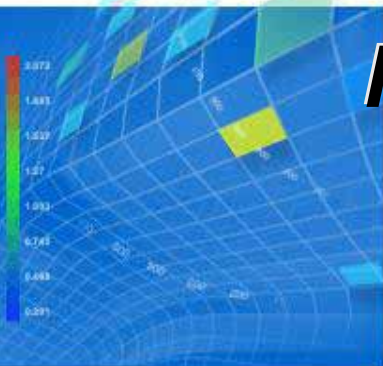




MSC.Nastran Explicit Nonlinear (SOL 700)

Nonlinear Structural Analysis

Technical Workshop



Agenda

- ✓ **MSC – LSTC Alliance**
- ✓ **Technology Roadmap**
- ✓ **Release Schedule**
- ✓ **Implicit vs Explicit**
- ✓ **Need for Implicit – Explicit Integration**
- ✓ **What is MSC.Nastran SOL 700 ?**
- ✓ **How does it benefit the Nastran user**
- ✓ **SOL 700 Target Industries and Applications**
- ✓ **How Does it Work ?**
- ✓ **What capabilities are included**
- ✓ **Recent Example Problems Solved with SOL 700**
- ✓ **Sample Live Problem**

MSC – LSTC Alliance

- ✓ **MSC has signed an Alliance Agreement with LSTC**
- ✓ **MSC to integrate & market the LS-DYNA solver with other MSC products as well as create new products**
- ✓ **Aligned with the MSC VPD Strategy to provide integrated, streamlined solutions**

Technology Requirements

Simulation of the real world requires...

- ✓ **Multi-Physics** (Mechanical, Thermal, Electric, Fluid..)
- ✓ **Multi-Formulations**
- ✓ **Multi-Stage**
- ✓ **Multi-Processing**

Formulations are Linear & Nonlinear...

Technology Roadmap

Virtual Product Design												
Stress	NVH	Durability	Ride & Handling	Structural Crash	Airbags			Occupant Safety			Stochastics	
					Pressure	Inflators	Full Gas Dynamics	IP	OOP	others		

Adams												
Fatigue												
Robust Design												



Virtual Product Design												
Stress	NVH	Durability	Ride & Handling	Structural Crash	Airbags			Occupant Safety			Stochastics	
					Pressure	Inflators	Full Gas Dynamics	IP	OOP	others		
Nastran					DMP							
Dytran LS-DYNA					DMP							

High Level Solver Release Content

- ✓ **LS-DYNA Integration with MSC.Dytran:**
 - ✓ V2004 (Q1 2004) – available on windows
 - ✓ V2005 (Q4 2004) – available on Unix/Linux
 - ✓ V2006 (Q4 2005) – with DytranFSI, FSI part on 1 CPU only
 - ✓ V2007 (Q4 2006) – with DytranFSI, FSI in DMP

- ✓ **Explicit NonLinear Solution in MSC.Nastran (Sol 700):**
 - ✓ V2005 (Q4 2004) – Beta capability
 - ✓ V2005R2 (Q1 2005) – LS-DYNA Structural capabilities (DMP)
 - ✓ V2006 (Q4 2005) – LS-DYNA Expanded Structural
 - ✓ V2007 (Q4 2006) – LS-DYNA Structural + Dytran FSI (DMP)

Implicit vs Explicit

- **Material Nonlinearity**

Linear isotropic elastic (metals)
Nonlinear isotropic elastic (rubber materials)
Linear orthotropic elastic (composites)
Elastic-perfectly plastic (limit analysis)
Elastoplastic, strain hardening (metals)
Viscoelastic (polymers)
Restricted orthotropic (metal-forming)
Damage accumulation and failure
Tearing and failure
Explosive detonation

Implicit

Explicit

- **Deformation Nonlinearity**

Infinitesimal strains and rotations
Infinitesimal strains and finite rotations
Finite strains and rotations
Large strains (100% plus) and large rotations
(Multi)Material flow

Implicit

Explicit

- **Contact Nonlinearity**

Small displacement gaps
Gaps with friction
Large displacement gaps
Contact surfaces
Single surface contact
Fluid-structure interaction

Implicit

Explicit

Implicit vs Explicit

- Motion

Static (infinite)
Quasi-static (noninertial)
Vibration, fundamental modes
Dynamics Shock and vibration
Stress wave propagation
Shock wave propagation
Detonation waves

Implicit

Explicit

Need for Implicit – Explicit Integration

- ✓ Many Real Life Applications are “Multi-Stage”:

- ✓ Stamping (Metal Forming)

- ✓ Pre-form with Implicit (Nastran or SOL 600)
 - ✓ Deep Drawing with Explicit (Dytran LS-DYNA)
 - ✓ Spring back with Implicit

- ✓ Pre-Stressing & Restart

- ✓ Pre-stress the Blades in jet engines prior to bird strike
 - ✓ Fasteners, bolted parts

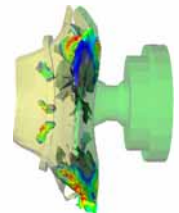
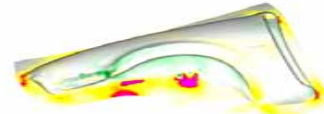
- ✓ Rigid Body Dynamics



- ✓ Adiabatic Simulation – Short duration applications where deformations result in heating but event is so rapid that heat has no time to diffuse through the material – High Speed Forming Process

- ✓ Coupled Acoustic-Structural-Fluid – Shock & Blast high amplitude propagation in the medium

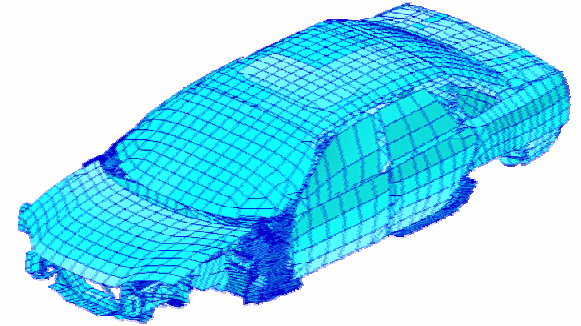
- ✓ Coupled Thermal-Structural-Fluid response



What is MSC.Nastran Sol 700 ?

- ✓ **MSC.Nastran Sol 700 (Explicit Solver)**
 - ✓ **Based on Dytran LS-DYNA Module**
 - ✓ **Nastran BDF based input and output**
 - ✓ **Support for MSC.Nastran solution sequences:**
 - ✓ 101, 106, 109, 129
 - ✓ **NVH and linear models can be run for explicit simulations**
 - ✓ **Supported by Patran - Nastran Preference**
 - ✓ **SOFY Support**
 - ✓ **No Fluid – Structure support (Phase 1)**
 - ✓ **FSI Support for Phases 2 & 3**

Customer Benefits



- ✓ Nastran Explicit solver
- ✓ Based on Dytran LS-DYNA module
 - ✓ Best Structural DMP (LS-DYNA enabled)
 - ✓ Common Modeling Environment
- ✓ Allows Nastran users to perform:
 - ✓ advanced nonlinear crash and impact analysis
- ✓ Includes contact, large deflection, large rotation, and large strain analysis capabilities never before available in Nastran
- ✓ Can use input decks from the many thousands of existing MSC.Nastran models.
- ✓ Provides solutions for simple to complex engineering problems including multi-body contact and severe nonlinearities and failure
- ✓ SOFY Support (Future releases):
 - ✓ Tailored Crash simulation environment
 - ✓ Conversion of Legacy Models from LS-DYNA, Radioss, Pamcrash
- ✓ MSC.MasterKey licensing on single or multiple processors
- ✓ WW support and training
- ✓ ISO Certified Development env!
- ✓ Meet more Certification requirements

SOL 700 Target Applications

SOL 700	TARGET INDUSTRIES			
	Auto	Aero	Defense	Consumer
Applications	Crash	Crashworthiness	Impact	Drop Test
	Bumpers	Engines Design	Penetration - Perforation	Bottles
	Component Crush – Energy Absorbtion	Containment Analysis	Survivability	BioMed
	Tire Performance	Tri-Hub Burst – Blade Out	Blast - Explosives	Containers
	Fuel Tanks	Bird Strike	HRAM	Composites
	Fuel Pumps	Seats Design	UNDEX	Papers
	Airbags & OS	Fuel Tanks - HRAM	Weapon Design	Boats

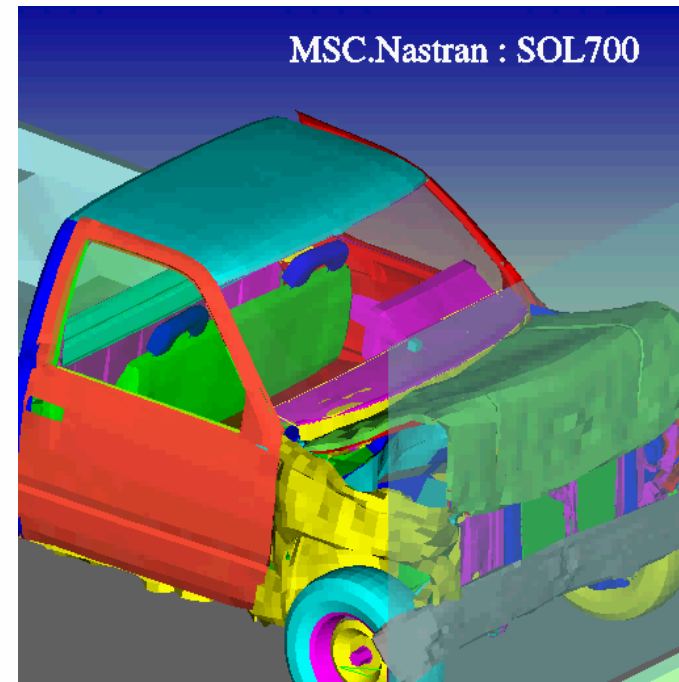
Note - The FSI Applications are highlighted in Yellow and will be part of Phase II & III

