Integration of MSC/PATRAN with Sandia National Laboratory's EXODUS II Database System

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A paper presented at the 1996 MSC World User's Conference

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ABSTRACT

This paper highlights the development, enhancement and use of the MSC/PATRAN "Preference" at Sandia. This preference integrates MSC/PATRAN with the EXODUS II database. The development of the preference demonstrates the flexibility of MSC/PATRAN's open architecture. There were some interesting challenges not normally encountered when integrating MSC/PATRAN with commercial FEA codes. Also, as the preference has been enhanced and upgraded through four MSC/PATRAN release cycles several development concepts have been discovered. Production use of the preference is now expanding at Sandia and other locations. Several examples will be presented of models developed at the labs. Finally, future development options will be outlined.

INTRODUCTION

Sandia National Labs is currently evolving their design and analysis process to "Model Based Design". This process uses Pro/ENGINEER as the geometry definition system, and has no paper drawings. This is a significant departure from previous methods of analysis at Sandia. Consequently, the engineers now need analysis tools that can integrate this geometry with all of the FEA tools that are used in the labs. Although commercial FEA codes are used, many of these programs are internal codes that use Sandia's EXODUS II analysis database system.

EXODUS II is a not an FEA program, but instead is a specialized database used to define the finite element model for the different analysis codes developed at the lab. Sandia's vision of analysis integration through the EXODUS II system is shown in Figure 1. These analysis codes cover all types of applications, including structural and thermal models, using explicit and implicit solvers.

In the past, Sandia engineers had two options. They could build the models using proprietary preprocessors that could create an EXODUS database. They could also use MSC/PATRAN Release 2.5 along with a Sandia developed interface to EXODUS I.

Neither option provides good integration to Pro/ENGINEER geometry. The internal preprocessors suffer from the same problem as most inhouse FEA tools: limited resources. Consequently, the support staff could not keep pace with enhancement requests, bug fixes, multiple platforms, user support, or integration to evolving CAD geometries. In addition, these modelers were designed to work in a research environment, and could not always handle the modeling complexities required of production analysis of commercial parts. The second option had limited functionality and would require upgrading the interface to work with next generation versions of both software systems (i.e., MSC/Patran and EXODUS). This would be a very large software development project built on an old architecture.

In contrast, MSC/PATRAN provides direct access to Pro/ENGINEER geometry, and has an open architecture that allows integration of all analysis codes. This concept was referred to as "Preferences" at the introduction of PATRAN3, and provides a level of integration unmatched by any other MCAE tool in the industry. Since Sandia engineers were already using MSC/PATRAN to create models for MSC/NASTRAN, MSC/PATRAN Thermal, and ABAQUS it was natural to select MSC/PATRAN to support this step in the evolution of the design/analysis process.

FUNCTIONAL REQUIREMENTS

The desire to develop an interface from MSC/PATRAN and EXODUS II led to a working relationship between Sandia and PDA Engineering (this occurred prior to the merger with MSC). Sandia would guide the development requirements of an interface between MSC/PATRAN and EXODUS II, and PDA would help with

implementation of the initial interface through the field support organization. This relationship has been ongoing since December, 1993 when the initial specification was agreed upon.

The initial design included the capability to export the model and import analysis results. All EXODUS II element types and attributes were included. The user could also create and export boundary conditions (Node Sets and Side Sets). The results import function was designed to let the user select the desired result at a particular time step. This was done for two reasons. First, it provides the needed flexibility to access any analysis result that can be stored in the EXODUS II database. Second, it allows the user to filter the amount of data coming into the MSC/PATRAN database. All development was done using PCL for the MSC/PATRAN graphical interface, and C for the database-to-database programs.

Element Properties

As noted above, all EXODUS II element types and attributes are supported. To take advantage of MSC/PATRAN's capabilities, all input can be applied to geometric or finite element entities. The elements in the EXODUS II system are summarized in Table 1, along with their attributes (element properties).

Note, in the EXODUS II system, all elements must belong to an element block (similar to a property set) which requires a Block ID in addition to the attributes listed in the table. All elements in a block must have identical attributes and must be consecutively numbered within the block.

Two of the specialized elements (SPHERE and CIRCLE) are not a part of the standard MSC/PATRAN template database. Consequently, these elements required the addition of two element types along with their property data (e.g., Radius). The addition of these two new elements was done by customizing the MSC/PATRAN database template used by the preference.

An example of the element property input forms for a 3d Beam is shown in Figure 2.

Boundary Conditions

As noted above, all EXODUS II boundary conditions are supported, including all Side Set definitions. This includes the faces of HEX/WEDGE/TETRA elements, edges of QUAD/TRIANGLE elements and faces or edges of SHELL elements. Also, all distribution factors are currently set to "1.0", but the code structure has been designed to support non-uniform distribution factors. (Note, distribution factors are somewhat analogous to a multiplier on the magnitude of a loading.) To take advantage of MSC/PATRAN's capabilities, all input can be applied to geometric or finite element entities.

The definition of boundary conditions in MSC/PATRAN went through two phases of development. Initially, the boundary condition definitions were defined using the existing LBC definitions (Displacements for Node Sets, and Pressures for

Side Sets). This convention was used for the first two versions (Releases 1.2 and 1.3). In the third version (for Release 1.4), new LBCs were added to the template. Now, users can create LBCs called Node Sets and Side Sets in MSC/PATRAN. (Note, the older input method is still supported for existing databases.)

Since EXODUS II does not carry any concept of "Load Cases", this interface requires the user to set the "Current Load Case" to "Default", and put all desired boundary conditions into this Load Case.

See Figure 3 for an example of the Side Set input forms for solid element faces.

Analysis Setup

Analysis forms were also created to allow the user to 1) define the EXODUS II database name, 2) select the dimensionality (2D/3D) of the model, 3) and set the precision of the EXODUS II database (single/double precision). The interface program to create the EXODUS II database can be submitted directly from the MSC/PATRAN session.

Results Import

Import of results was designed to interrogate for available results in the EXODUS II database (as there may be any type of result for a particular model). Once the user selects an EXODUS II database, available result types and variables are presented in the Analysis forms. The results types may be at the nodes, elements, or global. From this display, the user selects the desired result type and variable. Also, for element results the user selects an element block that includes the selected result. The time step for import must also be set by the user. Once this data is defined, the results are imported directly into the MSC/PATRAN database for post-processing with Results and Insight tools.

