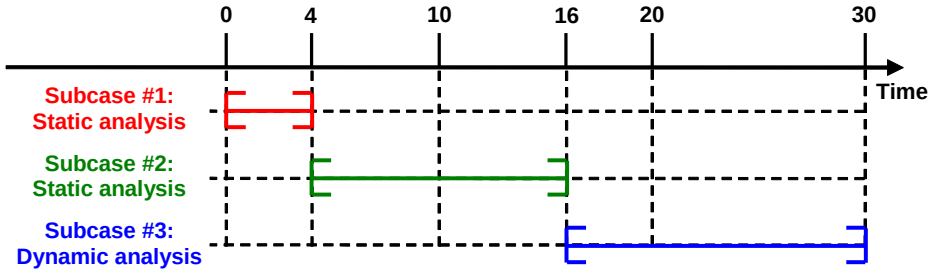


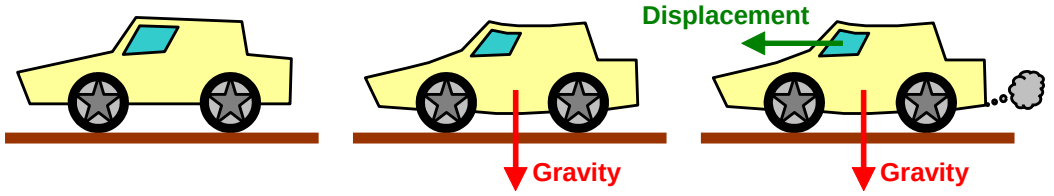
Transient Simulation (SOL 402)

Features

- Multiple time-step integration models
- Automatic time stepping
- Static, kinematic, and transient analysis

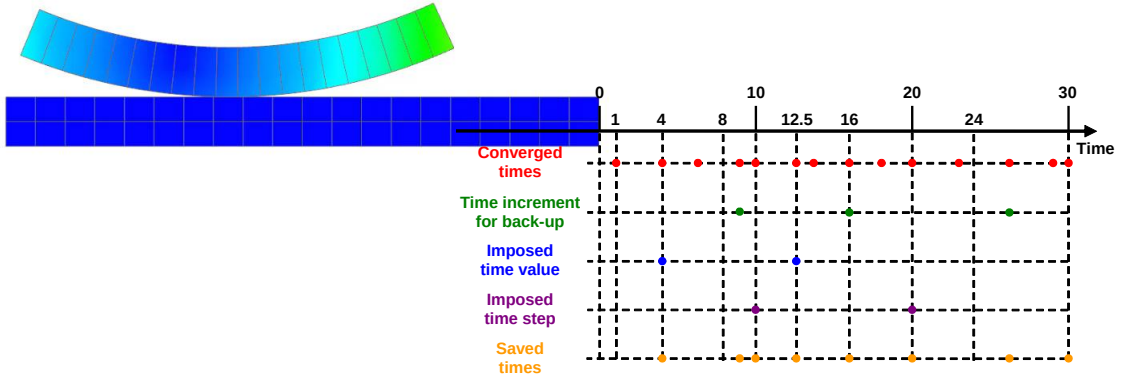
Response type	Equation solved
Static	$K_T.q = F$
Dynamic without inertia	$C.q + K_T.q = F$
Dynamic	$M.q + C.q + K_T.q = F$





Damping model

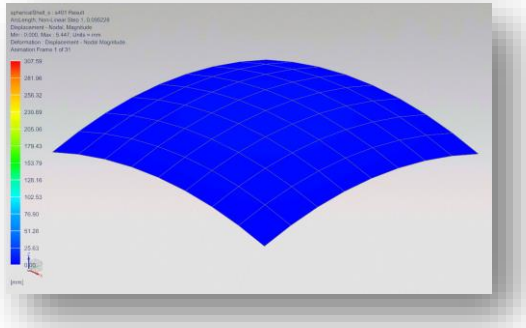
- Rayleigh
- Material



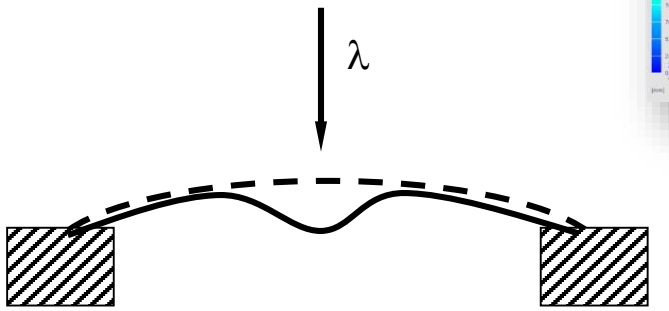
Post-Buckling Analysis (SOL401)