Nonlinear Capabilities in MSC.Nastran

MSC.Nastran SOL700 is the nonlinear capabilities of LS-Dyna delivered in an MSC.Nastran user interface

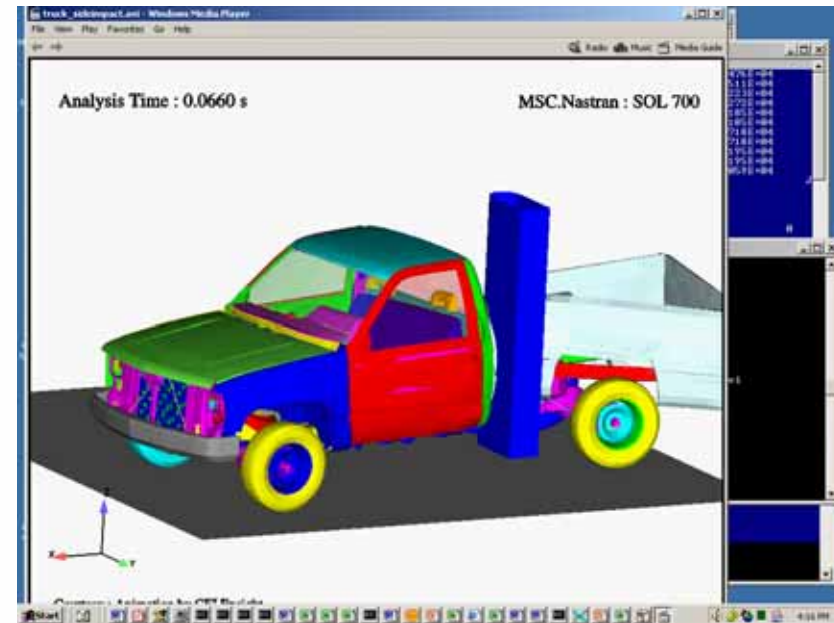
MSC.Nastran Explicit Nonlinear – SOL700:

- Provides FEA capability for the analysis of impact and crash analyses.
- Combines LSTC's advanced nonlinear finite element technology with the world's most widely used finite element code, MSC.Nastran



How Does MSC.Nastran SOL 700 Work ?

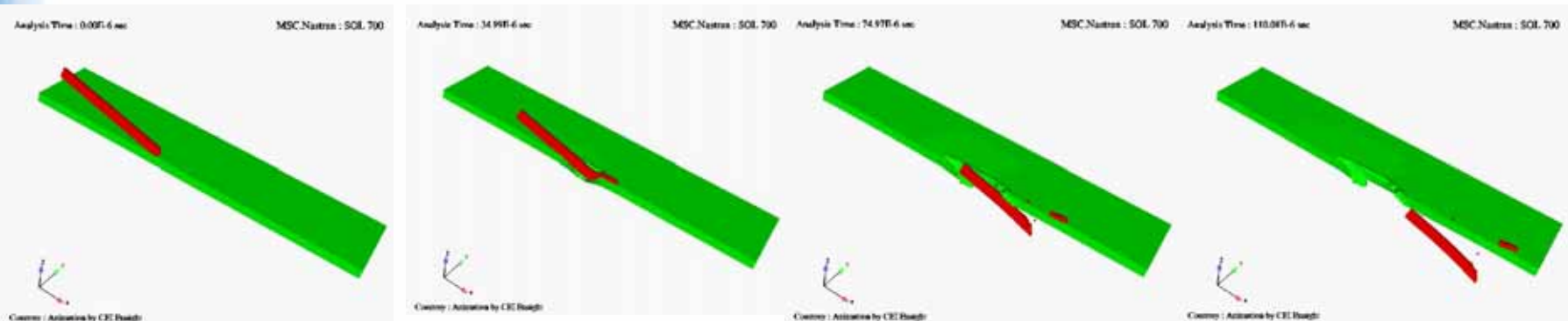
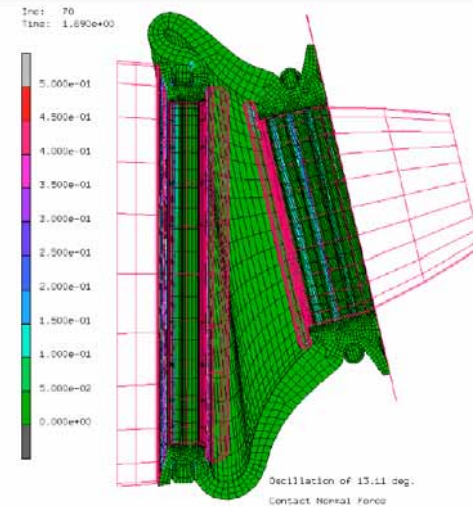
- MSC.Nastran Look and feel:
 - Input a standard Nastran input deck
 - Spawns LS-Dyna
 - Optional – d3plot results read back to Nastran database
 - Optional - standard Output from Nastran (f06,op2,xdb,punch)
- New Nastran text input:
 - Executive Command:
SOL 700,NLSTATIC outr= path=
 - New Case Control Command for 3D contact - BCONTACT
 - New Bulk Data Entries for 3D contact and advanced materials including rubber, large strain, visco-elastic, failure, ...



SOL 700 - Powerful Nonlinear Capabilities

LS-DYNA Mature Robust Nonlinear Algorithms provide:

- A powerful tool for simulating crash and impact
- multi-body contact analysis capability (easier to set up – same as SOL 600)
- long list of advanced material models and element technology. Over 30 LS-DYNA models incorporated with new Bulk Data names.



How Does MSC.Nastran SOL 700 Work ?

Nastran – LS-DYNA Integration

Input compatible with Sol 129, 109, 103, and 101

NLPARM, TSTEPNL, MATS1 etc.

Contact supported in the Nastran pref of Patran

- New exec control for Marc Input and Marc Execution

SOL 700, SID path= stop= outr= copyr=

- where SID is a Nastran solution sequence number: 129, 109, 101

New Case Control Command for contact

- **BCONTACT= 10**

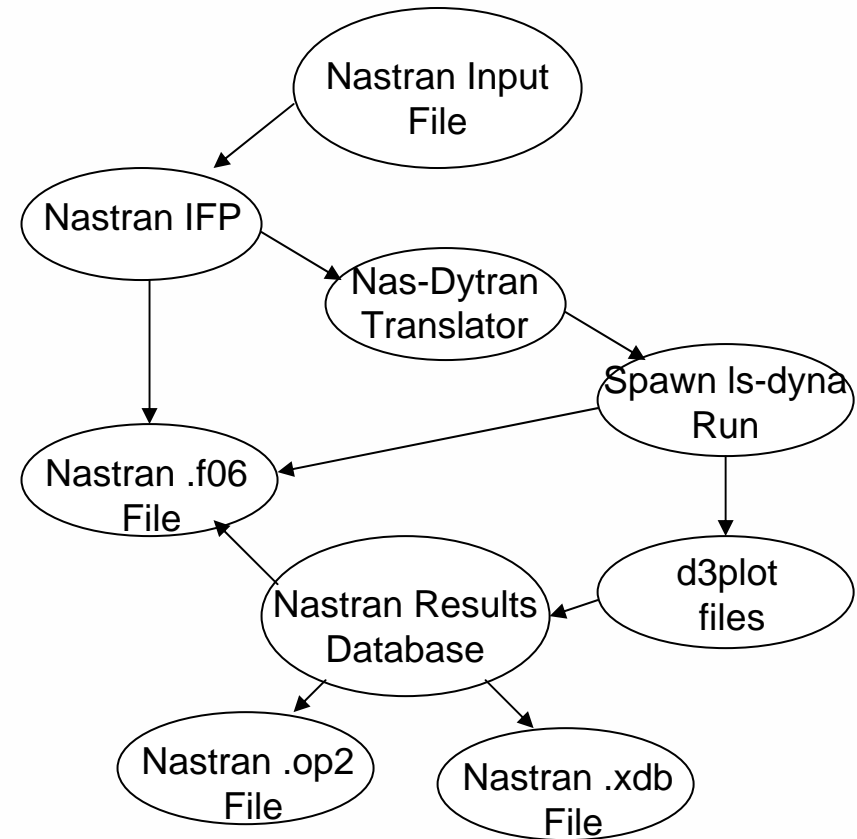
New bulk data entries for new capabilities

- **BCTABLE, BCBODY, BSURF, BCBOX, BCPROP, BCMAT** for contact
- **MATDxxx** LS-Dyna Material number xxx
- For example **MATD001** is LS-Dyna material 1
- d3plot output is converted to op2, xdb, f06, pch using Patran's DRA/DAC (work in progress)

How Does MSC.Nastran SOL 700 Work ?

• Nastran-Dytran Translator:

- Start Nastran, read the Nastran input file
- Generate a Dytran input file and run LS-Dyna in the background. MSC's version of LS-Dyna has a special reader for Dytran input
- Nastran (optionally) deletes intermediate files
- Needs a LS-Dyna and a Nastran executable (both are included on the Nastran CD)



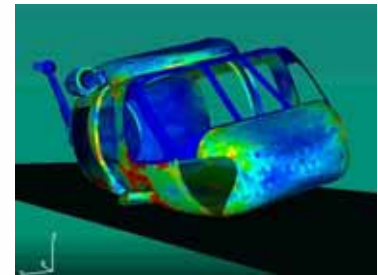
How Does MSC.Nastran SOL 700 Work ?