Figure 4 shows how the Results Import data is presented to the user.

Custom Menus

Since many EXODUS II users were not familiar with MSC/PATRAN (they had been using Sandia's internal modelers), a custom menu was developed to help create the appropriate model features (Element Blocks, Node Sets, Side Sets). This custom menu also had some model verification tools that would be useful for all users. The user is not required to create the model with these menus, as all EXODUS II model definition can be done in the standard MSC/PATRAN user interface. These extra menus were only designed to aid the transition to MSC/PATRAN.

Figure 5 shows one of the custom forms. It provides the user with Node ID and Element ID range information. The user can use this to insure the model will successfully convert to an EXODUS II database.

Porting, Updates, Enhancements

The initial plan did not cover porting or release updates. Since this project is now almost two years old, several ports and updates have occurred. These are summarized below:

July, 1994	First interface delivered on SunOS for MSC/PATRAN Releases 1.2 & 1.3
August, 1994	HP-UX support added
December, 1994	First bug fix version on SunOS and HP-UX
August, 1995	Upgrade to MSC/PATRAN Release 1.4 with enhancements; Solaris support added
Spring, 1996	Upgrade to MSC/PATRAN Version 5 with enhancements; added to shareware library

DEVELOPMENT CHALLENGES

Several functions became "critical" during the development of this interface. These did not initially appear to be difficult problems, but did require unique solutions to complete the project. They are presented here since they may be useful to others trying to solve similar problems.

Results Import

Since the available results in the EXODUS II database are not known in advance, the file has to be open and read twice to import results. First, an "interrogation operation" must be done to find out what results are available, which time steps are saved, and which element blocks store these results. This information must be presented to the user through PCL-based forms for selection during the Results Import step. This required the creation of a small program to query the EXODUS II database and automatically output an intermediate file with the necessary data to display in the forms. Once the user had selected the desired results, the EXODUS II file can then be reopened and the desired results transferred to the MSC/PATRAN database.

Model Import

During initial testing, the need for a "Model Import" function became apparent. There were no existing MSC/PATRAN models with EXODUS II results. Although this function was created out of desperation, this was added to the initial specification to complete the integration of MSC/PATRAN and EXODUS II.

Element Property ID Conflicts

As MSC added additional analysis preference support, conflicts began to arise between IDs selected for EXODUS II entities and preference data for new MSC developed preferences. Currently, the only way to resolve these conflicts is to change the IDs selected for the EXODUS II preference. This required coding changes in the interface programs and the PCL-based user interface. It also required database modification tools for databases upgraded from Release 1.3 to any later versions.

APPLICATIONS

Figure 6 shows an example problem used to test the completed software. The finite element mesh and results were successfully imported from an existing EXODUS II database.

Figures 7-9 shows the example problem used to demonstrate the completed interface at Sandia. The geometry was defined in Pro/ENGINEER and accessed by MSC/PATRAN (Figure 7). The mesh, element properties and LBCs were also created in MSC/PATRAN (Figure 8). The model was output to EXODUS II and analyzed with PRONTO at Sandia. The results were then imported and displayed with MSC/PATRAN (Figure 9 shows the Z displacement at time= 7.21E-6 sec).

FUTURE DEVELOPMENTS

The initial system was delivered to two divisions at Sandia (Structures and Thermal). Since that time a number of other sites have installed the this interface. Some of these include: a third location at Sandia-Albuquerque, Sandia-Livermore, Bettis Labs, NASA-JSC, and Southwest Research Institute.

Shareware Distribution

With the release of MSC/PATRAN Version 5, this software has been included in the shareware library. This should simplify support for future versions under shareware release system. This code is now compiled and linked using the same development environment as the MSC/PATRAN system. This should insure early detection of problems that may arise with new PATRAN versions. This also insures that users will have the correct version of the interface available when they update their MSC/PATRAN installations.

Preference Functionality

Support for future functionality will be driven based on the success of the current system. Some options that are under review include:

- Node and element ID maps (for non-consecutive numbering)
- Variable magnitude for distribution factors
- Results import of vector quantities
- Results import for multiple Element Blocks and/or Time Steps
- Results export to an EXODUS II database
- Model import of Element Block, Node Set, and Side Set Data
- Convert documentation to Online Help System

MSC Support

Many Sandia users would like to see MSC expand support of this preference from the shareware library and commercialize the software. This decision will be evaluated on a business basis as well as a technical basis. In addition to future commercial development of this preference, there are other requirements that MSC should provide to improve the development of all third party preferences.

PCL can be used to link to external C or FORTRAN programs. The functions that perform these operations are called "wrappers". However, they are not documented or available to external developers. The use of a wrapper would greatly simplify the "interrogation operation" used to determine the results to display to the user (no intermediate file would be required to pass the data). MSC should provide the ability to create wrappers in the MSC/PATRAN Develop toolkit product.

Based on the conflicts with new MSC developed preferences, it is obvious that an externally developed preference should use IDs that are VERY LARGE when compared to the IDs used by MSC applications. However, this does not prevent possible conflicts with other external preferences. Although it is highly unlikely that a user will ever try to use two different preferences with one model, the potential exists. At some point MSC should offer to register the IDs used by the external preferences. This would guarantee that no other registered preference would use the same IDs.

CONCLUSIONS

The development of a robust MSC/PATRAN preference to the EXODUS II database has been detailed. This development has successfully demonstrated the flexibility, portability and stability of the MSC/PATRAN system. The software was originally developed under SunOS on a SparcStation2 and has now been ported to Sun Solaris and HP-UX with very few difficulties. All of the porting bugs can be attributed to poor C coding practices used early in the development. Also, the code for existing functionality has required very little maintenance between releases.

In addition, usage of the preference has demonstrated the value of tightly integrating these two FEA systems. Users at Sandia can easily access Pro/ENGINEER geometry and create their finite element models. Also, this leverages the investment in MSC/PATRAN, as one modeling system can be used to create models for commercial and internal FEA systems. Also, finite element models can be transferred between different analysis systems through the MSC/PATRAN system. Finally, training requirements should be reduced when fewer analysis tools are required to develop a model.

ACKNOWLEDGEMENTS

The author wishes to thank Sandia National Laboratories in Albuquerque for their support of this effort, especially Larry Schoof for his help with EXODUS II database issues and Kenneth Gwinn for his constant encouragement.