Description

- Arc length method allows analysis of post-buckling and snap through types of problems
- Nonlinear Statics step with zero delta time
  - Incremental loads defined in the step are proportional
  - Loads applied in prior steps are held constant
- An initial imperfection/mesh perturbation can be applied

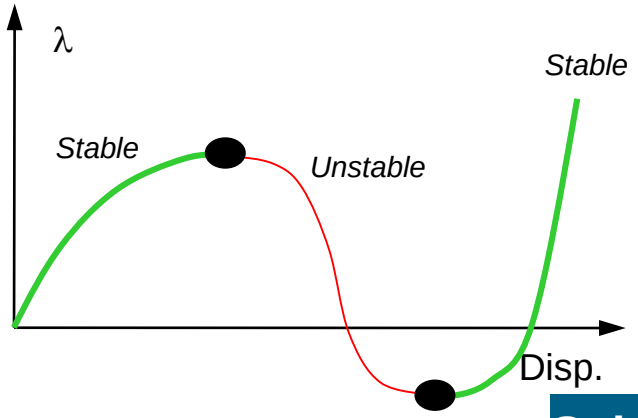


Limit point



Snap through

Riks method



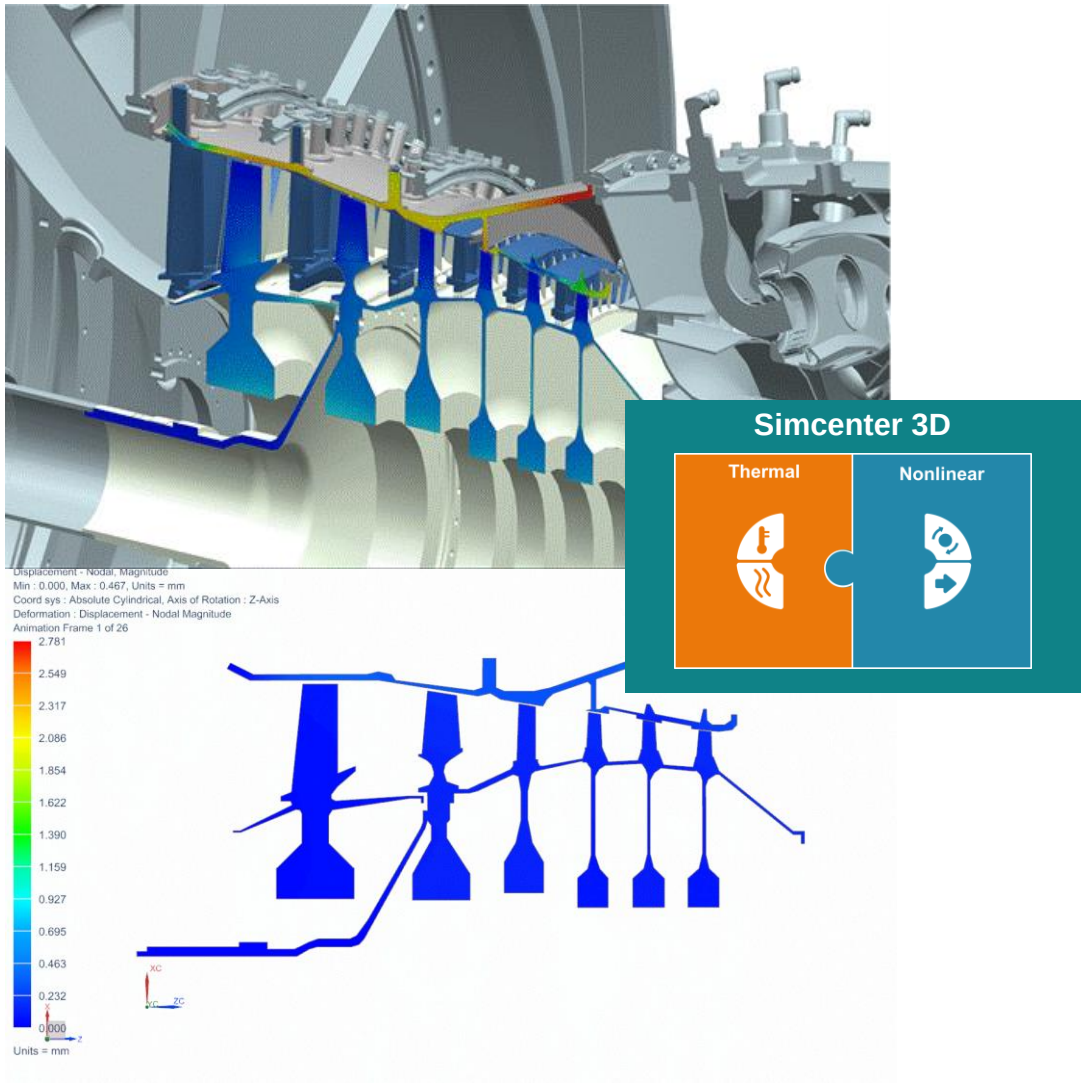
Value

- Finds possible buckled states that are below the perceived buckling load.
- Imperfections in geometry can reduce buckling loads – important to include the effect

Thermal-Mechanical Solutions(SOL401)

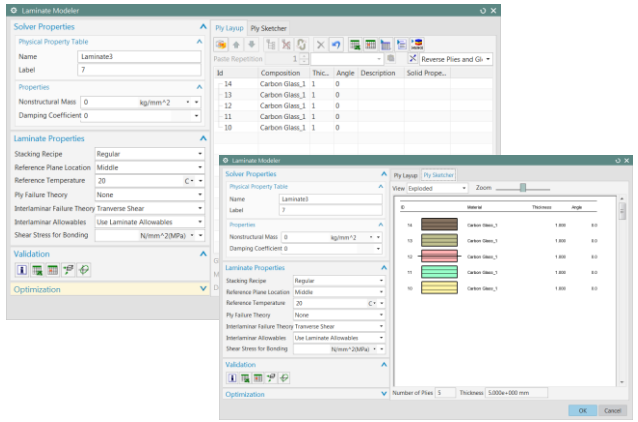
NX Nastran couples to Simcenter Thermal

- Cosimulation solution
- API's developed for both solvers
- MP Driver will sequence each solution and transfer data
- Coupling behavior
  - Contact changes heat and load paths