- ✓ **LS-Dyna becomes a background process run by Nastran**
- ✓ **Nastran uses Patran's DRA/DAC to obtain results in Nastran format (in progress)**
- ✓ **All standard Nastran output formats will be available – Nastran toolkit used to create**
 - ✓ **XDB**
 - ✓ **OP2**
 - ✓ **F06**
 - ✓ **PUNCH**

MSC.Nastran SOL 700 Features

MSC.Nastran SOL700 Features:

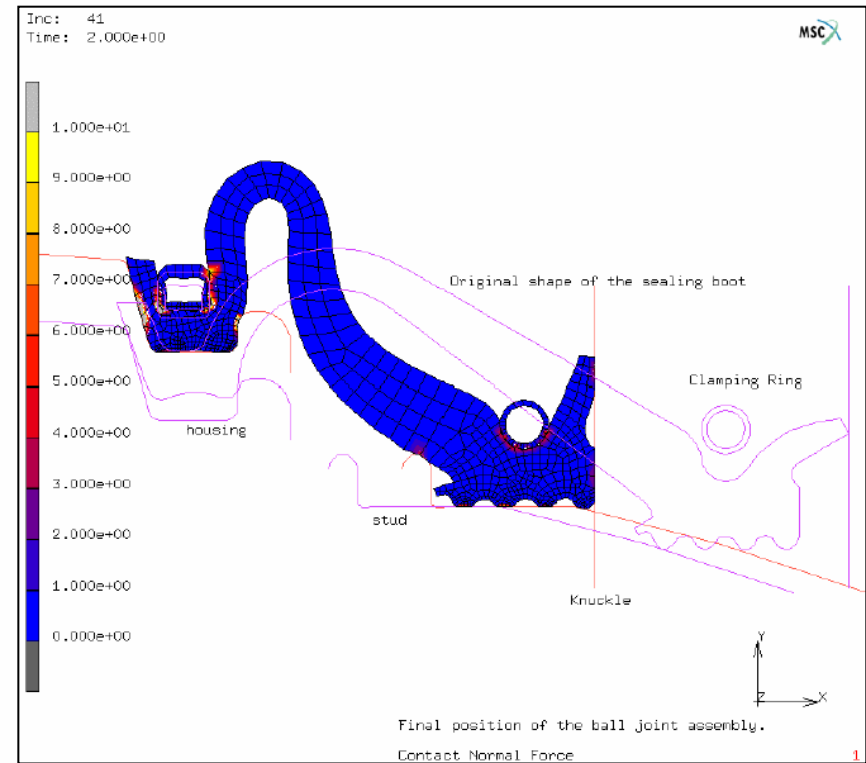
- Structural (2005), Coupled fluids, air bags, seat belts, dummy passengers (2006 and 2007)
- Material, Geometric, large strain, failure and Contact Non-linearity (2005)
- Parallel Processing (2005)



Non-linear Features in MSC.Nastran SOL 700

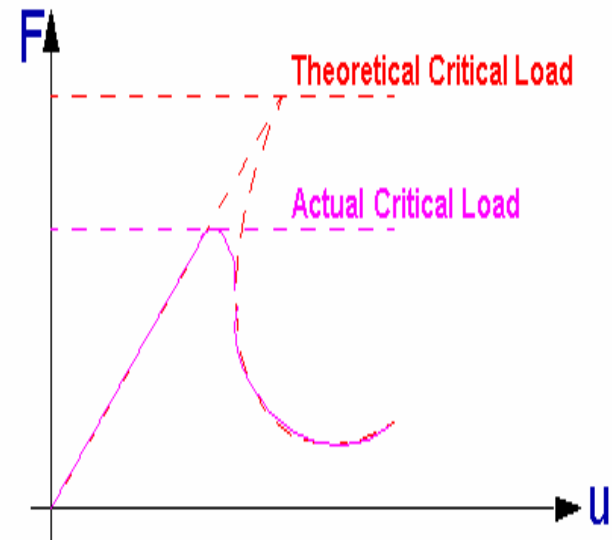
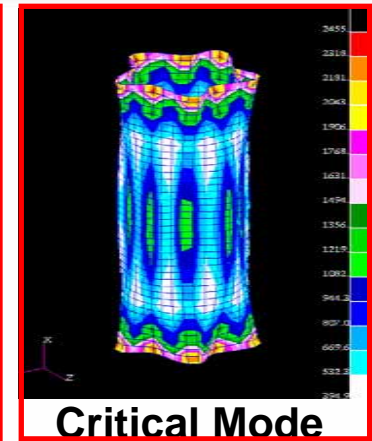
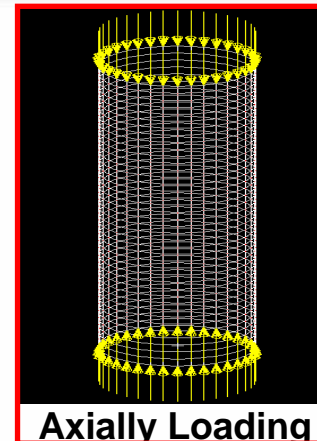
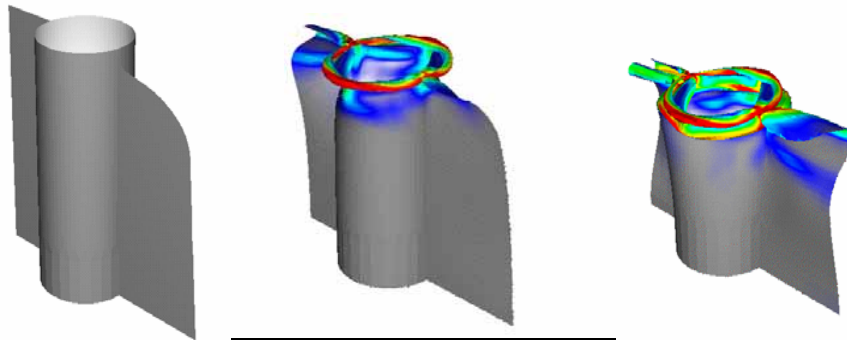
Brings Powerful, Mature, Robust Nonlinear Technology to the MSC.Nastran Community

- Geometric Non-linearities
- Materially Non-linear Models
- Boundary Condition Non-linearities (Contact)



Geometric Nonlinear

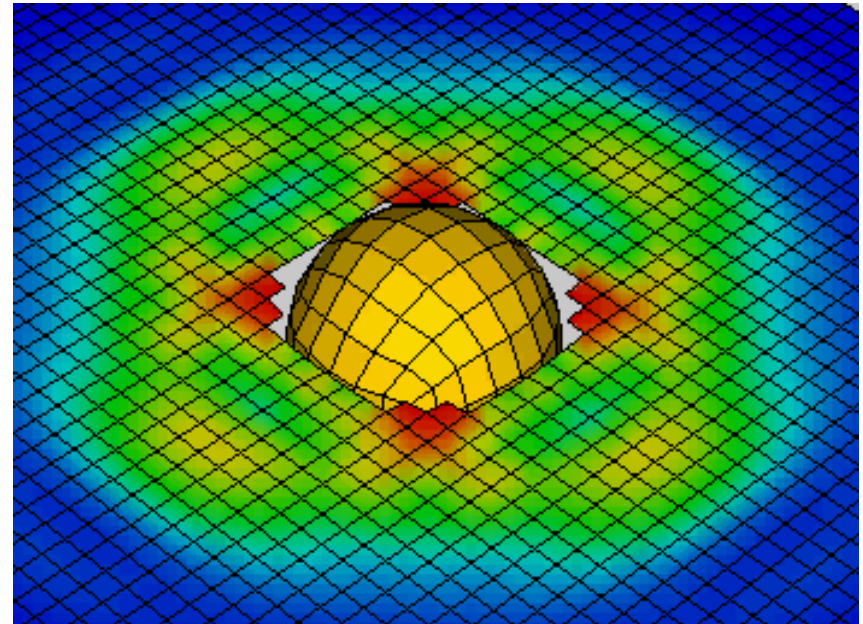
- Large Displacement and rotations
- Large Strain Analyses
- Post-buckling behavior



Large Deformation & Rotation

Finite Deformation

- Large Deflection, Rotation and Strain:
 - Large Deformation and Rotation of rigid elements RBE2, RBE3, RBAR
 - Large (Finite) Strain With Choice of Strain Definitions
 - Finite Strain Plasticity
 - Failure
- Automatic dt determination

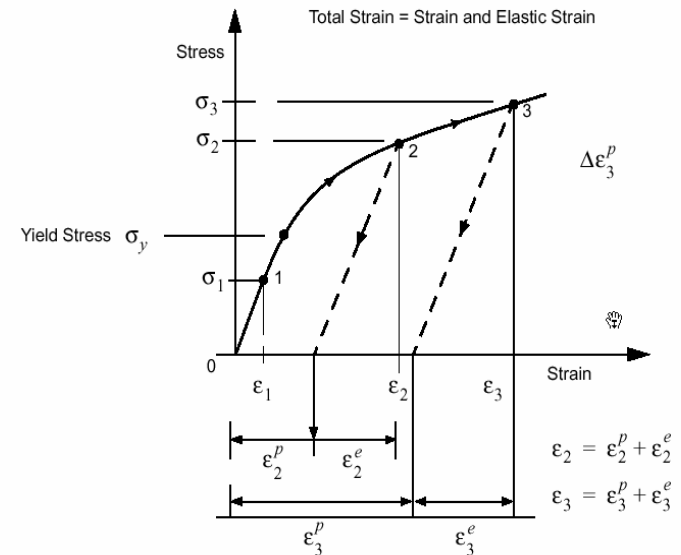
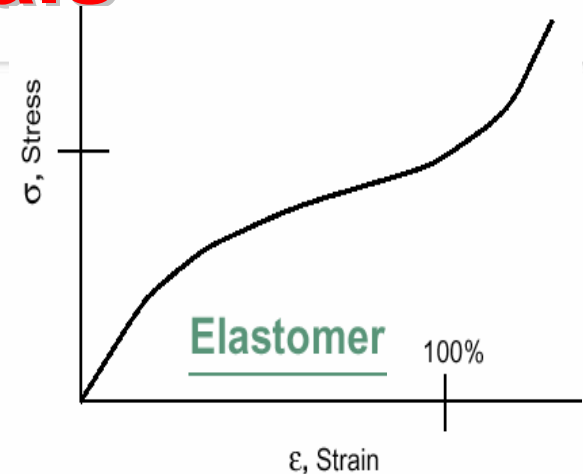


