The Focus

A Publication for ANSYS Users

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Post Processing: Paths and Surfaces in ANSYS

by Eric Miller, PADT

Post processing is an oft-maligned part of the analysis process. Real analysts focus on meshing and running their models. But the fact is that getting meaningful answers is the whole point of doing a simulation, and spending a little bit of time to learn how to produce more concise and digestible results is a good investment. To that end, we will be covering a couple of key ways to produce higher quality results using POST1 and POST26 including listing, graphing, animation, and for our fifth article, the ins and outs of getting results at arbitrary locations in you model and then operating on them.

Most results review is based upon looking at results values calculated at the node points, element surface or element centroid. But sometimes, you need to know the results at some arbitrary point, along some curve in space, or over a surface. In addition, you may want to do some complex math with those values. ANSYS provides this very useful feature in the path and surface family of commands. We will talk about using path commands first then move on to the new surface family.

Remember when life's path is steep to keep an even mind.

— Horace (65 BC – 8 BC)

A Simple Path Between Two Points

The path command is as simple as it is powerful. You basically define a path name, assign it a series of points in your model, then tell ANSYS to get results on the path. A Path is a data item in ANSYS that consists of:

|	
Path Name:	Eight character (maximum) name assigned by the user.
Defining Points:	These are points in space or nodes. The path exists as line segments between these points. You can have up to 1000 of these.
Interpolation Points:	ANSYS creates internal points evenly spaced along each line segment in the path. It interpolates the data you ask for at these points.

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Path Items: These are the values interpolated from the model that are stored along the path. Each path comes with four default items: XG, YG, ZG, and S. The first three are the X, Y, Z position of each interpolation point and the distance of the point along the path, S. The user defines up to

Once you have path results you can then do a whole host of operations, information extractions, and plots. The best way to illustrate the command is with a simple example:

```
path,exmp1,2,8,20
ppath,1,,0,0,.25
ppath,2,,0,0,1.25
pdef,ux,u,x
pdef,uy,u,y
pdef,uz,u,z
pdef,usum,u,sum

/yrange,-4,12
plpath,ux,uy,uz,usum
```
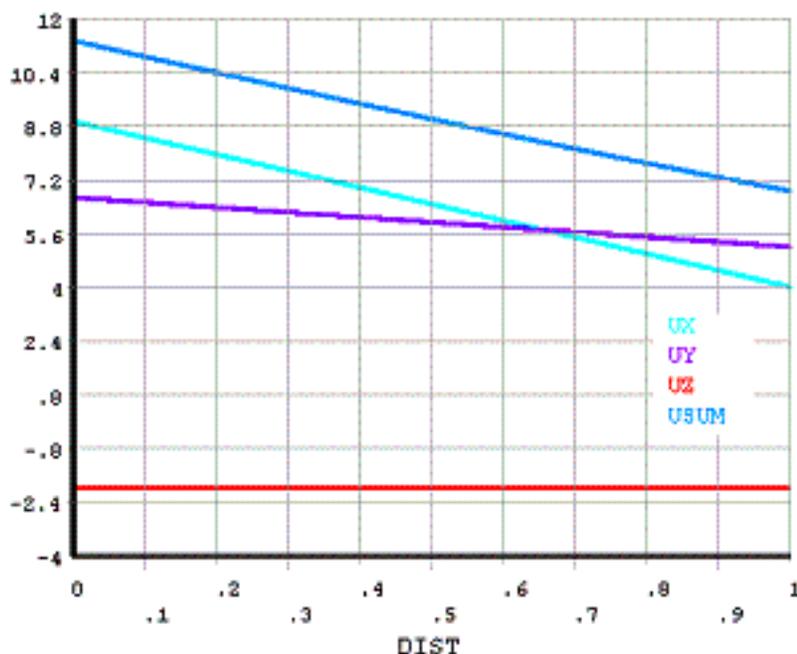
One thing you should notice from this example is that the path family of commands work on the concept of an "active" path. You can create as many as you want, but only one is active at a time and all commands apply to the active command. In our example, we create the active path and call it "exmp1". It has two points that define it, 8 sets of data, and it will interpolate 19 points between every defined point (20 divisions). The example then tells ANSYS to interpolate the X, Y, Z and Total deflection at each of those points. The resulting values are then plotted with the PLPATH command.