REFERENCES

[1] Schoof, L.A., and Yarberry, V.R., "EXODUS II: A Finite Element Data Model", Sandia Report SAND92-2137, Sandia National Laboratories, Albuquerque, NM, July, 1994

[2] *MSC/PATRAN User's Manual*, The MacNeal-Schwendler Corporation, Los Angeles, CA, May, 1995

[3] *MSC/PATRAN PCL Reference Manual*, The MacNeal-Schwendler Corporation, Los Angeles, CA, May, 1995

TABLE 1

Element Type	Attributes
HEX	None
WEDGE	None
TETRA	None
SHELL	Thickness
BEAM	Area, I1, I2, J, Orientation Vector
SPHERE	Radius
QUAD (2d)	None
TRIANGLE (2d)	None
BEAM (2d)	Area, I1, J
TRUSS (2d)	Area
CIRCLE (2d)	Radius

Note: The EXODUS II database carries a "dimensionality" flag that is used to determine whether the model is defined in a "2d" or "3d" system. All elements are 3d elements unless noted above.

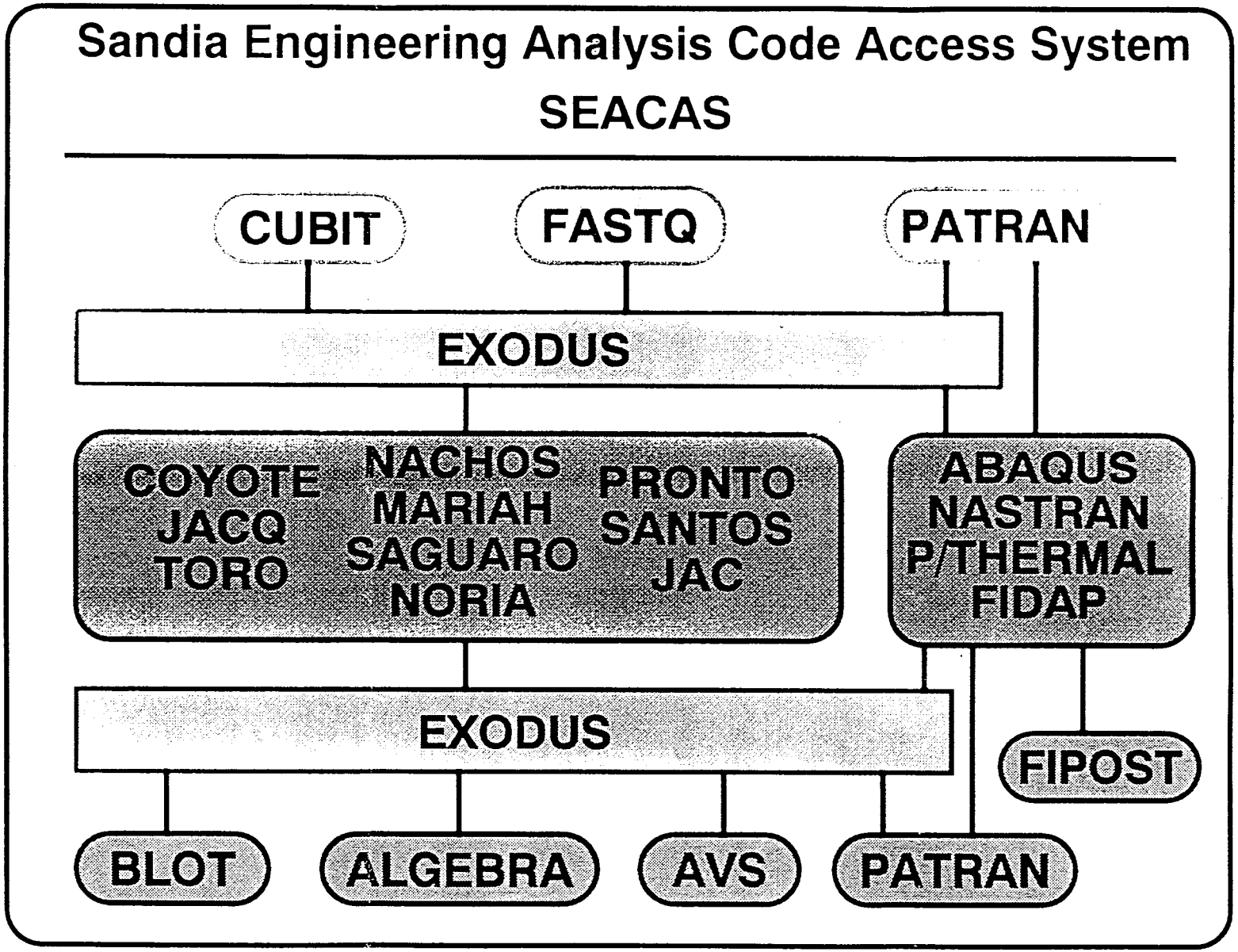

Sandia Engineering Analysis Code Access System
SEACAS
CUBIT
FASTQ
PATRAN
EXODUS
COYOTE
JACQ
TORO
NACHOS
MARIAH
SAGUARO
NORIA
PRONTO
SANTOS
JAC
ABAQUS
NASTRAN
P/THERMAL
FIDAP
EXODUS
FIPOST
BLOT
ALGEBRA
AVS
PATRAN