Nonlinear Materials

- Isotropic, Orthotropic and Anisotropic Material Models
- Includes 3D Laminated Composites, and Failure
- Includes Temperature, Strain Rate Dependencies and equations of state

- **Elastic**

- **Plastic:** Small and large strain
- **Hyper-elastic** (for Elastomers)
- **Creep and Visco-elastic**
- **20 LS-Dyna Materials - MATDxxx**

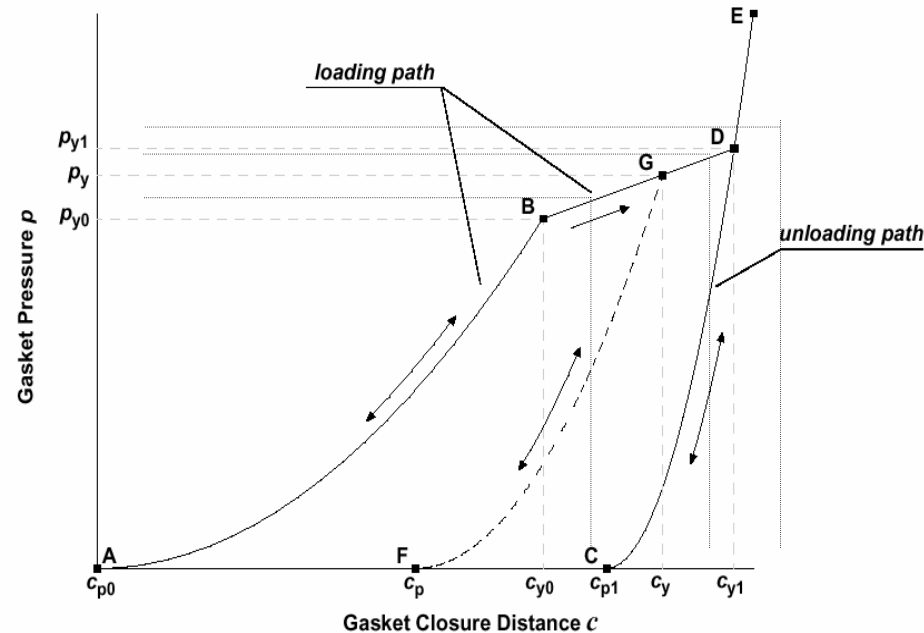


Time-Independent Inelastic Behavior

Nonlinear Materials

Materials

- Advance Nonlinear Materials:
 - Linear Elastic
 - Elastic-Plastic:
 - Elastic-Perfectly Plastic
 - Elastic-Plastic With Work Hardening:
 - Isotropic
 - Kinematic
 - Combined
 - Rigid - Plastic
 - Hyper-elastic for Elastomers (Rubber) for Bushings and Seals

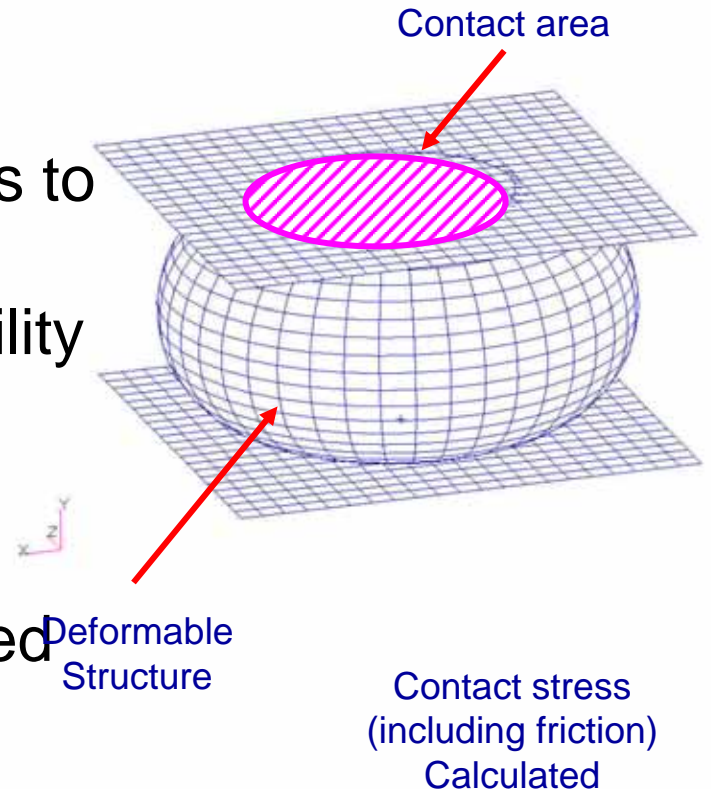


MSC.Nastran SOL 700 Contact

Contact Capabilities

Brings Advanced Contact Capabilities to MSC.Nastran:

- Easy to Use Multi-Body Capability
- 2-D and Full 3-D Contact
- Supports Rigid-Deformable Contact
 - Position, Velocity or Enforced Motion Rigid Bodies



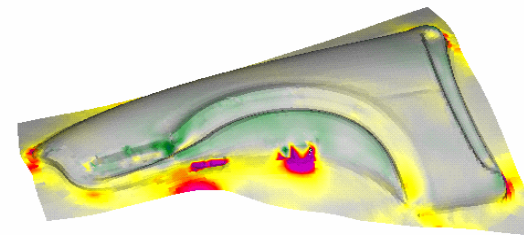
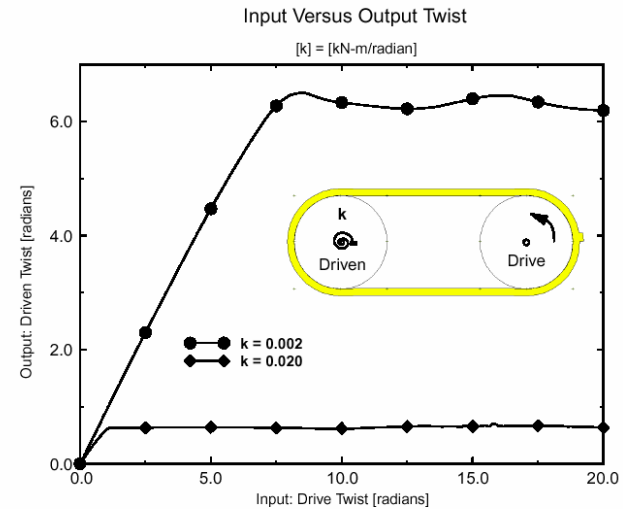
Boundary Condition Non-Linearity

Multi-Body Contact

- Very Easy to Set-Up
- Automatic detection of contact surfaces
- 2D and 3D contact

Finds widespread use in areas like:

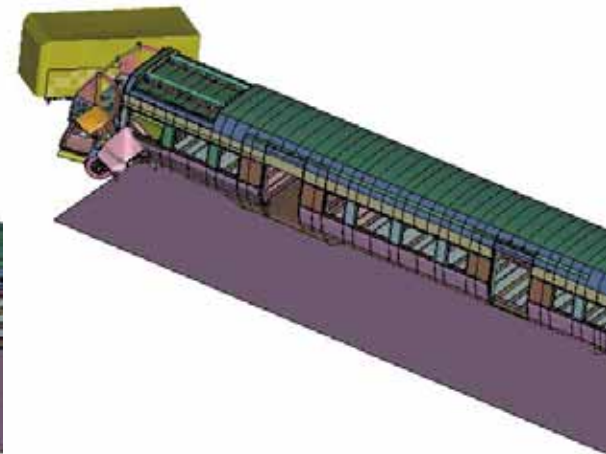
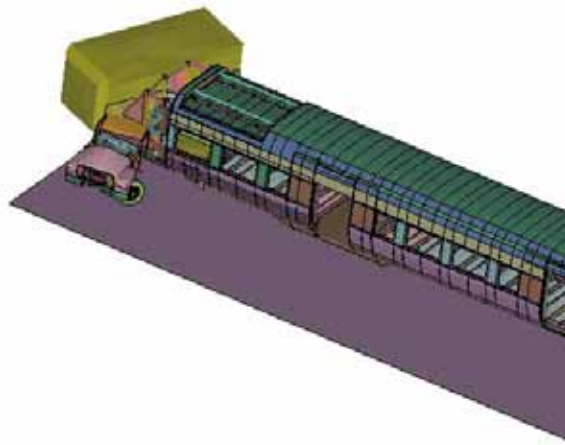
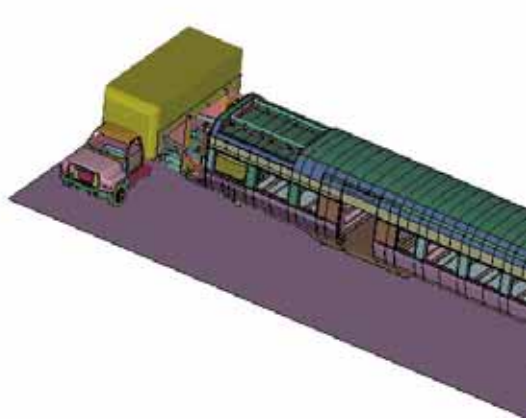
- > Portions of structure that hit due to large deformation.
- > Manufacturing Simulations for sheet metal forming, deep drawing, mounting seals and other process simulations, bio-medical simulations and more