Do not go where the path may lead; go instead where there is no path and leave a trail.

— Ralph Waldo Emerson (1803–1882)

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A Plethora of Path Commands for Proper Perusal

Three are so many options in this family that we don't have room to cover them all. To be brief, here is a summary of the commands we have found useful.

PATH	This is the big command that sets up a path. Also use it as PATH, name to change the active path.
PPATH	Defines the points for the path.
PMAP	Used to define how the interpolation points are distributed. By default they are even, but with this command you can put refinement at the ends of each line segment or force a point at a discontinuity.
PDEF	Does the interpolation from the model of solution values.
PVECT	Does the interpolation from the model of geometry values such as the tangent, normal, and radius from the origin along the path. Used to change the active path.
PADELE	Used to delete paths. PADELE deletes the current path, PADELE, ALL deletes all of them and PADELE,name deletes the path "name".
PRANGE	Used to specify what is actually plotted or listed.
PAGET	Used to write and read path information from array variables. This
PAPUT	is how you get your path info into APDL.
PASAVE	Path information does not get stored in the *.db or *.rst. If you want
PARESU	to save your definitions, then use the commands to write and read
PSEL	them. Use PSEL to determine what paths get written before you issue the PASAVE command.
PCALC	You can use this command to create new path items by doing math operations on existing items. This not only includes your standard add / sub / mult / div / exp / sin / cos / asin / acos / log, but also the ability to find the derivatives and integrals!
PLPATH	Plots path items on an ANSYS graph.
PLAGM	Displays path items as a ribbon plot.
PRPATH	Prints path items.
PCROSS	Vector operations.
PDOT	
PLSECT	This is used to linearize stresses and display the resulting values.
PRSECT	Structural types love this command.
/PBC,PATH,1	Use this variation of the /PBC command to view your paths in your plots of nodes, elements and results.

So, very briefly, that is a summary of the path commands. To close out this topic, here are some additional hints/tips:

- Ever want to get the stress as some arbitrary point in space? You can use path commands to do that. Here is an example:
    - path,pp,2,5,1
    - ppath,1,,0,0,.35
    - ppath,2,,0,0,.35
    - pdef,sig1,s,1
    - *get,s_z_p35,path,,last,sig1
    - *msg,,s_z_p35
    - Stress at Z(0.35) = %g

- The PCALC command is great if you want to operate between two items in a given path. But if you want to add values from two paths you need the full power of array operations. Use the PAPUT command to get the data into an array, operate on it, and bring it back with PAGET for plotting/listing. Be careful though, make sure your paths are the same or that they have the same lengths.

- By default, PRPATH and PLPATH use the distance along the curve (S) as the X axis or first column. If you want to change it use the PRANGE command to specify a different item.

- You can't really do much with a path until you run PDEF on it. This includes plotting, saving, and other operations.

As with everything we discuss here, you need to read the manual and try it out to get a handle on what this command can do. But after spending some time with it, especially if you are doing field problems like EMAG, you will find this stuff very useful.

I will choose a path that's clear, I will choose free will.

— Neil Peart, "Free Will"