  - Heat transfer changes with gap distances
- Levels of Coupling
  - Sequential coupled – At each coupling step, state from previous step is used
  - Iterative coupled – At each coupling step, state from previous step is used as starting point of iterations to convergence

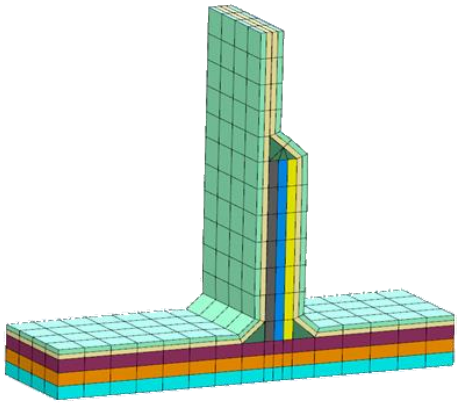


 2018-10-05

Centralized pre/post
to efficiently build models for your solver of choice



Layup definition



Mesh definition

NX Nastran

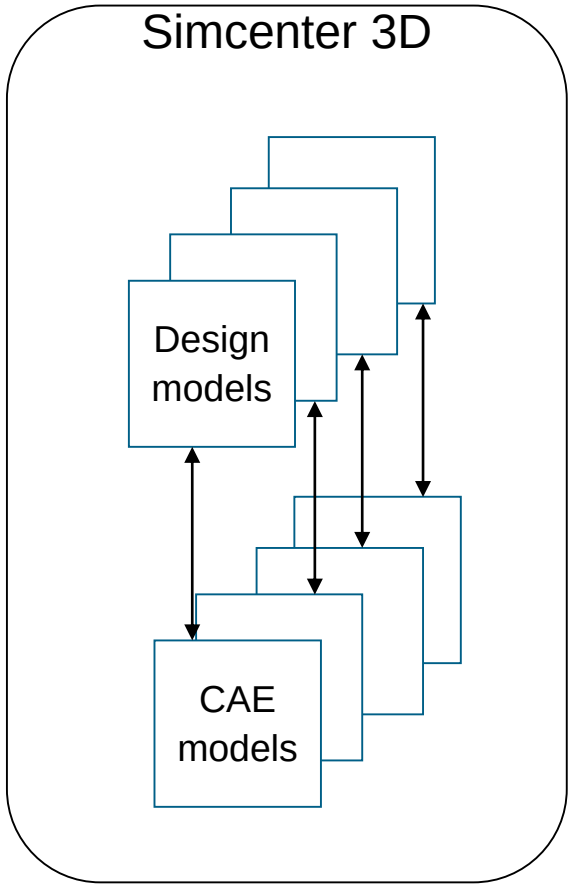
```
$*
$* PROPERTY CARDS
$*
$*  Property: Laminate1
PCOMPG          2          0.0000                    20.0000  0.0000          +
+               1       11.000000  0.0000       NO                           +
+               2       11.000000  0.0000       NO                           +
+               3       11.000000 90.0000       NO                           +
+               4       11.000000 90.0000       NO
$*
```