Boundary Condition Non-Linearity

Contact Capabilities:

- Rigid and Deformable
- Reports Interface Results
- Surface Interactions
 - Contact Thickness Definition
 - Contact Penetration
 - Friction models



When To Use Sol 700 Vs 129

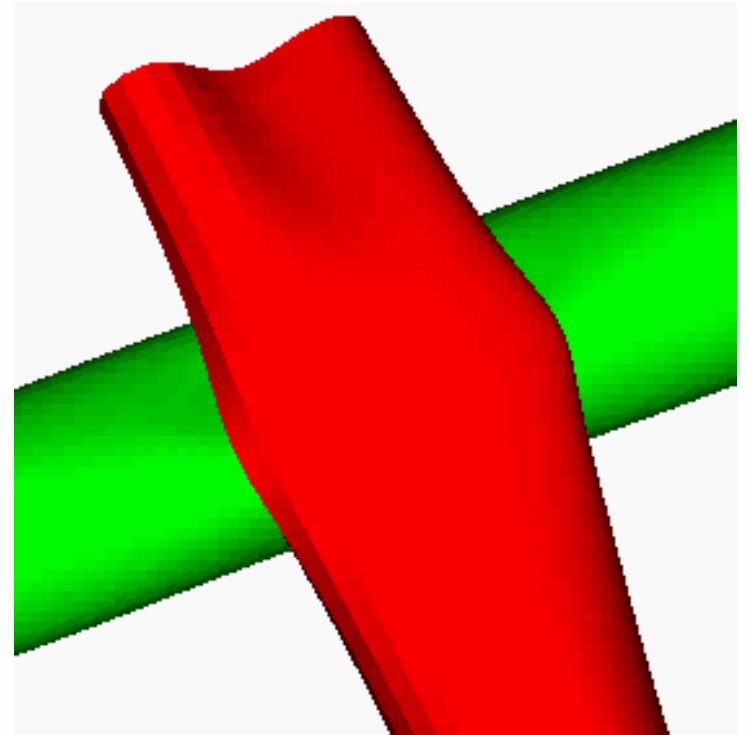
Most Common Reasons to Use MSC.Nastran SOL 700:

- ✓ Need to simulate high impact or crash
- ✓ Need to Model 3D or Multi-Body Contact
- ✓ Large Strains or Large Strain Rates

SOL 700 Parallel DMP

Advantages and Benefits ...

- ✓ Linearly-Scalable
Distributed Memory
Parallel
- ✓ MSC.Nastran SOL 700's
DMP capability allows you
to solve problems in hours
that would take days to
solve using a Single CPU



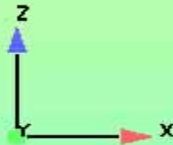
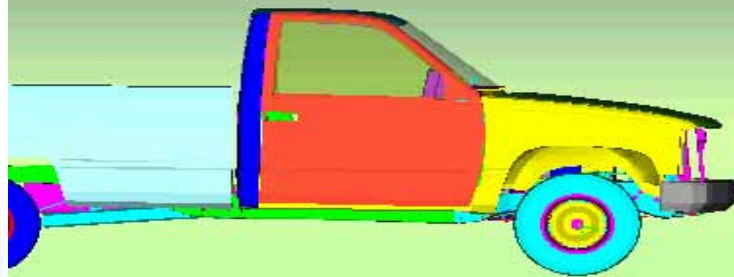
SOL 700 Examples

- ✓ **Pickup Truck Frontal Crash**
- ✓ **Pickup Truck Side Impact**
- ✓ **Train – Truck Crash**
- ✓ **Pipe Whip**
- ✓ **Ball Impact on Plate with Failure**
- ✓ **Beam Crush**
- ✓ **Projectile Penetration**

Truck Frontal Crash Analysis

Analysis Time : 0.0000 s

MSC.Nastran : SOL700

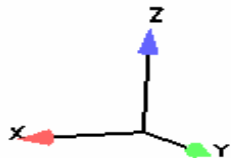


Courtesy : Animation by CEI.Ensight

Truck Side Impact

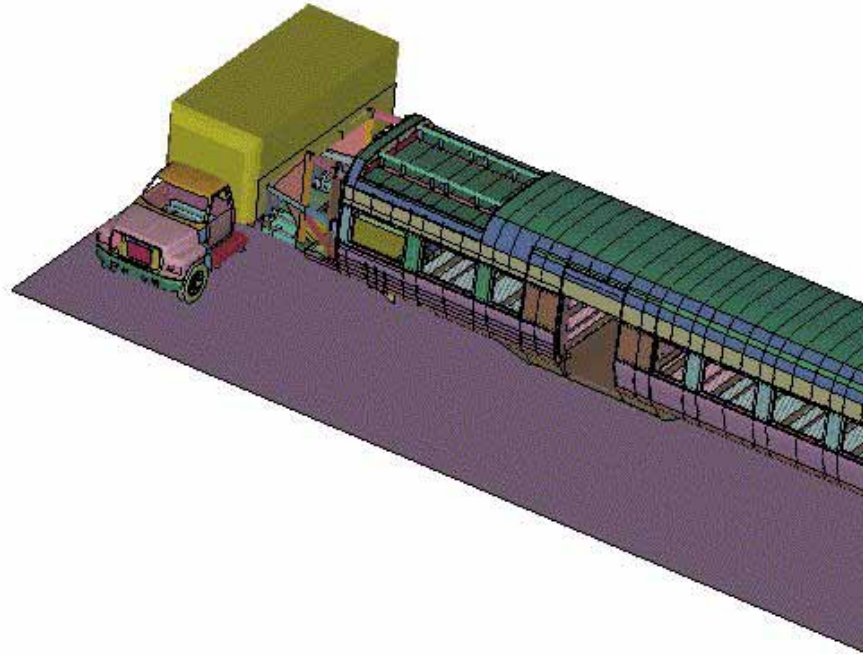
Analysis Time : 0.0000 s

MSC.Nastran : SOL 700



Courtesy : Animation by CELEnsight

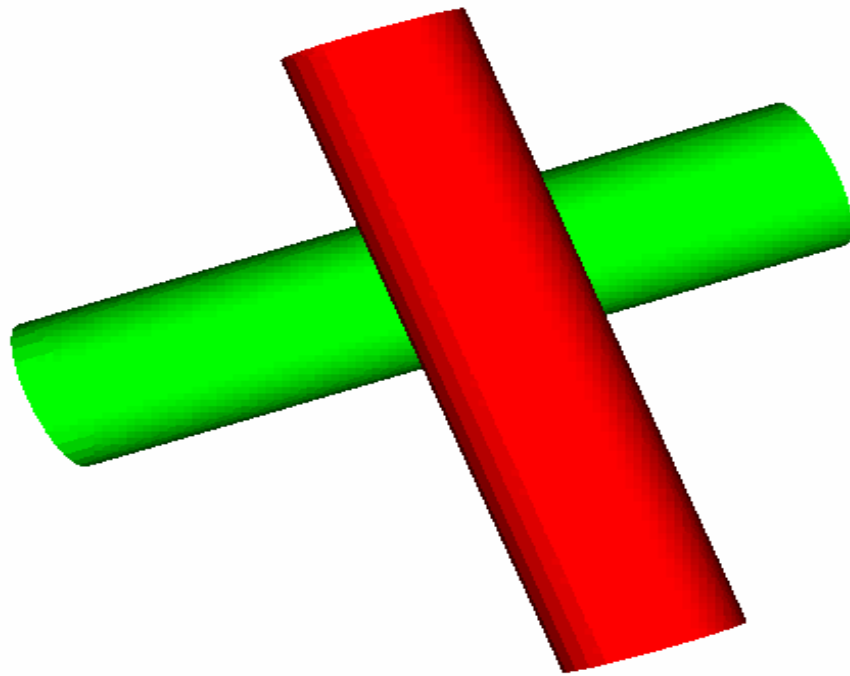
Train – Truck Crash



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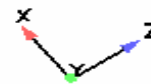
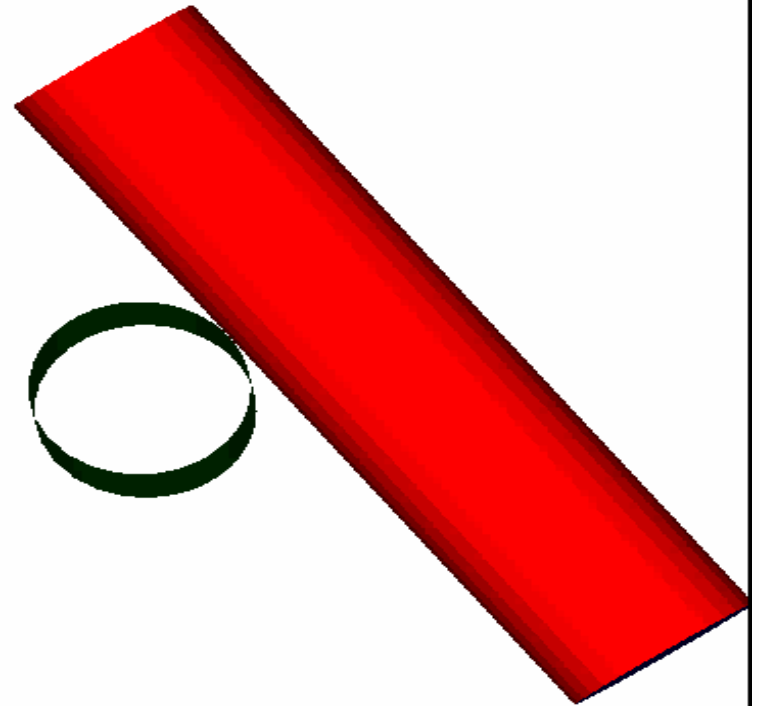
Pipe Whip

