Engineering News

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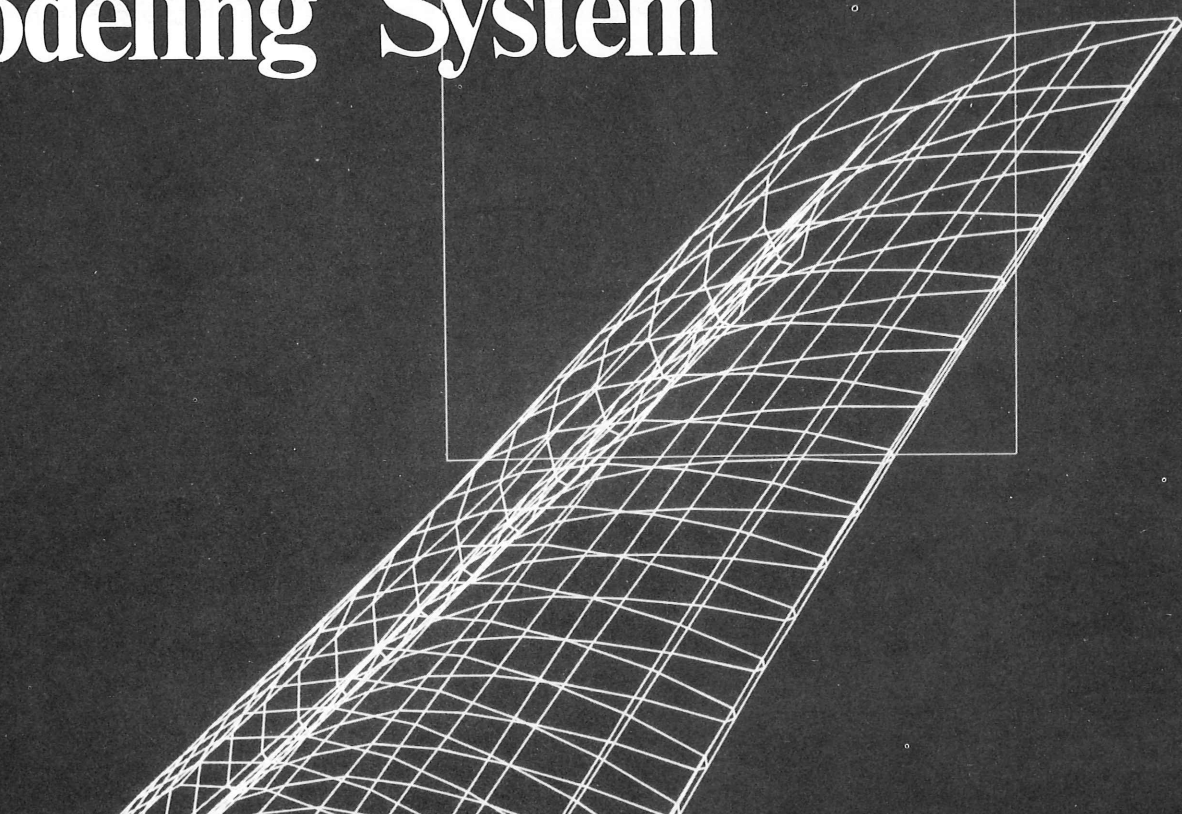
A Finite Element Modeling System



A STAND-ALONE INTERACTIVE GRAPHICS FINITE ELEMENT MODELING SYSTEM

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Jeff Gingerich presented this paper first at the SAP Users Conference (an association of the users of a structural analysis program developed by the University of Southern California) in June, and then Gary Romans presented it in a slightly different form at the Sixth NASTRAN Users Colloquium (an association of users of the National Aeronautical and Space Administration's structural analysis program) in September. The intelligent terminal referred to in the paper is the TEKTRONIX 4081 Interactive Graphics Terminal.

ABSTRACT

The finite element modeling (FEM) system described here is an interactive graphics system designed for use with an intelligent terminal. It offers an economical alternative to the conventional methods (hand compilation and remote terminals) of 2- and 3-dimensional model generation.