Adding a Dimension to Paths: Surface Commands

As ANSYS grew stronger in field problems like CFD and EMAG, it became
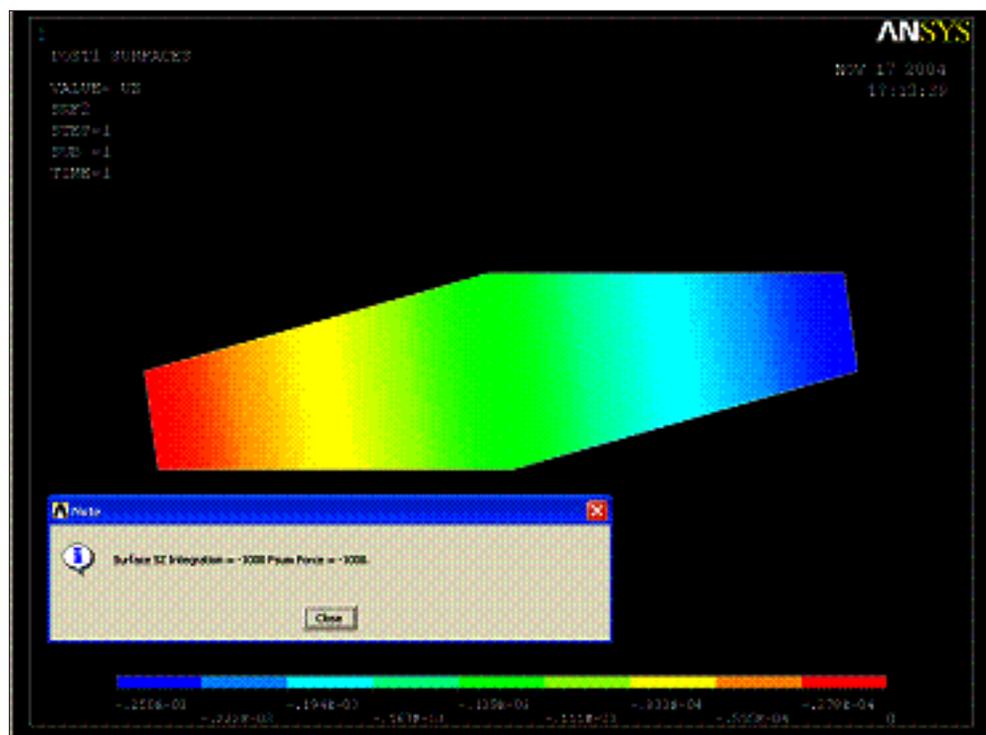
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pretty obvious that the program needed a function that allowed people to do what they do with paths, but for arbitrary surfaces as well. Release 8.0 saw the introduction of this new family of commands, and in Release 9.0 they move from awkward adolescence to young adulthood. Because they are new commands, they are a little more concise and easier to use then the older path family.

At Release 9.0 you can specify a planar, spherical, or cylindrical surface. You do this using the working plane rather than nodes or points in space. Once you position the working plane, you are done with the planar surface and you only need to specify a radius for spherical and cylindrical surfaces. Use the SUCR (sucker!!!!) command to set it up.

What actually happens internally when you create a surface is that it intersects the surface with your mesh. Each element intersection creates a 3- or 4-sided facet on the surface. The program then adds additional facets as you request to give more refinement. (See the hint below about refinement and the /efacet command.)

Once you have defined the surface, you use the SUMAP command to create result sets. Every result item you can invoke with the PLNSOL command also works with SUMAP. Here is a simple example of two planes on a silly model:

BLOCK,-1,1,-1,1,0,10,

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```
esize,.2 $ et,1,45 $vmesh,all
$ex,1,10e6 $nuxy,1,.23

nsel,s,loc,z,0 $d,all,uz
nsel,r,loc,x,0 $d,all,ux,0
nsle,r,loc,y,0 $d,all,uy,0

nsel,s,loc,z,10 $sf,all,pres,250
nsel,all

finish $/solu $solve

/post1

zval = 5
wplane,1,0,0,zval,1,0,zval,0,1,zval
sucr,srf1,cplane,2

sumap,sz,s,z
sueval,szint1,sz,intg

fsum
*get,fsmfz,fsum,,item,fz
*msg,ui,szint1,fsmfz
Surface SZ Integration = %g Fsum
Force = %g