Figure 1

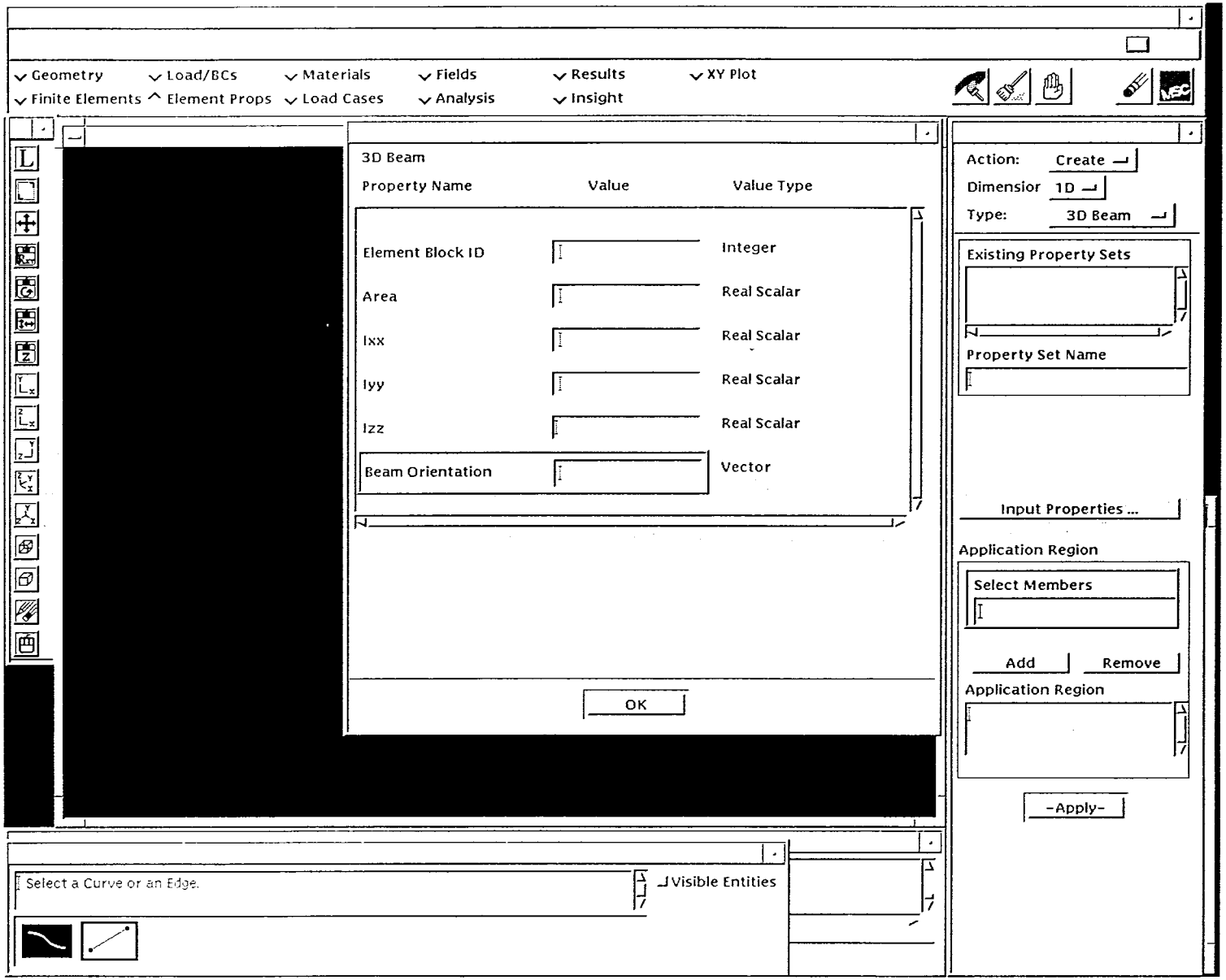

Geometry
Load/BCs
Materials
Fields
Results
XY Plot
Finite Elements
Element Props
Load Cases
Analysis
Insight
3D Beam
Property Name
Value
Value Type
Element Block ID
Integer
Area
Real Scalar
Ixx
Real Scalar
Iyy
Real Scalar
Izz
Real Scalar
Beam Orientation
Vector
OK
Action:
Create
Dimension
1D
Type:
3D Beam
Existing Property Sets
Property Set Name
Input Properties ...
Application Region
Select Members
Add
Remove
Application Region
-Apply-
Select a Curve or an Edge.
Visible Entities