Using local computing and local storage, this FEM system allows the operator to create and display 3-dimensional models entirely off-line from the host computer. This eliminates costly on-line computer and host-processing time, and makes the user more effective by greatly reducing computer response time.

The system allows model generation by down-loading node and element data from the host computer or by using the system's model generation operations for digitizing and automatic creation. The system then generates completed model information in the desired analysis package's bulk data format and transmits it to the host computer for finite element analysis.

INTRODUCTION

In the past twenty years, finite element analysis has become a widely accepted design technique. The use of computers made feasible this numerical analysis and recently has assisted in the preparation and reviewing of data for finite element analysis.

Model generation is definitely the most time-consuming part of the finite element analysis (FEA) of a three-dimensional object. There are three distinct ways to do that modeling:

—hand compilation
—timesharing (remote) graphic terminal modeling
—off-line (stand-alone) interactive graphic terminal modeling

See figure 1.

The first alternative, *hand compilation,* is very tedious and time consuming. It is also extremely error-prone. A misplaced decimal can go totally unnoticed until a preview geometry plot graphically reveals the error or, worse yet, an unexpected analysis result voids an expensive computer run.

The second choice, using a *time-sharing graphic terminal,* offers the convenience of node digitization from drawings, "automatic creation" commands and step-by-step visual verification of the modeling process. However, remote graphic terminals require constant line connection to a host time-shared computer. Constant line connection is not only costly, but it is also slow for graphic displays and command executions, especially if the tie-line data exchange rate is 1200 baud or less.

The third choice, using an *off-line intelligent graphic terminal,* offers the same advantages as a remote graphic terminal: ease of use and constant visual verification. Additionally, the stand-alone system eliminates the expense and slow response of the host computer.

A FEM SYSTEM

Three Tasks

Figure 2 shows the equipment used in the off-line FEM system described here. The system has three main tasks:
— Generate node:/point spatial data.
— Define element connectivity and some property information related to the nodal data.
— create the model bulk data for finite element analysis (FEA).

Node/Point Data

Nodal and element creation is handled by the system in the off-line mode. This independence from the timesharing service is complemented by many automatic creation commands that make model generation quick and efficient. Nodes can be digitized from drawings, down-loaded from the host computer, automatically generated by command, or typed in if high resolution is a must.

Element Connectivity

Element connectivity can also be downloaded from the host computer, automatically generated by command, or can be individually specified, graphically, using this system. Many display features allow the model generation to be visually verified. The 3-dimensional rotations, scaling and selective displaying of the model also allow more convenient model generation by selecting the proper view. Node numbering, element connectivity orientation, and element libraries are user defined and controlled.

Bulk Data

The model bulk data is also generated by the system in the off-line mode. The model information for nodes, elements and properties is compiled and formatted for any finite element analysis package through the system's bulk data formatter module. This formatting module retrieves the model information, and compiles and formats it into the card image required by the selected analysis package. The formatting is user controlled by simple but powerful commands. The bulk data file is written onto disk storage in an 80-column, card-image format which may be transmitted to the host.