susel,u,srf1
wplane,1,0,0,zval,1,1,zval,1,2,0

sucr,srf2,cplane,2
sumap,uz,u,z
supl,all,uz
```

This example shows a fairly typical application of calculating the equivalent force from integrating the stress in one direction over the area.

Just as with the path commands, there are similar commands for storing, transferring to APDL, and doing calculations with your surface results. Take a look at the manual to get a good summary.

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Some things to note about this command family:

- If you don't like working with the Working Plane (CSYS 4) using the GUI, then I recommend you write some simple macros that allow you to specify surfaces based upon X, Y, Z location, node, or geometry locations. Simply convert your input into commands to move and orient the working plane.

- When you create a surface, ANSYS then creates a faceted representation by slicing your elements. By default it puts one facet through the intersection of each element. If you need more accuracy, then use the 3rd argument on the SUCR command to specify a refinement factor of 0, 1, 2, or 3. In most cases that would be 1, 2, 4, or 6 facets per element, respectively. But if you use /efacet to create a more refined plot, then the number of surface facets goes up accordingly. I have brought my machine to its knees trying to get a surface on refined mesh with a factor of 3 and an /efacet of 3.

- The surface commands have one big difference in their behavior when compared to the path commands. The path commands operate on a single "active" path. The surface commands act on all selected surfaces. Use the SUSEL command to manage this.

If you do CFD, EMAG, or any other field oriented analysis, you probably already use this command. We find that it is also useful for a variety of other applications.

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Technical Guidelines for Big Memory Usage

by Gene Poole, Technical Fellow, ANSYS Inc.

The recently announced ANSYS breakthrough, solving over 100 million DOFs using big memory and parallel processing, demonstrates a real leadership position for ANSYS. We have achieved this computing milestone first in our industry and we have done so using parallel processing that demonstrates we can solve these large problems in very reasonable solution times. The announced results were achieved on a large Linux64 server from SGI which today costs around 100K dollars. But the big memory capability in ANSYS is also important to an even larger segment of users who now have or will soon have desktop 64-bit workstations with 8 Gigabytes (GB) of memory or more at very affordable prices. This document describes how to utilize the larger memory systems to obtain superior performance.

SOLVER PERFORMANCE

To exploit the big memory capabilities in ANSYS one must understand some clear differences between the iterative (PCG and DPCG) and direct (sparse and block Lanczos) solvers. Each solver can substantially benefit from the large memory capability in ANSYS but there are important distinctions for the two solvers.

PCG and DPCG Solvers

The iterative solvers in ANSYS are capable of solving the largest problems. This is due to the basic characteristic of iterative solvers; they require no expensive factorization of the assembled stiffness matrix. Instead, an iterative process that consists of sparse matrix multiplications and other sparse matrix operations refines an initial random guess to the correct solution to the large linear system of equations.

The success of any iterative method depends on mathematical conditions of the linear system that ensure convergence to a solution. ANSYS has a proprietary, industry leading, iterative method that has been used for over 10 years inside

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ANSYS and now runs on distributed processing cluster systems as well as shared memory multi-processor computers.

The PCG and DPCG solvers perform well on most static analyses and certain nonlinear analyses. Contact analyses which use penalty-based methods work well with the PCG solver as long as contact is fully maintained throughout the nonlinear iterations. However, Lagrange-formulation contact methods and incompressible formulations require use of the sparse solver.

Fine meshes containing elements with good aspect ratios perform much better than models with elongated elements. The time required for solution grows linearly with problems size for iterative methods so huge models can still be solved within very reasonable times.

A special memory saving option should always be used when solving large models. This option is enabled using the command MSAVE,ON and applies to SOLID92, 95, 186, and 187 elements. In ANSYS 9.0, SOLID45 and 185 will also support this option. When MSAVE,ON is enabled the elements that use this option are not assembled into the global stiffness matrix. Instead, the matrix-vector multiplications are carried out using individual element stiffness matrices using a very efficient technique that eliminates the need to store the elements or the assembled matrix coefficients from these elements. The memory usage estimation for models, which can use the MSAVE,ON feature, is 0.3 Gigabytes (GB) per million degrees of freedom versus 1 GB for MSAVE,OFF. An added benefit of using MSAVE,ON is improved parallel processing performance for both the PCG and DPCG solvers.