Figure 2

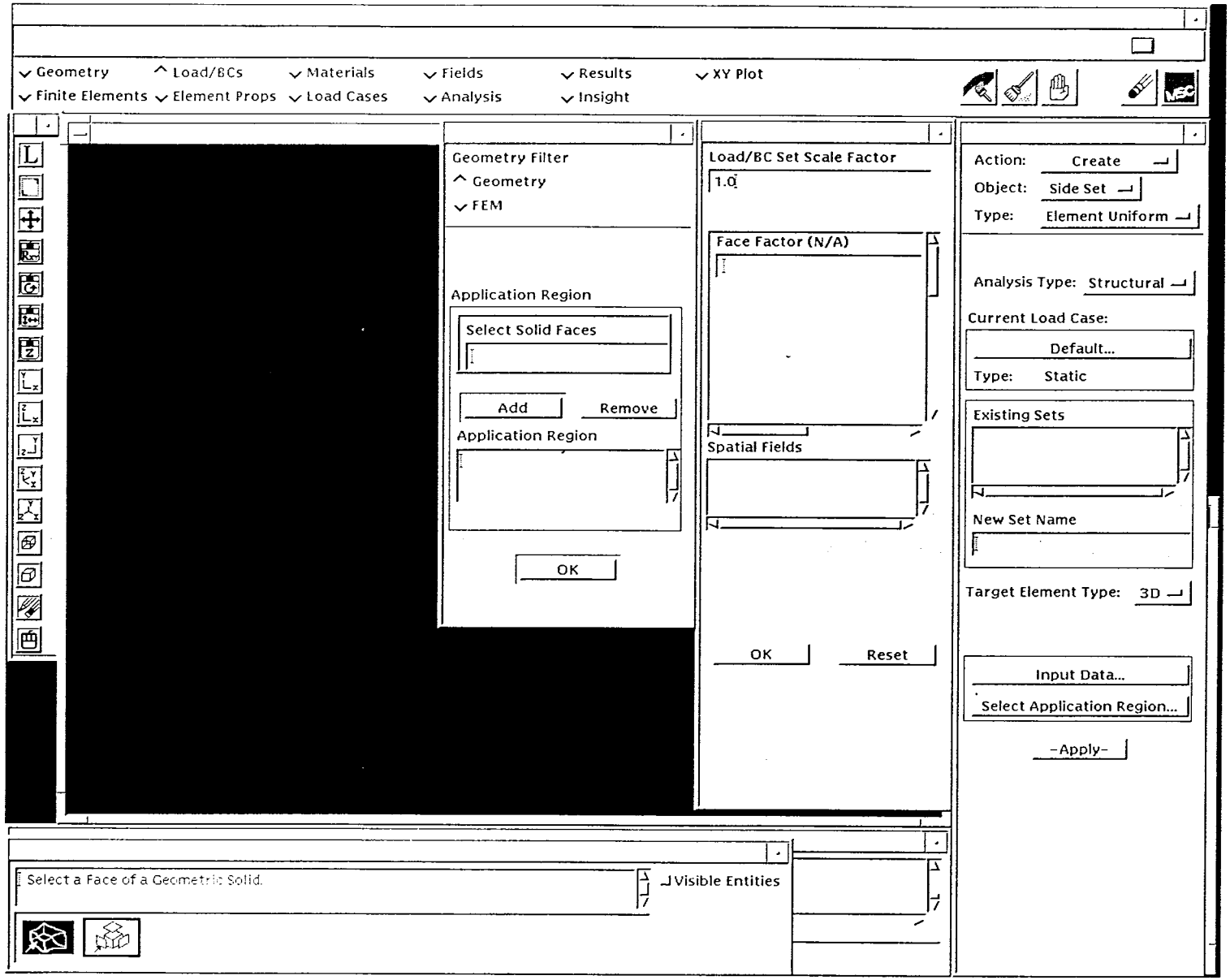

Geometry
Load/BCs
Materials
Fields
Results
XY Plot
Finite Elements
Element Props
Load Cases
Analysis
Insight
Geometry Filter
Geometry
FEM
Application Region
Select Solid Faces
Add
Remove
Application Region
OK
Load/BC Set Scale Factor
1.0
Face Factor (N/A)
Spatial Fields
OK
Reset
Action:
Create
Object:
Side Set
Type:
Element Uniform
Analysis Type:
Structural
Current Load Case:
Default...
Type:
Static
Existing Sets
New Set Name
Target Element Type:
3D
Input Data...
Select Application Region...
-Apply-
Select a Face of a Geometric Solid.
Visible Entities

Figure 3

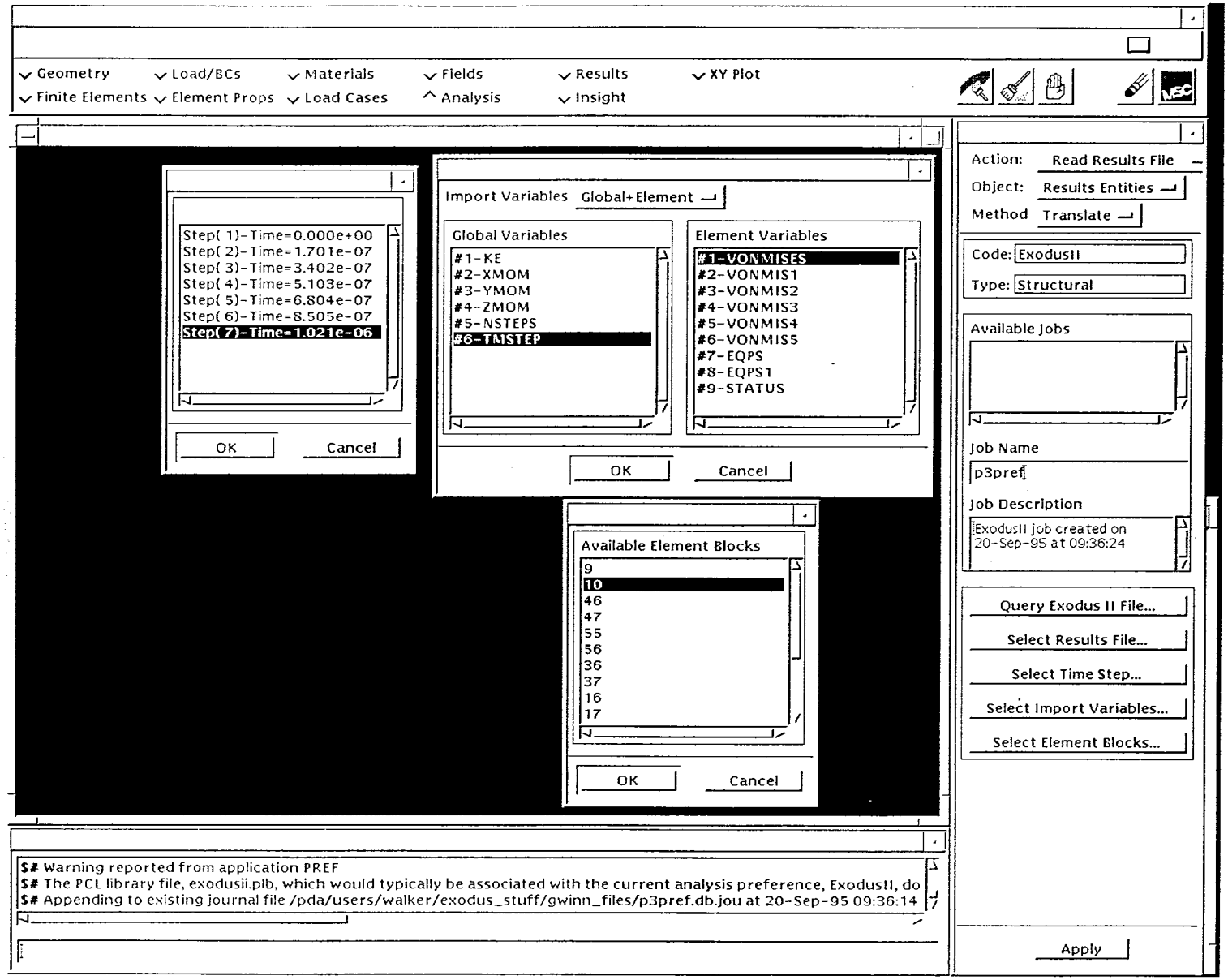

Geometry
Load/BCs
Materials
Fields
Results
XY Plot
Finite Elements
Element Props
Load Cases
Analysis
Insight
Step(1)-Time=0.000e+00
Step(2)-Time=1.701e-07
Step(3)-Time=3.402e-07
Step(4)-Time=5.103e-07
Step(5)-Time=6.804e-07
Step(6)-Time=8.505e-07
Step(7)-Time=1.021e-06
OK
Cancel
Import Variables
Global+Element
Global Variables
#1-KE
#2-XMOM
#3-YMOM
#4-ZMOM
#5-NSTEPS
#6-TMSTEP
Element Variables
#1-VONMISES
#2-VONMIS1
#3-VONMIS2
#4-VONMIS3
#5-VONMIS4
#6-VONMIS5
#7-EQPS
#8-EQPS1
#9-STATUS
OK
Cancel
Available Element Blocks
9
10
46
47
55
56
36
37
16
17
OK
Cancel
Action:
Read Results File
Object:
Results Entities
Method
Translate
Code:
ExodusII
Type:
Structural
Available Jobs
Job Name
p3pref
Job Description
ExodusII job created on
20-Sep-95 at 09:36:24
Query Exodus II File...
Select Results File...
Select Time Step...
Select Import Variables...
Select Element Blocks...
Apply
S# Warning reported from application PREF
S# The PCL library file, exodusii.plb, which would typically be associated with the current analysis preference, ExodusII, do
S# Appending to existing journal file /pda/users/walker/exodus_stuff/gwinn_files/p3pref.db.jou at 20-Sep-95 09:36:14