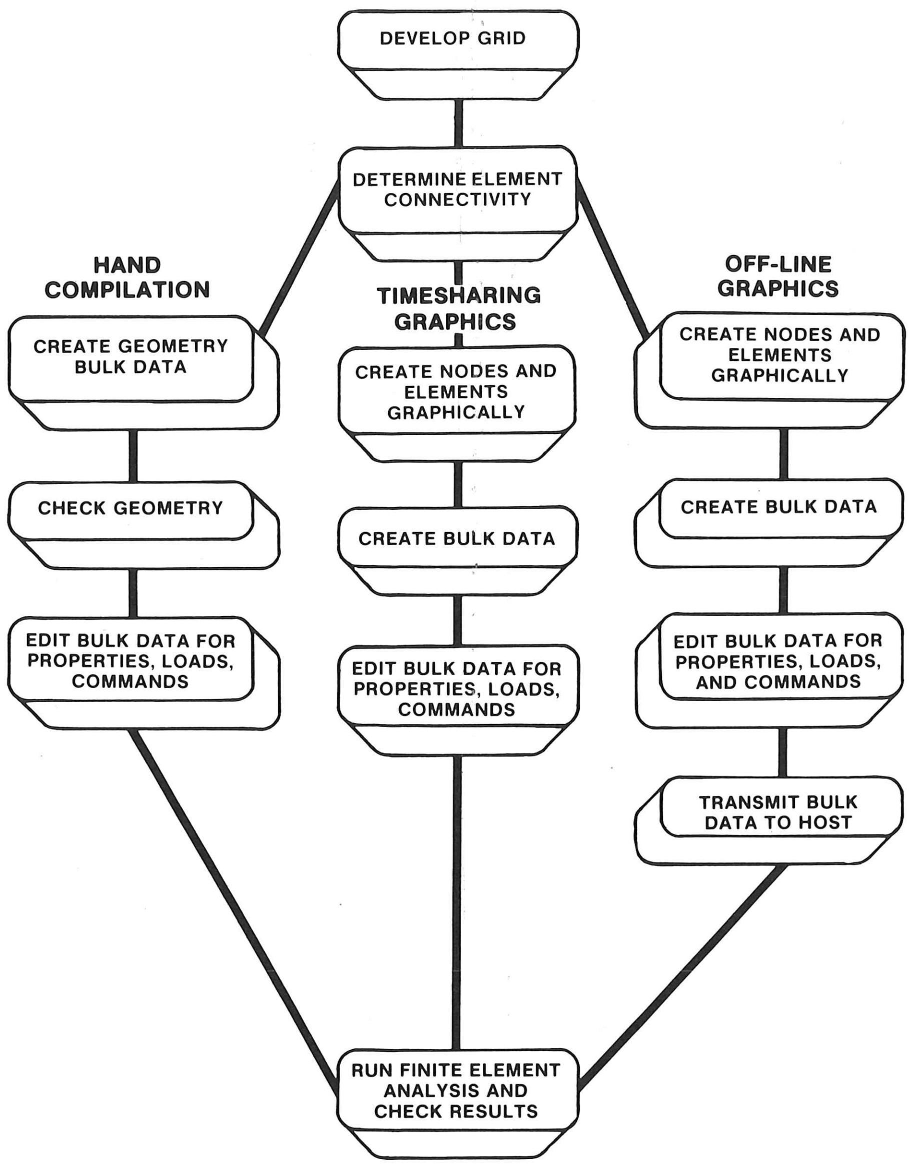


Figure 1. There are three main approaches to modeling. Hand compilation is tedious, time consuming, and prone to error. Using timesharing graphics offers many advantages, but it is costly. Using off-line graphics (with a stand-alone terminal) offers the advantages of timesharing graphics, but at greatly reduced cost.

OPERATION

The operation of the FEM system is shown in figure 3.

The data loader is useful for generating models from existing bulk data decks or other sources. It can also be used as an initial source of node and element data. The model generation module can then edit the nodes, properties and connectivity when necessary.

Flexibility

The system makes use of the intelligent terminal's capabilities, and it is as easy to use as possible while still being powerful. The operations are all repeatable without repeating commands. For example, if the user wants to digitize nodes, all that need be done is to tell the system to digitize nodes until done. The complement of this capability is the ability to bail out of the current operation at any time. For example, if the user is creating a 20-node element with this system, and discovers that he doesn't need the element after all, he doesn't have to complete all 20 nodes and delete the element. He can terminate the operation.

The operations are listed in a menu structure that is selected by positioning a box around the commands displayed on the terminal screen. The box and a cursor for selecting parts of the model are controlled by moving a pen on a digitizing tablet. When the user pushes the pen point down over a point on the tablet, the operation or the selection is transmitted to the system for processing.