SPARSE SOLVER and BLOCK LANCZOS METHOD

The sparse solver in ANSYS remains the most robust and reliable solver and is the default solver in most cases. Unlike iterative methods that may not converge to any solution if certain numerical conditions are not satisfied, direct factorization methods will always give an answer provided that the linear system is not singular. Even when the system is singular the user can be warned and usually the problem can be easily fixed. In ANSYS, the sparse solver is part of a software package from Boeing Computer Services that also includes a block Lanczos method used for modal analyses. A unique feature of this sparse solver is its ability to run completely in memory automatically if sufficient memory is available. Herein lies the advantage of big memory for the sparse solver.

Though the sparse solver can run efficiently in optimal out-of-core mode,

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requiring about the same memory usage as the PCG solver (1 GB per million DOFs), it will require I/O to store the factored matrix file, usually 10 GB per million DOFs. The amount of I/O required for a typical static analysis is three times the size of the matrix factor file – one time to write the file and a forward and backward read for each load solution. The block Lanczos solver, on the other hand, will require dozens of forward/backward reads through the matrix factor file in a typical modal analysis. Running the factorization in-core (completely in memory) for modal runs can save hours of I/O wait time. For nonlinear runs, with repeated factor/solve steps running in-core can save hours of elapsed time.

In ANSYS 8.1 the sparse solver and Lanczos solver can access a full 16 GB of memory for solver workspace. Previously block Lanczos was limited to just 8 GB and it was not possible in many cases to allocate a single large block of memory due to 32-bit integer overflow conditions. In ANSYS 9.0 the 16 GB limitation will be removed meaning that a 100 GB memory computer system should be able to solve 10 million degrees of freedom in-core in most cases. Even larger problems will be possible with beam/shell models that typically require much less than 10 GB per million DOFs to run in-core.

The best way to use big memory with sparse solver jobs is to understand the memory requirements for a particular job or class of jobs. The BCSOPTION command provides the necessary information on memory usage for in-core, optimal out-of-core, and minimum out-of-core operation. In most cases, users can just increase the total job memory to increase available memory to the sparse solver. However, for the very large jobs where the sparse solver work array will exceed 2 GB in size users will have to specify the sparse solver memory explicitly to obtain big memory blocks for the sparse solver. The BCSOPTION command documents how to specify in-core mode for the sparse solver as well as the size of memory allocated for the sparse solver memory. Some memory heuristics are still applied in addition to the user input to arrive at the final sparse solver memory usage settings.

If the sparse solver memory required to run in-core exceeds 16 GB, or if the user system available memory is less than the memory required to run in-core, it is better to run the sparse solver in optimal out-of-core mode. Additional memory beyond the optimal out-of-core memory reduces free memory that the system can use to reduce I/O time.

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I/O AND POST-PROCESSING

I/O performance with big memory

One of the hidden system benefits of big memory systems is the ability to cache large I/O requests. Even for modest sized ANSYS jobs a considerable reduction in the cost of I/O can occur when the system free memory is larger than the sum of file sizes active in an ANSYS job. This feature, often called buffer cache, is a system tunable parameter and can effectively move all I/O traffic to memory copy speeds. The system details are different for various vendors and users should consult the hardware manufacturer for details on their systems. A system with 64 GB has more memory than many desktop systems have for disk space and all but the largest ANSYS jobs can easily run within 10 to 20 GB of disk space.

Post-Processing with big memory

Finally, big memory can be used to make it possible to view results for very large models very effectively. The key to good graphics performance on these large models is to use PowerGraphics and allow enough memory for the database (–db) so that large models can be rotated, zoomed and results viewed easily. Even with smaller models it is a good practice to finish the solve command, save the results, and enter post processing with a new ANSYS run. The new run allows a user to start up ANSYS with a large –db space. Page file estimates can be obtained at the end of a solve run or by observing the size of the file.page in a current run. Increase –db at the start of a post processing run to bring the entire database into memory. In ANSYS 8.1 it is possible to use –db settings well beyond 16000. If large models are post processesd with small –db settings the graphics response can be extremely slow or cumbersome to use.