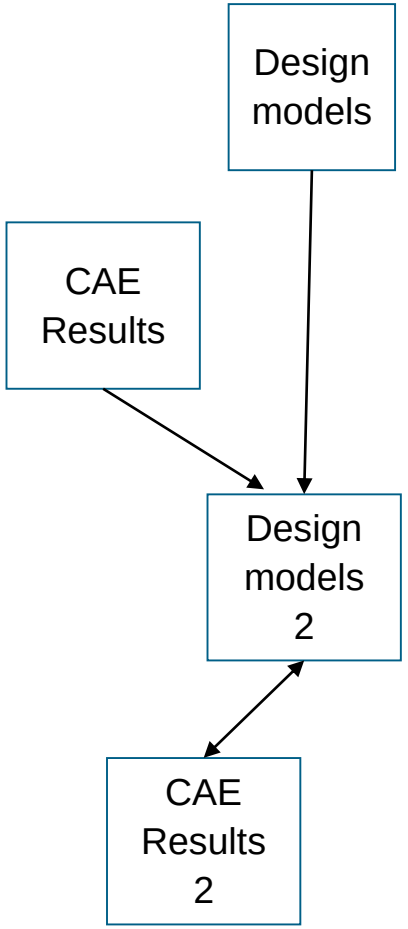
LMS Samcef

```
.PLI
 PLI 1 ANGLE 0 T 1 MAT 1
 PLI 2 ANGLE 0 T 1 MAT 1
 PLI 3 ANGLE 90 T 1 MAT 1
 PLI 4 ANGLE 90 T 1 MAT 1
! Samcef Bank File : LAMINATES.
! ------------------------------
.LAM
 LAM 1 PLI 1 2 3 4
```

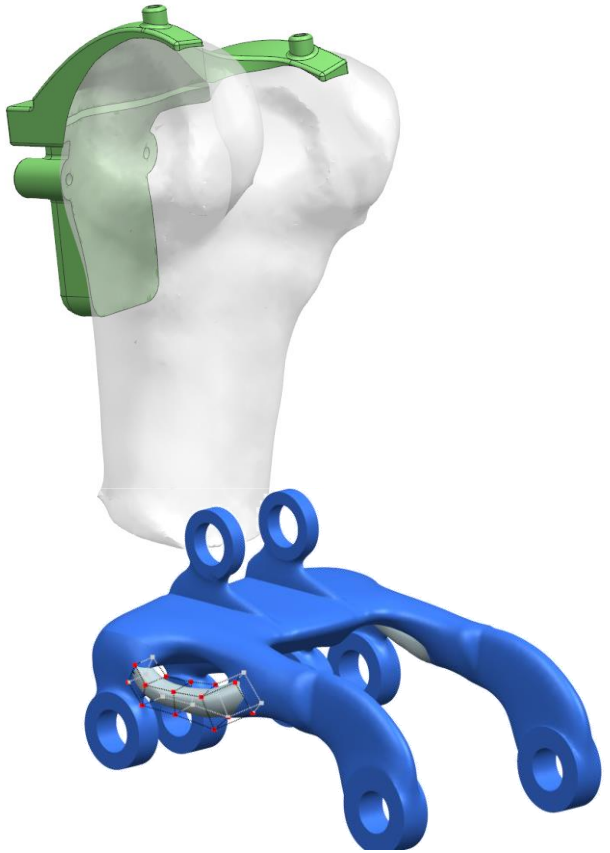

Exchange data to accelerate the design process

Associativity CAD/CAE





Convergent Modeling™ in CAE



Conclusion
How are Simcenter 3D nonlinear solutions customers benefitting?

SIEMENS
Ingenuity for life

Flexible licensing trough Simcenter Tokens

Assessment of continuous improvement to support new virtual design workflow

Cumulated Siemens experience of 70 years for reaching

Quality

Better designs, faster!

Up to

20%-40%

time savings for complete virtual product development workflow with Simcenter 3D Engineering Desktop

SIEMENS
Ingenuity for life

Überblick von NX Nastran Multistep Nonlinear Solutions 401 und 402

Martin.Kuessner@siemens.com
Global Simcenter Portfolio Development
Linz, 5.10.2018