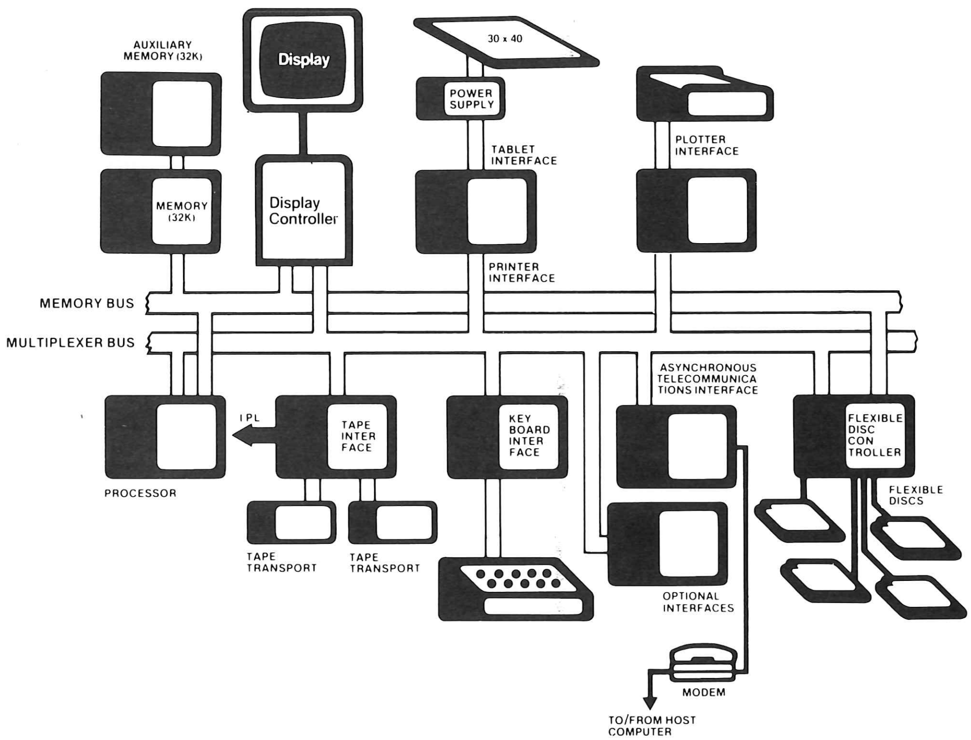


Figure 2. The equipment used for the FEM system described.

The Screen Format

The display screen is sectioned into the four following areas: the static menu, the dynamic menus, the prompt band and the work area. See figure 4.

The *static menu* lists the main operations available to the user for model generation and display. The *dynamic menu* lists sub-operations for the selected main operation. The prompt band is a message space that displays the current status of the system. This area constantly tells what operation the user is in, what the system is expecting, or what the user has done wrong. The work area is the largest display area.

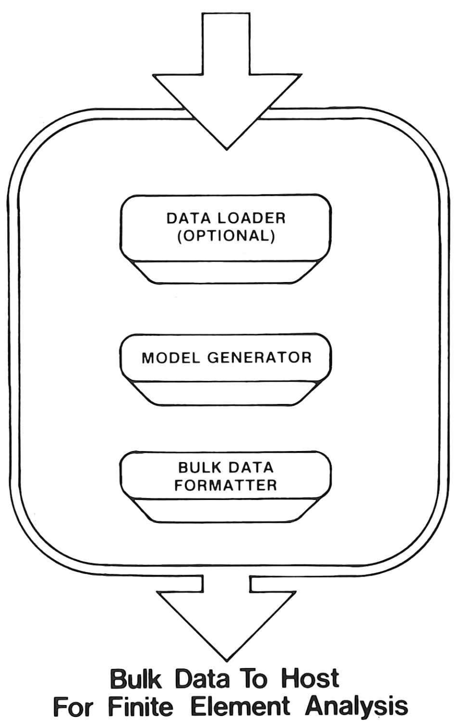


Figure 3. Finite element modeling system operation.