Analysis Time : 0.0000s



Courtesy : Animation by CEI.Ensight

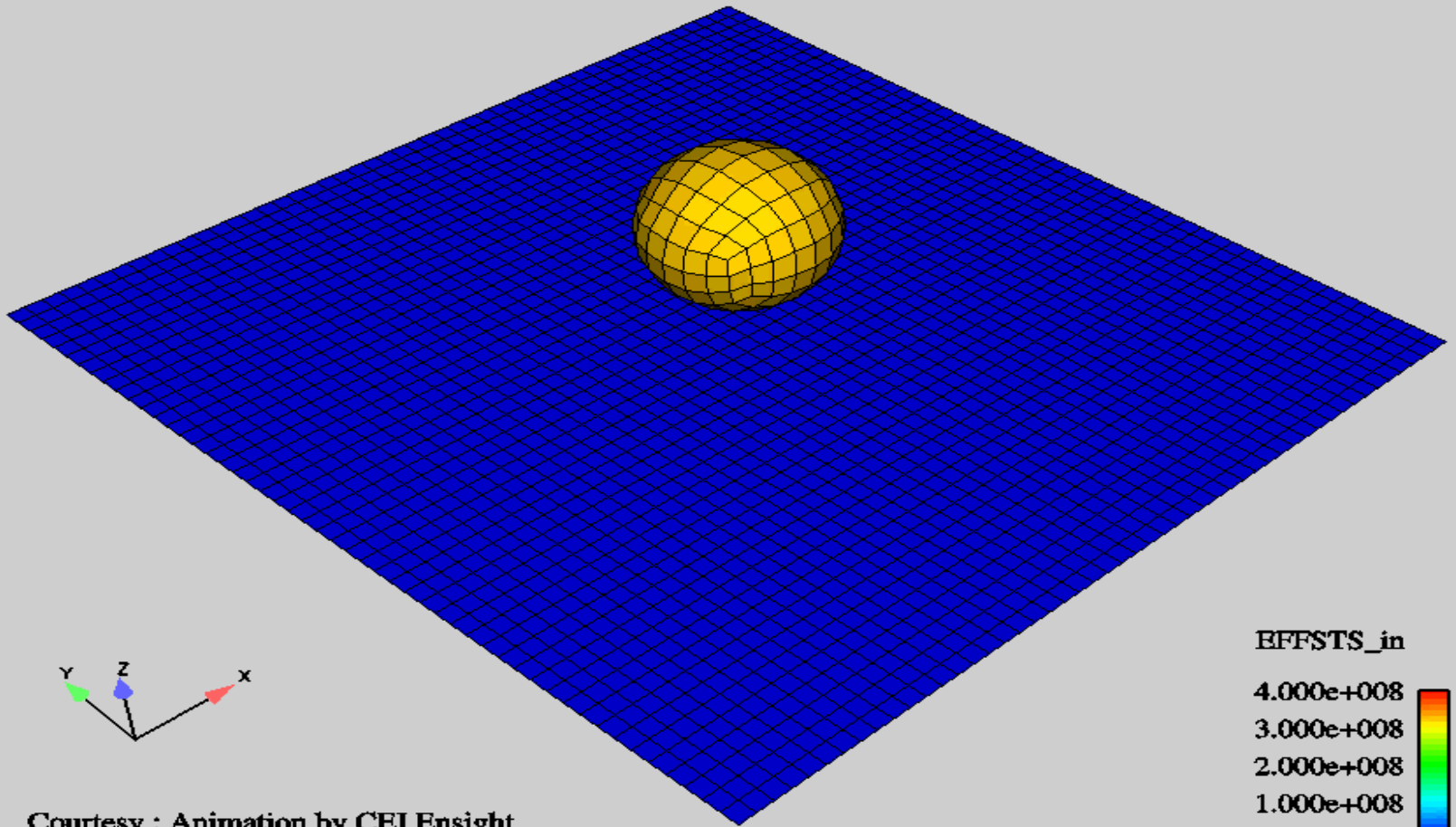
MSC.Nastran : SOL 700



Ball Penetrates Plate with Failure

Analysis Time : 0.0000 s

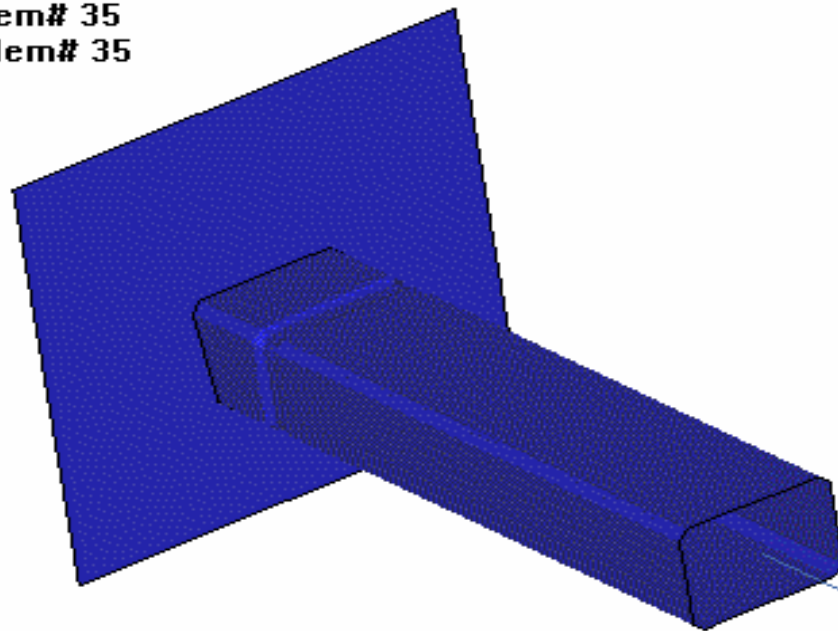
MSC.Nastran : SOL 700



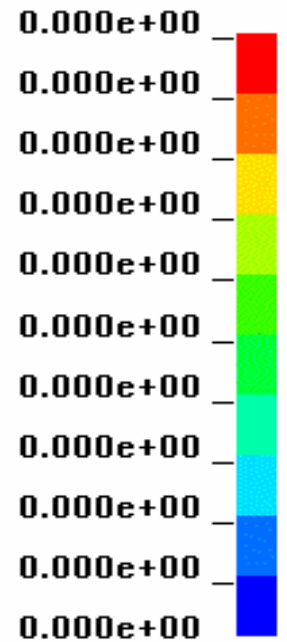
Courtesy : Animation by CEI Insight

Beam Crush

MSC.Nastran SOL 700 (LS-DYNA)
Time = 0
Contours of Effective Stress (v-m)
max ipt. value
min=0, at elem# 35
max=0, at elem# 35



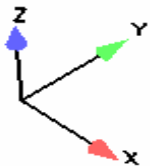
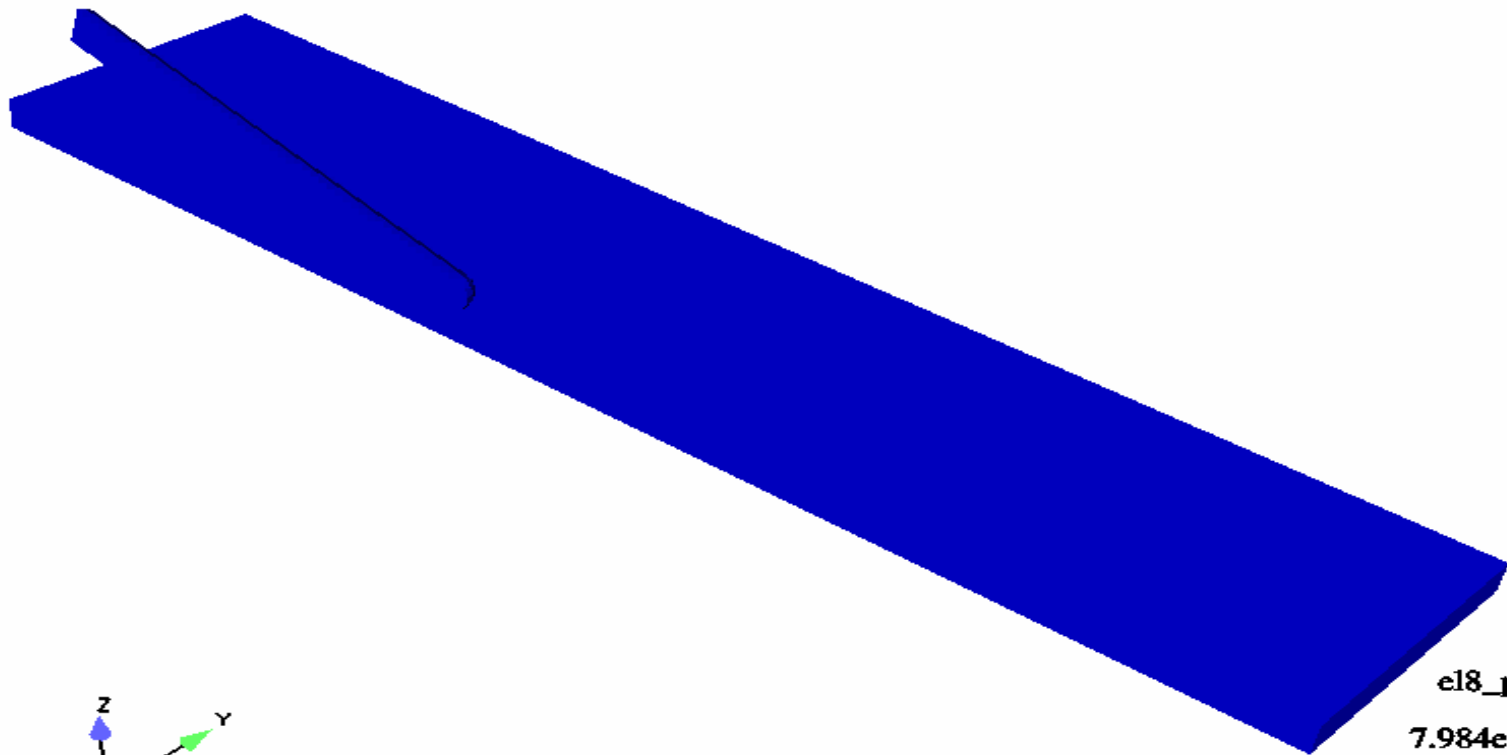
Fringe Levels