Figure 4

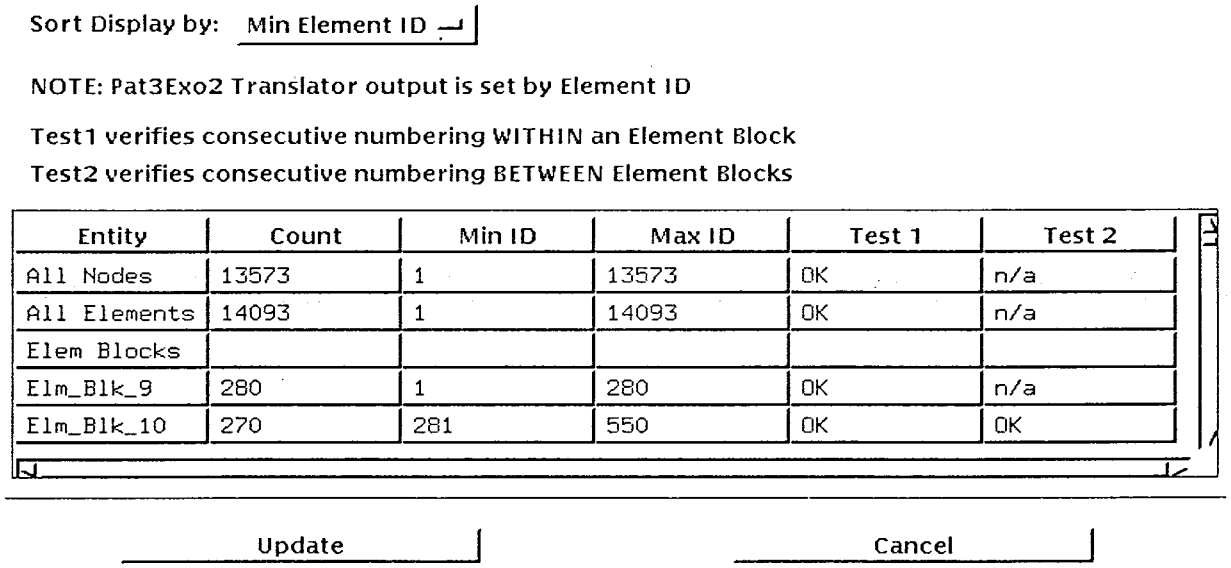

Sort Display by: Min Element ID
NOTE: Pat3Exo2 Translator output is set by Element ID
Test1 verifies consecutive numbering WITHIN an Element Block
Test2 verifies consecutive numbering BETWEEN Element Blocks
Entity | Count | Min ID | Max ID | Test 1 | Test 2
All Nodes | 13573 | 1 | 13573 | OK | n/a
All Elements | 14093 | 1 | 14093 | OK | n/a
Elem Blocks
Elm_Blk_9 | 280 | 1 | 280 | OK | n/a
Elm_Blk_10 | 270 | 281 | 550 | OK | OK
Update
Cancel