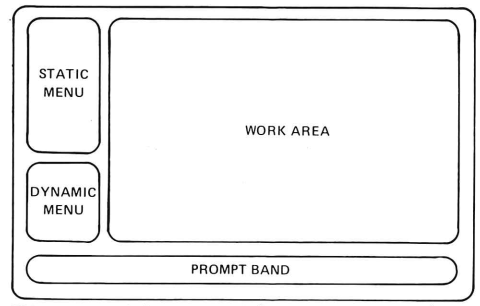


Figure 4. Display screen format.

EXAMPLE USER'S SESSION

The following example shows how the system creates a model. (Minor operational details are not discussed.)

The Object

The object to be modeled is a pipe elbow with a 60 cm material center diameter cross-section, a downward spiral of 3 cm every 20° along the 50 cm radius.

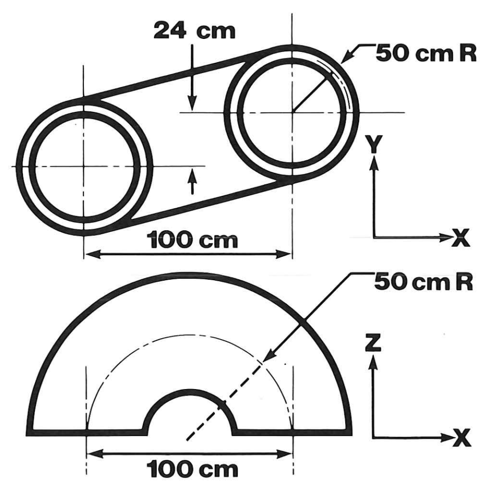


Figure 5. The example pipe elbow.

The Model

The model is composed of quadrilateral elements (QUAD2). The user may choose to digitize in the circular section of the pipe or, in this example, the user may employ the node creation commands to generate the circular section. By typing the values of x = 80 cm, y = 0 cm, z = 0 cm, the first node is generated and displayed. This first node is then copied by using the COPY operation with the rotation parameters x = 0°, y = 0°, z = 20°, new origin x = 50 cm, y = 0 cm, z = 0 cm and 17 iterations to produce the circular section as displayed in figure 6. Now nodes 1 thru 18 are copied 9 times with rotation parameters x = 0°, y = 20°, z = 0°, translation parameters x = 0 cm, y = 3 cm, z = 0 cm and nine iterations. The resulting automatic node generation is shown in figure 7.