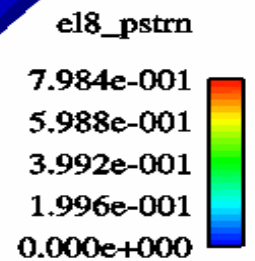
Projectile Penetration

Analysis Time : 0.00E-6 sec

MSC.Nastran : SOL 700



Courtesy : Animation by CEI Ensignt



Effect of DMP on Run Speed

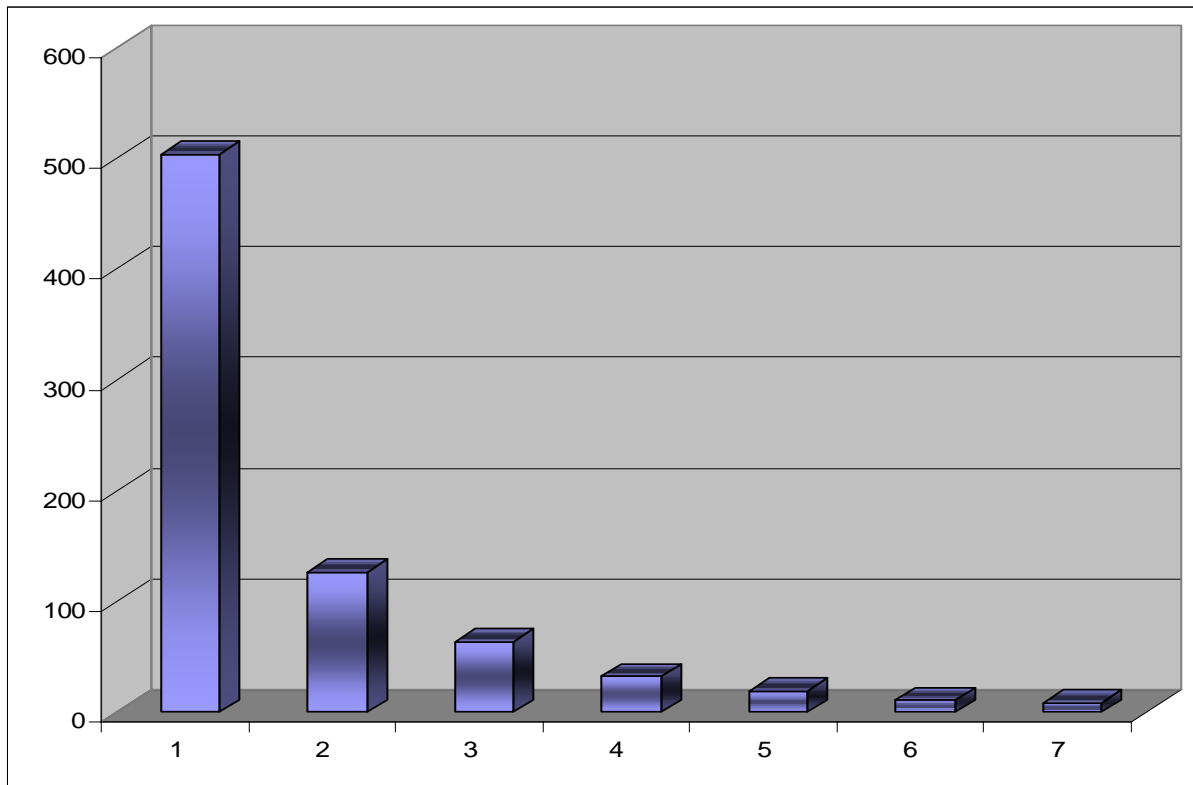
~493,000 elements , 370,815 cycles
LS-DYNA/MPP 960, 6/2001

CPU#	Time	Speedup
1	~21 days	1.00
4	127.03hrs	4.00
8	64.18hrs	7.92
16	32.26hrs	15.75
32	19.52hrs	26.03
64	11.05hrs	45.98
96	8.80hrs	57.74

***4 hours on 12 Intel 2.4 GHz P4,
Less than 2 hrs TODAY !***

Effect of DMP on Run Speed

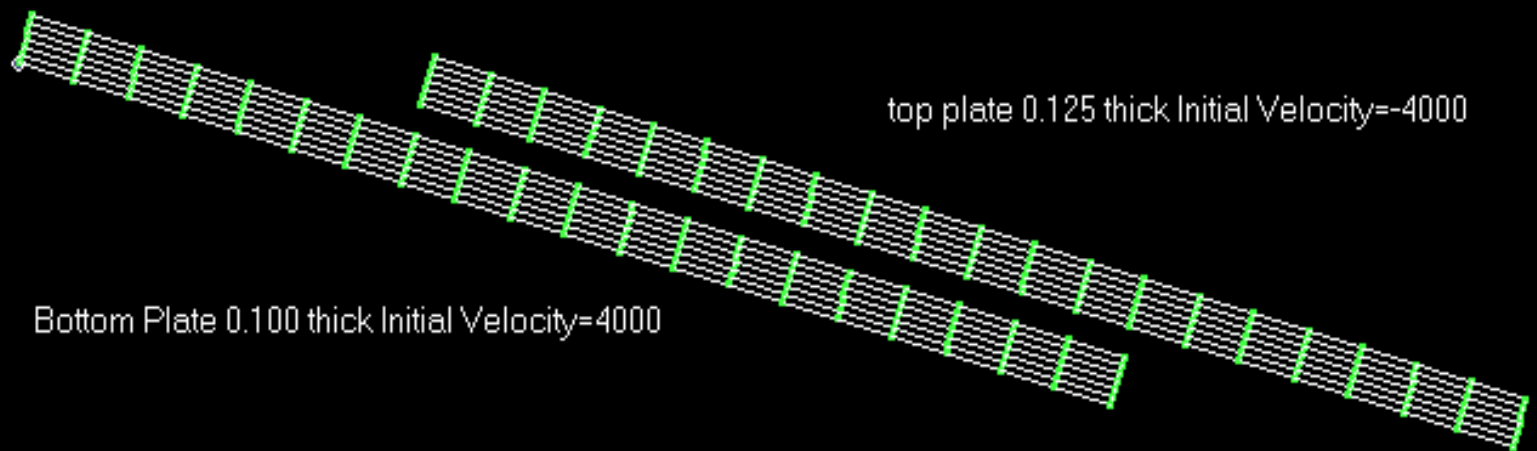
~493,000 elements , 370,815 cycles
LS-DYNA/MPP 960, 6/2001



1	4	8	16	32	64	96
504	127	64	32	19	11	8.8

Real Time Example

SOL 700 Example contac1a.dat



Real Time Example

```
SOL 700,NLTRAN path=1 stop=1
```

```
CEND
```

```
ECHO = NONE
```

```
DISPLACEMENT(PLOT) = ALL
```

```
Stress(PLOT) = ALL
```

```
Strain(PLOT) = ALL
```

```
SPC = 1
```

```
bcontact=121
```

```
IC=444
```

```
TSTEPNL = 20
```

```
BEGIN BULK
```

```
$2345678 2345678 2345678 2345678
```

```
TSTEPNL 20 10 1.00E-5
```