In ANSYS 8.1 there are some limitations in the size of the results file. Though the file can exceed 8 GB in size, it is not possible to store element results that exceed the 2 GB limitation. This limitation can be controlled in ANSYS 8.1 by saving only results on the surface on a model and/or for only a subset of the element results, e.g. stresses only. In ANSYS 9.0 this restriction will be removed.

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DEMONSTRATING THE ADVANTAGE

The best way to demonstrate the advantage of a big memory system is to use one. Customer jobs of 10 million DOFs can be routine with the PCG solver on systems with 16 GB of memory. Sparse solver jobs of several million DOFs may still require I/O but even assembly for matrices with more than 1.5 million DOFs can be tricky or impossible on 2 GB systems. Modal analyses that can run in-core using 6 to 8 GB of memory (500,000 to 750,000 DOFs, 100 or more modes) will show at least a 30 or 40 percent improvement in time to solution over a 2 GB system. In some cases, where 32-bit systems may be configured with very nominal I/O performance, a 10x or more improvement may be seen on the big memory systems.

Parallel processing should always be used on large models. The sparse solver has highly tuned computational kernels that are called in parallel for the expensive matrix factorization. The PCG solver has several key computation steps running in parallel. For the PCG and sparse solvers there is no need to use more than 4 processors for a single ANSYS job. With the parallel processing license (Parallel Performance for ANSYS), additional distributed parallel solvers are available. The most important of these in ANSYS 8.1 is the DPCG solver. This solver demonstrates superior parallel performance to the shared memory PCG solver at the added cost of some extra memory. In ANSYS 9.0 even more improvements will be added to the distributed solvers further reducing time to solution for large models.

The final factor in demonstrating the advantage of big memory systems is system configuration. It is always better for ANSYS performance to use processor/memory configurations that maximize the memory per node. An 8 processor, 64 GB system is much more powerful for large memory jobs than a 32 processor 64 GB system. ANSYS cannot effectively use 32 processors for one job, but ANSYS can use 64 GB very effectively to increase the size of models and reduce solution time.

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PADT Goes Euro

by Rod Scholl, PADT

When one night in Arizona my wife started throwing out places her career might wanna move her to, like a rolling stone (nod to Muddy Waters), I thought a bit, and said, "Sure, wherever you want." I figured, "I'm an engineer. We're like gas pump attendants. Every city has 'em."

A couple years down the road I find myself living in a second story flat in the Netherlands.

The might I say visionary leadership at PADT agreed to keep me employed, so I have been working from remote via VPN for a couple of years now. And I use the word "working" loosely. Just kidding. Actually, I was so worried about slacking off I heard I was getting a whole lot more done while working remote! Damn, does that mean when I come back to the office they'll expect the same productivity? Hope not…

I bought a bike, and now tour around the region by foot, pedal, and train. Because, I'm about a ten-minute ride to downtown Amsterdam, there are tons of sights, cafés and restaurants to keep us busy. And I know you're itchin' to insert an Amsterdam joke here – everyone else does – so I won't drag (cough-cough) you down with my own remarks.

We also travel around France, Germany, Switzerland, and have more trips planned to other locales in the coming months.

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I'm the one on the right.

Notice the shirt. Who says
you can't do Paris in a day!

This is my house. I room with a guy
named Leonardo.

Amsterdam boat tour. We tried to lose the
secret service agent behind us.
But he's crafty — and mean, too.
And there's that shirt again! I must like it.

I've learned a few Dutch words, but no one can understand me when I say them. There's a trick
to pronouncing a Dutch *G*, which despite my practice, everyone gives me looks when I use it as
if I just spit at them. Well, now that I think about it, maybe I did just spit at them. Luckily for me,
the tram stop I use has **three** *G*'s in it, so a typical conversation with a ticket taker goes like this.

Me: Middenveg and Hogeveg, please.
Ticket Guy: What?
Me: Hogggg-e-vegggg .

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> Ticket Guy: Hogeveg?
> Me: Yeah, Hoggg-e-veggg. [*Sounds identical to me.*]
> Ticket Guy: [*Shakes his head and stamps my ticket.*]

Once, the ticket guy even got on the microphone a couple minutes later and announced the stop (which they never do). He said "Next stop Hoggg-e-veggg," then laughed and waved at me in the back of the bus. I pretended I was oblivious, because how does one react to that? A city with a **hundred thousand** tourists per day, and I get made fun of. Go figure.

I stay busy with work (too busy according to Her) doing ANSYS analysis, support, etc. In fact, very few of my tasks have changed. The digital age is nigh. Further, we seem to find customers in the areas I live whom are glad to take advantage of our proximity.