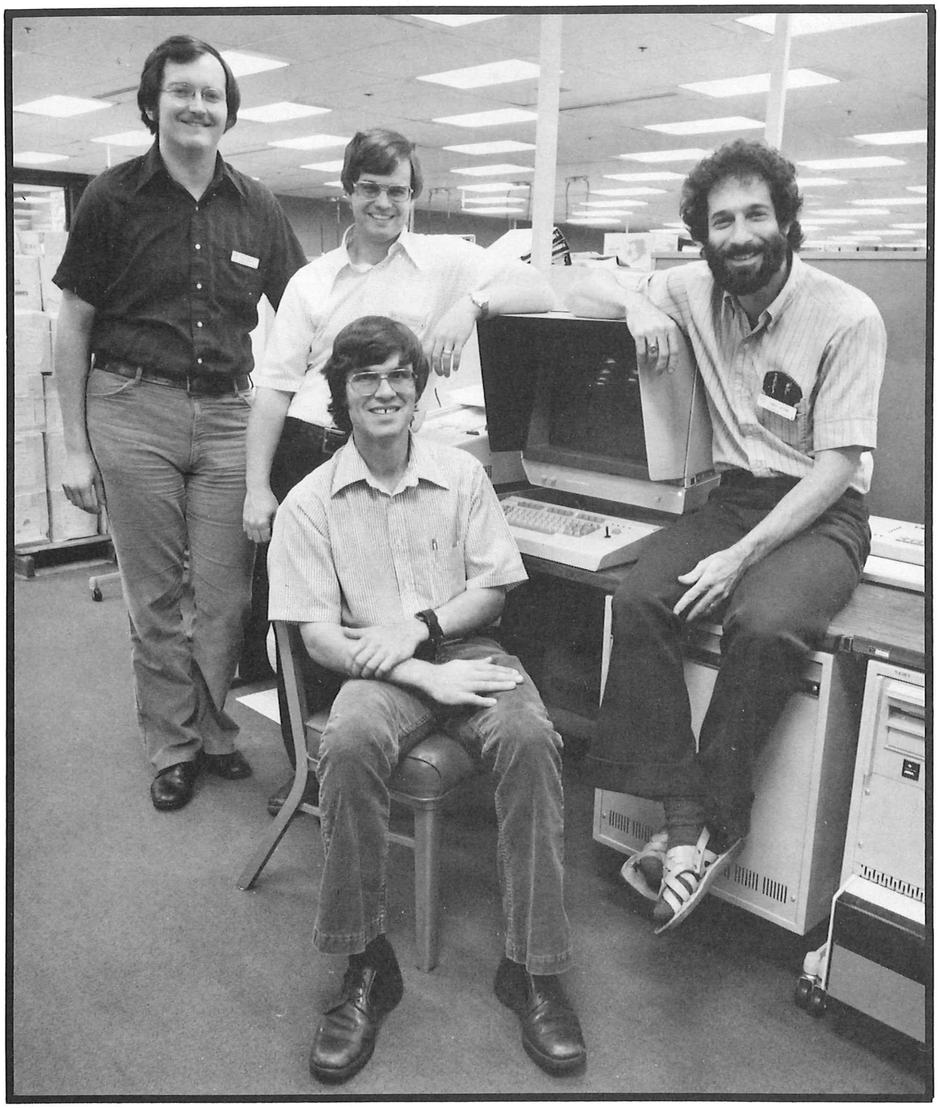
Commands

There are three major types of command for model generation: environmental display, utility, and model generation. Each category has a series of operations and suboperations. The operations are always displayed (in storage mode) in the static menu as shown in figure 8. The sub-operations are displayed (in refresh mode) in dynamic menus when the corresponding operation is requested by the user.

Table 1 is a complete list of all the operations and suboperations available with this FEM system.

Quadrilateral Elements

After completing the nodes, the user can next create the quadrilateral elements by indicating a master set of nodes that define the element's connectivity. By using the master set as a template, the elements can be generated automatically as shown in figures 9, 10, and 11. The pipe elbow model has 162 nodes and 144 elements and takes about 20 minutes to generate. The geometry of the model is visually correct, so the bulk data deck can now be generated.



From left to right, four of the five co-authors: Gary Romans (Applications Project Manager), Jeff Gingerich (Applications Project Manager), Randy Vinecore (Development Engineer), and Barry Ratihn (Development Engineer). Marv Abe (Development Engineer) is not shown. All the co-authors work in IDS Development.

WRITING A PAPER?

One of the main functions of the Technical Information Department is helping Tektronix engineers communicate with the technical world outside Tektronix.

If you are writing a paper for a conference, an article for a magazine, or presenting a technical talk, give Technical Information a call (ext. 5674). We provide editing, typing, and illustrating for papers and articles, and coaching and graphics for slide shows.

Table 1. The complete menu of operations and suboperations available with this FEM system.

Model Generation Commands

Model	
Cre	create model
Del	delete model
Get	retrieve model
Zone	
Cre	create zone
Del	delete zone
Get	retrieve zone
Lim	set node range for zone
Element	
Cre	create element
Del	delete element
Mod	modify element
Cpy	copy master element to create elements
Node	
Lin	automatically create nodes on line defined by two nodes
D-C	digitize nodes and create connectors at same time
Dig	digitize nodes
XYZ	type in coordinates for node creation
Del	delete node
Mod	modify node coordinates
Num	set node numbering scheme for generation
Ren	renumber a node
T-O	orient tablet to drawing
Property	
Cre	enter or replace a floating point number in the property table
LPT	list the property table
N-A	associate a range of nodes with a property
N-D	disassociate a range of nodes from its properties
N-L	list a range of nodes and their properties
E-A	associate a range of element numbers with a property
E-D	disassociate a range of elements from their properties
E-L	list a range of elements and their properties
Arc	
Cre	create arc
Del	delete arc
Connector	
Cr2	create connector by detecting two nodes
Cr1	create connector by detecting one node (connector goes to last node detected)
Del	delete connector
Mul	create multiple connectors between node sequences
Copy	copy nodes, elements, connectors
Org	new origin for copy transformation
Trn	translate on the 3 axes
Rot	rotate on the 3 axes
Scl	scale about the 3 axes
Itr	iteration number
Go	start the copy