Figure 5

Pat3Exo2
Exodus II Model Import

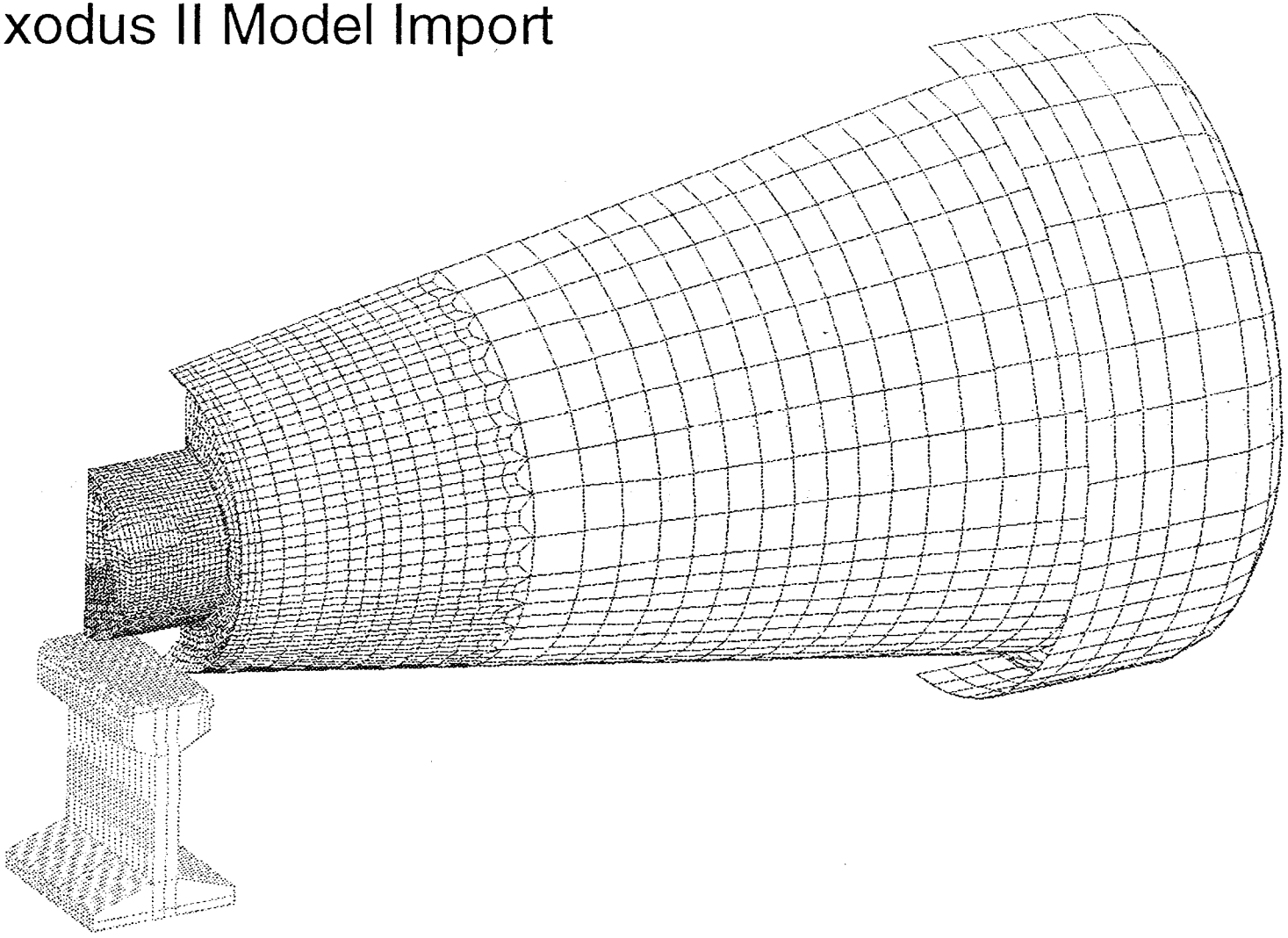
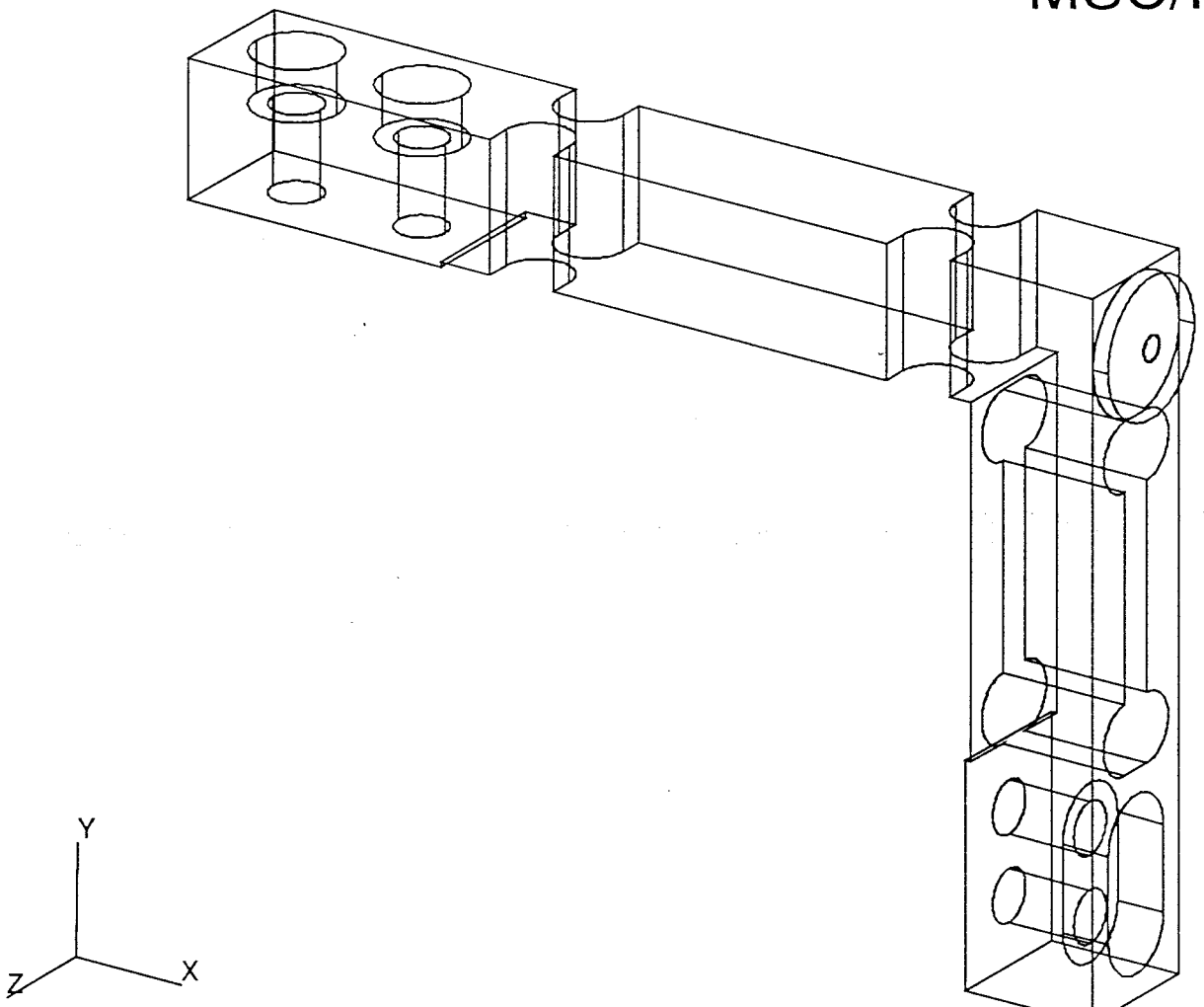