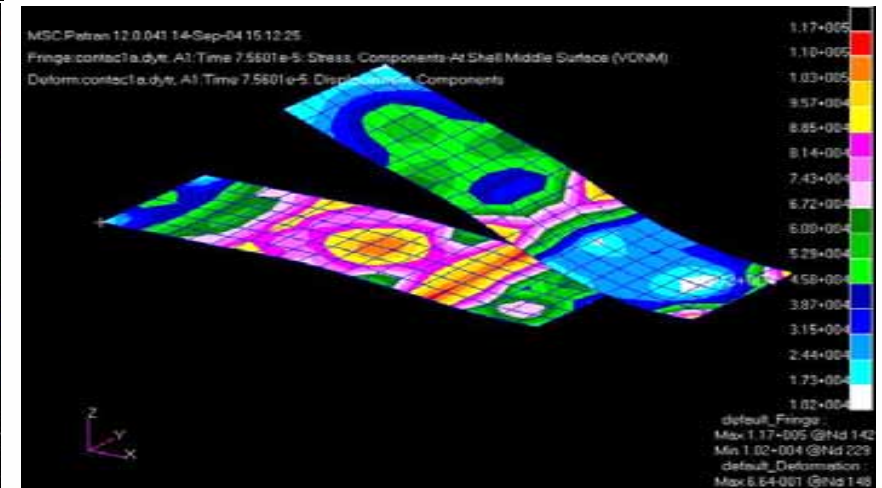
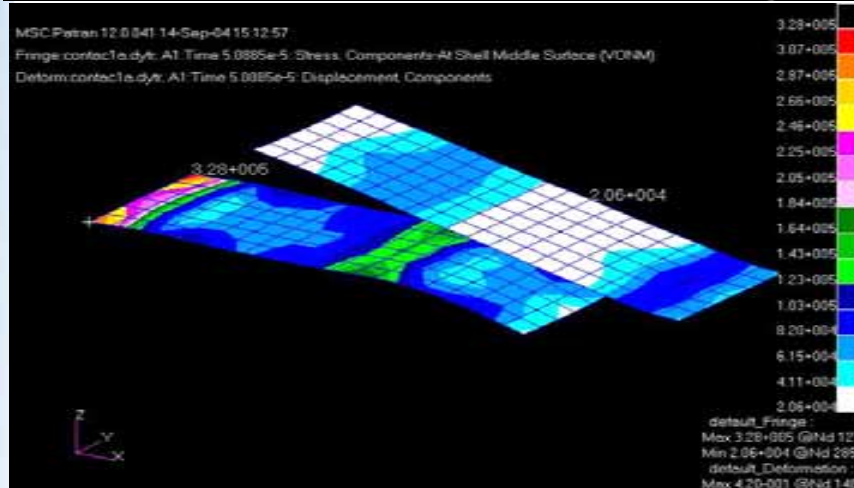
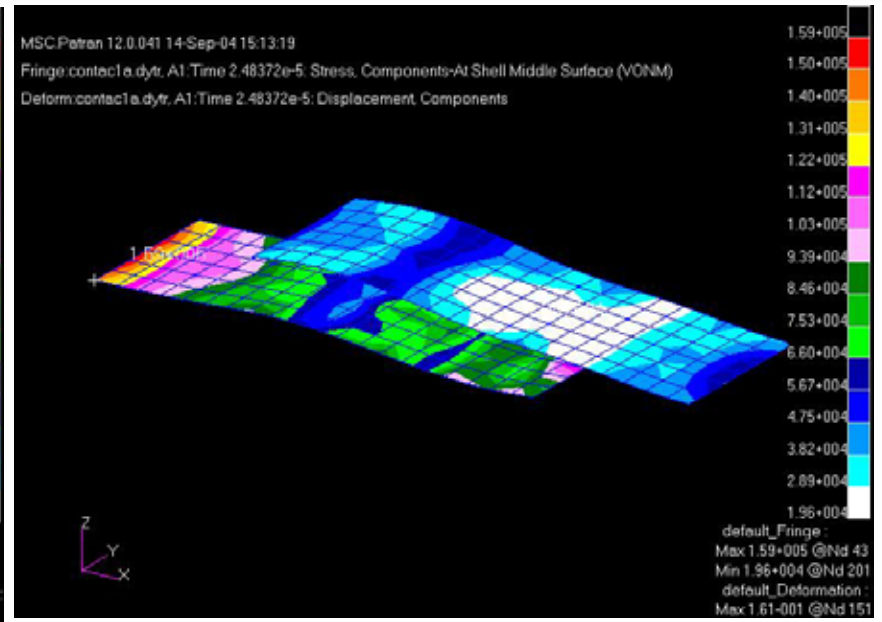
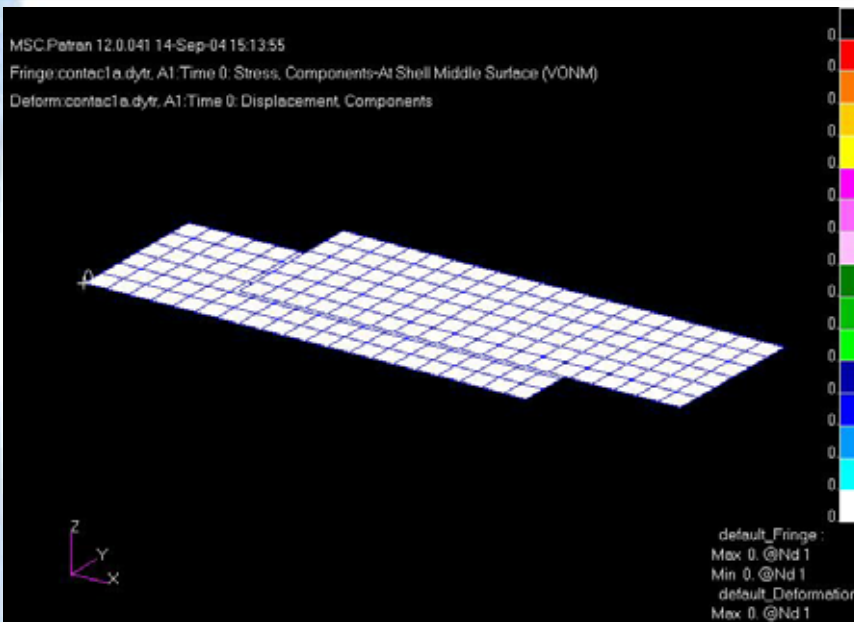
```
TICD, 444, 1, 3, 0., 4000., 147, 1
```

```
TICD, 444, 148, 3, 0., -4000., 294, 1
```

Real Time Example

```
CQUAD4      239      2      271      272      293      292
CQUAD4      240      2      272      273      294      293
BSURF, 101, 1, THRU, 120
BSURF, 102, 121, THRU, 240
BCBODY, 111, , DEFORM, 101, 0, .05
BCBODY, 112, , DEFORM, 102, 0, .04
BCTABLE, 121, , , 1, , , , +
+ , SLAVE, 111, .005, .12, .0501,
+ , MASTER, 112
ENDDATA
```

Real Time Example



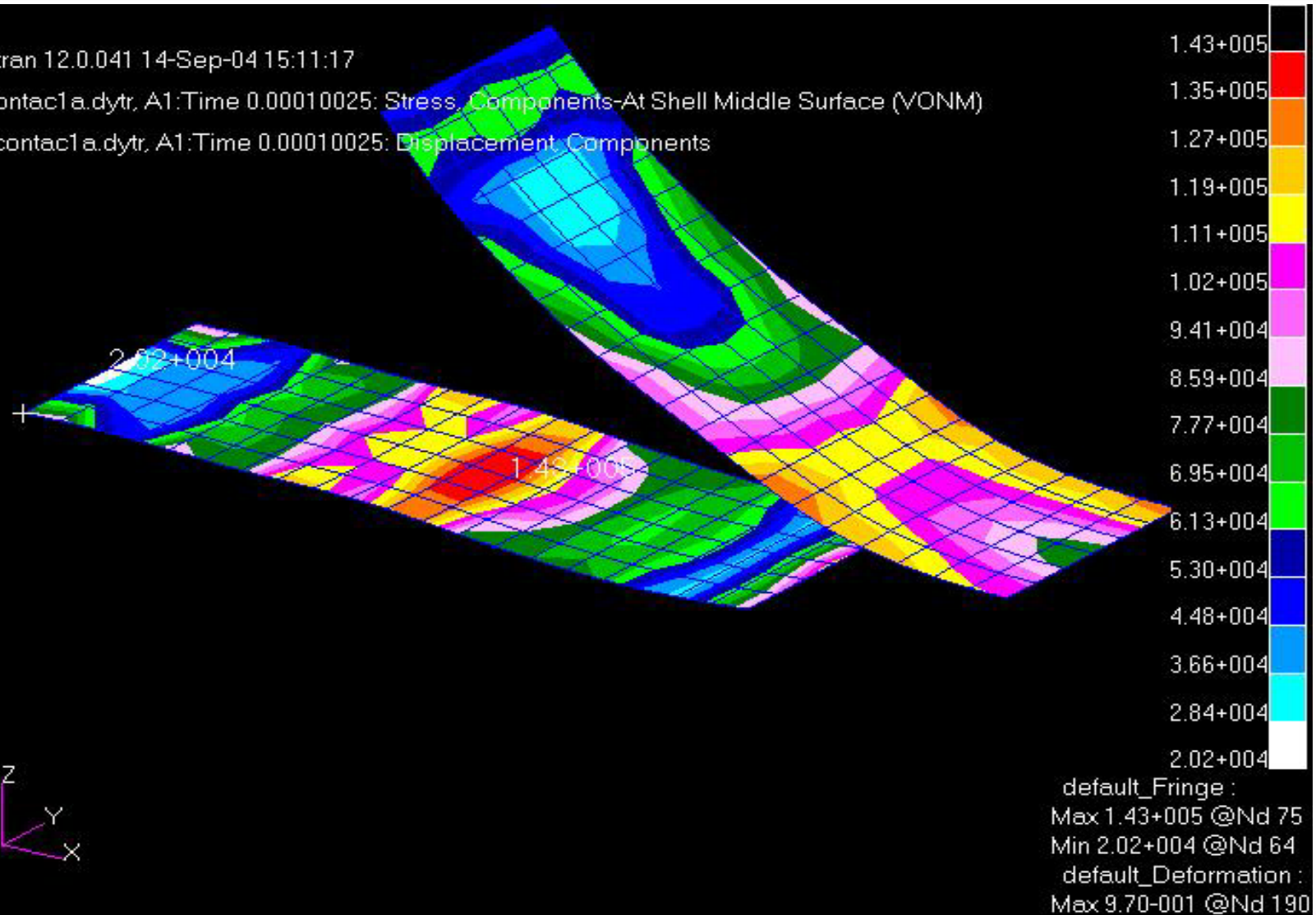
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Real Time Example

MSC.Patran 12.0.041 14-Sep-04 15:11:17

Fringe:contact1a.dytr, A1:Time 0.00010025: Stress, Components-At Shell Middle Surface (VONM)

Deform:contact1a.dytr, A1:Time 0.00010025: Displacement, Components



Thank you!