Environmental Display Commands

Rotate	Rotate model about any of the model axes
X	
Y	Rotate model about the screen axes
Z	
Cont	Continuously rotate about screen axes
ZoomIn	Scale up model display
ZoomOut	Scale down model display
Paint	Display model
Options	
ZFg	turn Z-plane clipping on and off
Z-P	set front and back Z-plane values for clipping
Vew	adjust viewpoint for perspective projections
Iso	turn isometric projection on and off
Zon	control zone display range
Ety	control element display type range
Ela	control element tags display
ENo	control element display range
Arc	control node display range
NLa	control node tags display
Con	control connector display

Utility Commands

Report	generate model status report
Help	generate help listing of commands
End	terminate session
Geometry	
Loc	type out node id's and coordinates
Dist	determine and type out distance between nodes
Tol	set cursor locate tolerance
Misc	
ElmLib	
Cre	create element library entry
Del	delete element library entry
Mod	modify
Dis	display element library entries
Men	redisplay the static menu
TBW	specify tablet window size
PLOT	generate plot of model

Card Image

The bulk data formatter portion of the system allows many different card formats to be output from the system's data base. This is accomplished by using a command language to format the card image. The commands used for this model need to generate the nodal point data and the quadrilateral elements. (The user created these commands beforehand and stored them in a disk file that generates NASTRAN formatted card images.) The two commands used for the blade model are shown below.

```
generation command
GEN, NODE, ALL, generate all nodes;
1, A4, 'GRID', grid type;
9, I8, ID, grid identification number;
25, F8.3, X, x, coordinate;
33, F8.3, Y, y coordinate;
41, F8.3, Z, z coordinate/

GEN, QUAD2, ALL, generate all quad2
elements;
1, A6, 'CQUAD2', element type;
9, I8, ID, element identification number;
17, I8, P1, property card id. number;
25, I8, N1, grid point number 1;
33, I8, N2, grid point number 2;
41, I8, N3, grid point number 3;
49, I8, N4, grid point number 4/

card field definition syntax:
card column start, format,
internal variable or
constant, optional comment
```

These two commands tell the system to generate the nodes and plates in the NASTRAN format. (In the example above, properties and control cards aren't shown.)

The command language allows the user to access data in the system model data base and output it in card format according to the card field specified. The internal variables used by the bulk data formatter are listed in Table 2.

INTERNAL VARIABLE	DATA BASE INFORMATION	DATA TYPE
M	Model name	character
TN	Total number of nodes	integer
TT	Total number of element types	integer
TEn	Total number of elements where n is element type (1-60)	integer
GPn	General property value array where n is array location (1-97)	real
ID	Node or element identification number/tag	integer
X	Node X value	real
Y	Node Y value	real
Z	Node Z value	real
ET	Element type number	integer
EN	Number of nodes in element	integer
Nn	Element node points where n is element node number (1-64)	integer
Pn	Node or element property value (1-2)	real

Table 2. Internal variables used by the bulk data formatter.