On that note, a big advantage for my European peers/customers is that we decided to keep our labor rates at the dollar's standard which is a 20% discount below the Euro! Thus if you have some work in Europe you could use a hand on, drop me a note. I'll train over and see if we can help out. (Sold my soul to the company store… for a 20% discount, no less!)

Also, thanks to my European hosts and contacts, including Infinite, who've been very welcoming and kind.

Everyone wants to know about what differences I'm encountering. Well, silverware is smaller:

No wonder everyone is so svelte!

And they have bike parking lots.
Now **do not** forget where you parked!

And around Halloween, I found out too late that they have no idea who Laverne, Shirley, and Squiggy are.

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And lastly, I think maybe the 240 Hz power is making ANSYS solve twice as fast?! Where are my benchmarks, anyway.

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An FEA Xmas

by Rod Scholl, PADT

'Twas the night before Christmas and all through the cubes,
Not a worker was stirring except this techie rube.

The PCs were nestled all snug under tables,
While dreams filtered in via lighted LAN cables.

But deep in the cube farm, one PC still stirred,
An old Pentium II's cooling fans whirred.

When up on the screen there arose such a clutter,
I sat up in my chair and started to mutter.

Clicking through the windows I flew like a flash,
Minimized windows and sent .abt's to the trash.

When what to my wondering eyes did appear,
A GST plot showing the solution's not near.

My mind raced back through log file-tracked picks,
Then sighed to myself, "this'd be faster with bricks."

I scoured my input, looking from whence the bug came,
I fretted and frowned and cursed each by name;

Now DSYM, now DSYS, now CSYS and VGEN!
Now /COMMENT, now /CPLANE, now DL and ENGEN!

From the top of the page to the last end-of-file;
Now dash away! Dash away! Dash away all!
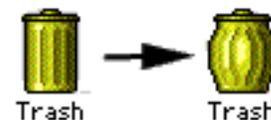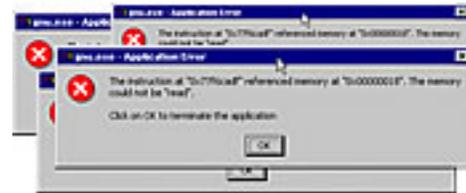
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As I entered a CNCHECK and was turning 'round,
Down the chute of my mind an idea came with a bound!

I sprung to my feet, lifting the donut from my belly,
Alt-Tab'd to the output, and took a bite – mmm, it's a jelly!

With a blink of an eye and the nod of my head,
Scrolled in the output to /STATUS and read.

I had added plasticity, the death and the birth,
Even some friction for whatever that's worth.

The contact was standard, the keyoptions set,
FKN was quite low, what'd I forget?

$$\mu = 0.05?$$
$$\mu = 0.15?$$
$$\mu = 0.25????$$

Pinball Region

If two objects in contact are initally apart,
There's a command you should issue before every start.

The pinball is used to see if a target's around;
Outside the pinball, no contact is found!

In small deformation, the pinball won't follow deflection.
It stays fixed on the surface at the original location!

For pinball detection to follow along
You have to include NLGEOM,ON.

I spoke not a word, but went straight to work,
Edited the file, then typed SOLVE with a jerk.

And checking the outfut to see it was right
I packed up my stuff, and left for the night!!

From PADT, Happy Holidays to all and to all a good night!

This season, talk with someone at PADT about your FEA work. Not only may we offer a couple suggestions, PADT does dozens of outsource analyses every year. Take advantage of our skills, low rates, and open communication to lighten the

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load of your sleigh this season.

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Upcoming Training at PADT

A complete schedule of the training courses for the next three months is shown below. Learn more about how the **Training Services** offered by PADT can save you time and money. Or, feel free to drop an e-mail to our training coordinator, Ted Harris!

Month	Start	End	Course	Description	Location
Jan '05	1/10	1/12	101	Introduction to ANSYS, Part I	Tempe, AZ
	1/17	1/18	104	ANSYS Workbench Simulation - Intro	Irvine, CA
	1/19	1/19	105	ANSYS Workbench Simulation - Advanced	Irvine, CA
	1/20	1/21	801	Introduction to APDL	Tempe, AZ
	1/24	1/25	201	Basic Structural Nonlinearities	Irvine, CA
Feb '05	2/7	2/9	101	Introduction to ANSYS, Part I	Irvine, CA
	2/10	2/11	202	Advanced Structural Nonlinearities	Tempe, AZ
	2/14	2/15	104	ANSYS Workbench Simulation - Intro	Tempe, AZ
	2/16	2/16	105	ANSYS Workbench Simulation - Advanced	Tempe, AZ
	2/17	2/18	301	Heat Transfer	Tempe, AZ
Mar '05	3/7	3/9	101	Introduction to ANSYS, Part I	Albuquerque, NM
	3/10	3/11	102	Introduction to ANSYS, Part II	Albuquerque, NM
	3/17	3/18	203	Dynamics	Tempe, AZ

Whether it s one of our regularly-scheduled classes at our training facility, or a customized class tailored to your specifications and location, you can be assured that the training you receive will have immediate, positive results on your capabilities in design, analysis, and product and process improvement.

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About *The Focus*

The Focus is a periodic electronic publication published by PADT, aimed at the general ANSYS user. The goal of the feature articles is to inform users of the capabilities ANSYS offers and to provide useful tips and hints on using these products more effectively. *The Focus* may be freely redistributed in its entirety. For administrative questions, please contact [Rod Scholl](#) at PADT.

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