Figure 6

MSC/Patran



Pro/Engineer Geometry Access

Figure 7

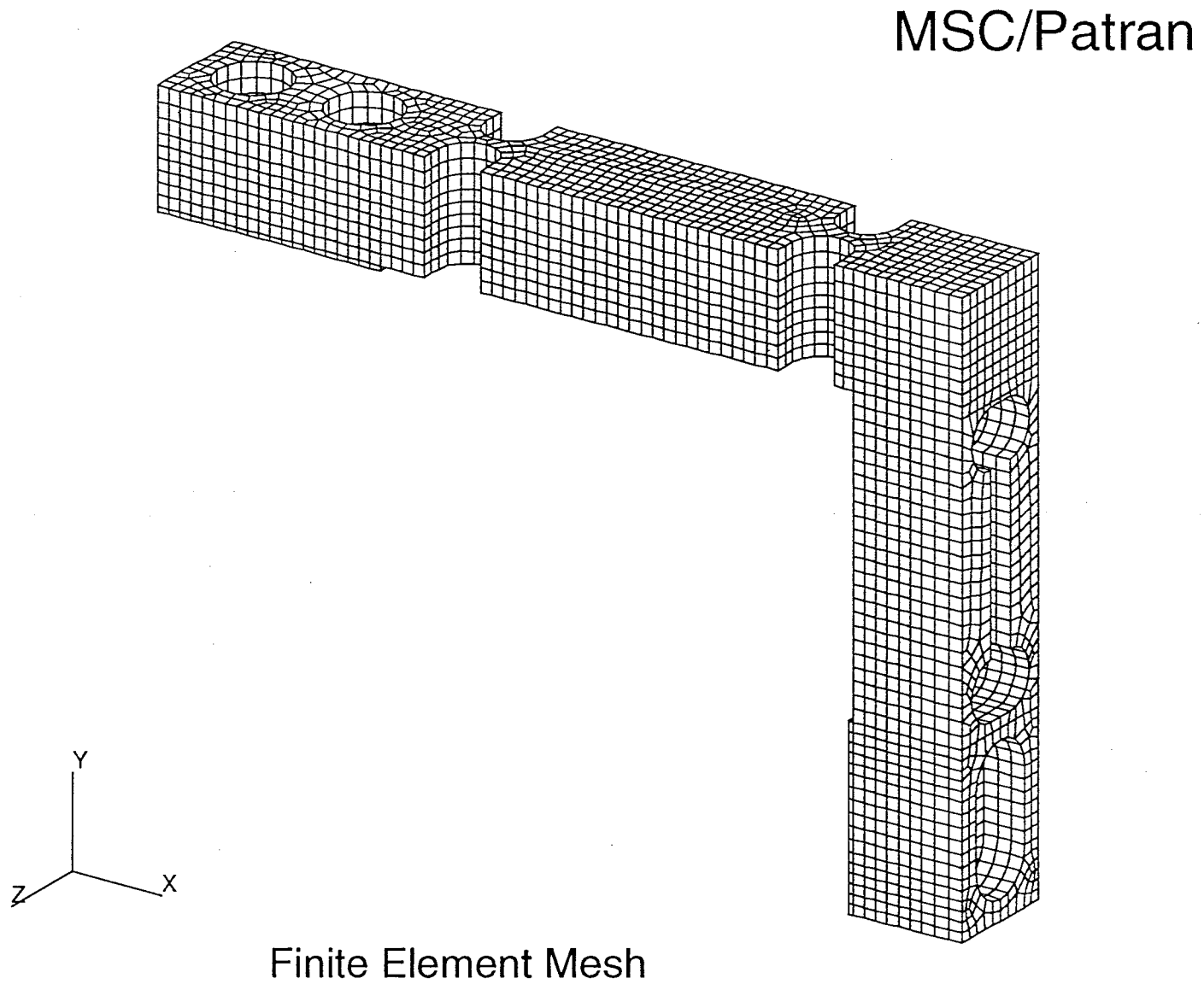


Figure 8

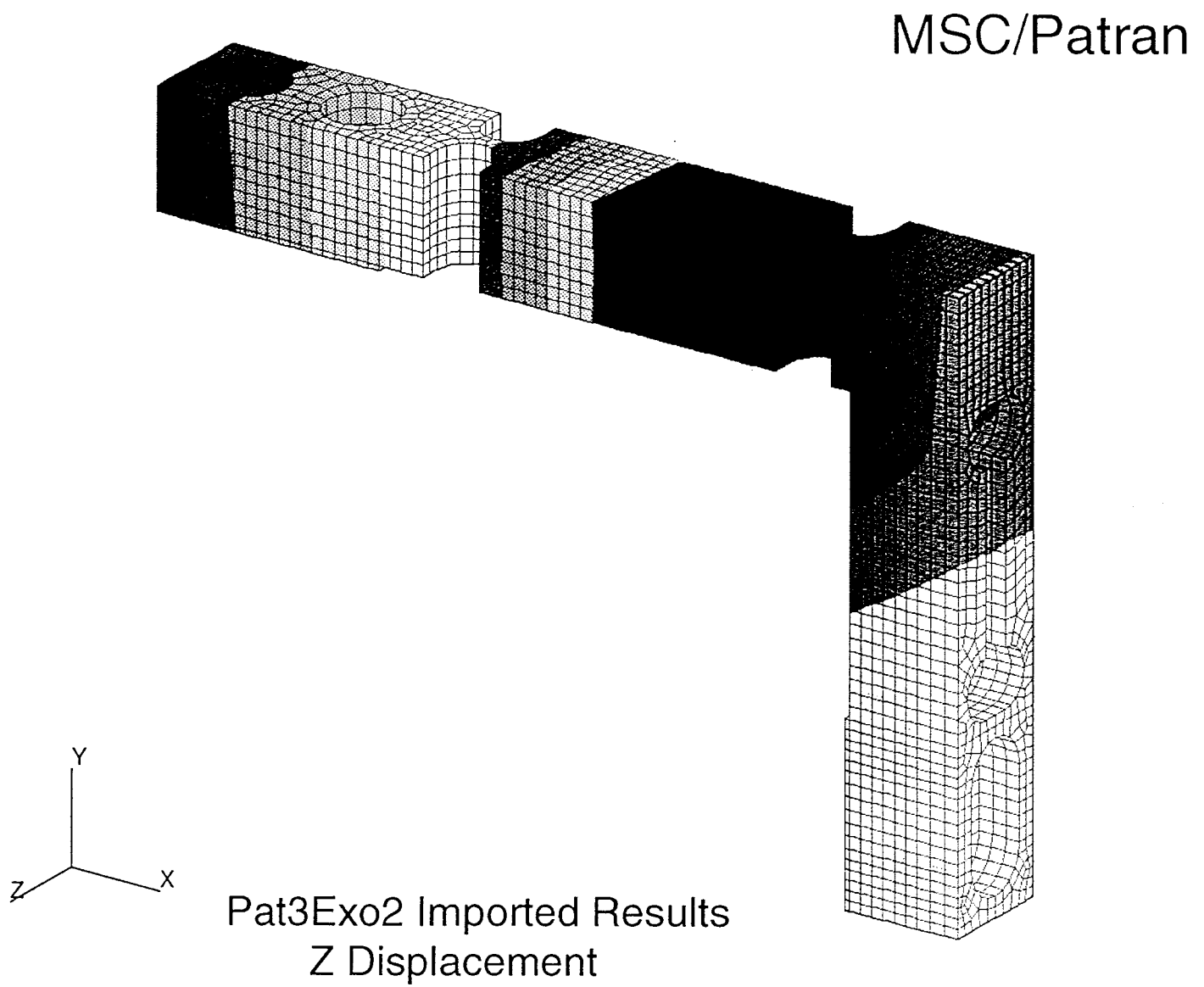


Figure 9