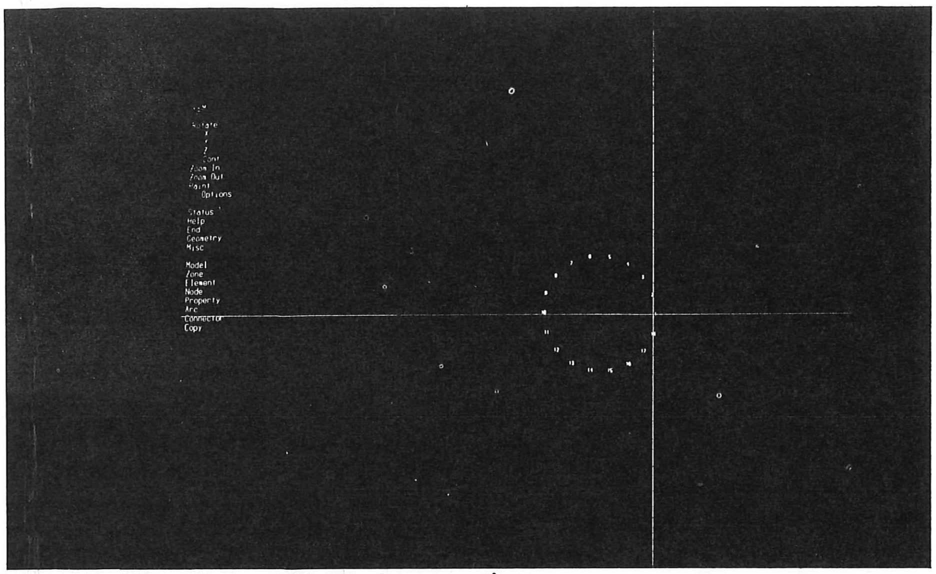


Figure 6. Pipe elbow, initial node generation.

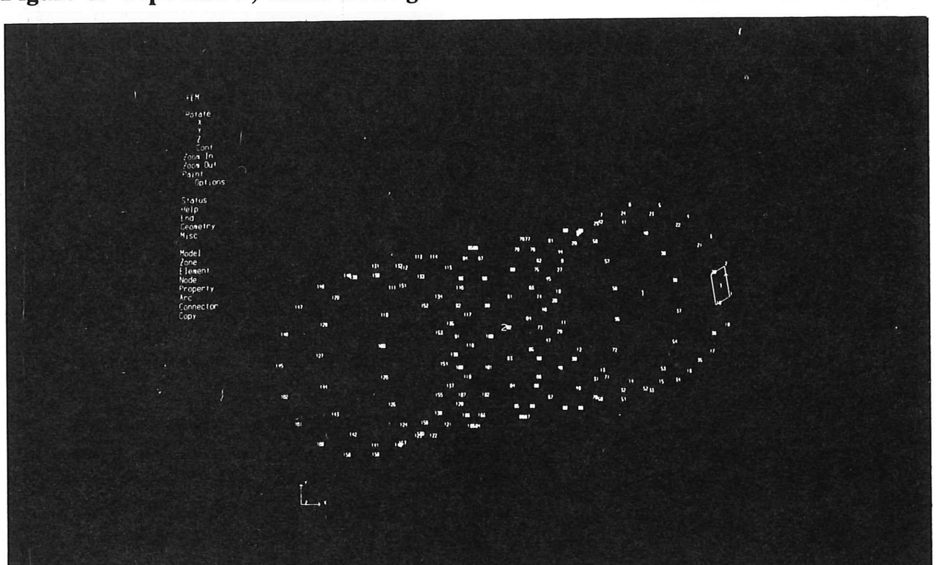


Figure 7. Pipe elbow, final node generation.

FEM

Rotate
X
Y
Z
Cont
Zoom In
Zoom Out
Point
Options

Environmental Display Commands

Report
Help
End
Geometry
Misc

Utility Commands

Model
Zone
Element
Node
Property
Arc
Connector
Copy

Model Generation Commands

Figure 8. The static menu is a display of the operations available in each of the three categories of commands.

Editing

The user should now edit the bulk data deck for the properties, loads, and control cards that were not handled by the system. Then the system transmits the data to the host timeshared computer for analysis, thus completing the pre-processing.

FOR MORE INFORMATION

For more information, call Jeff Gingerich on ext. 2337.

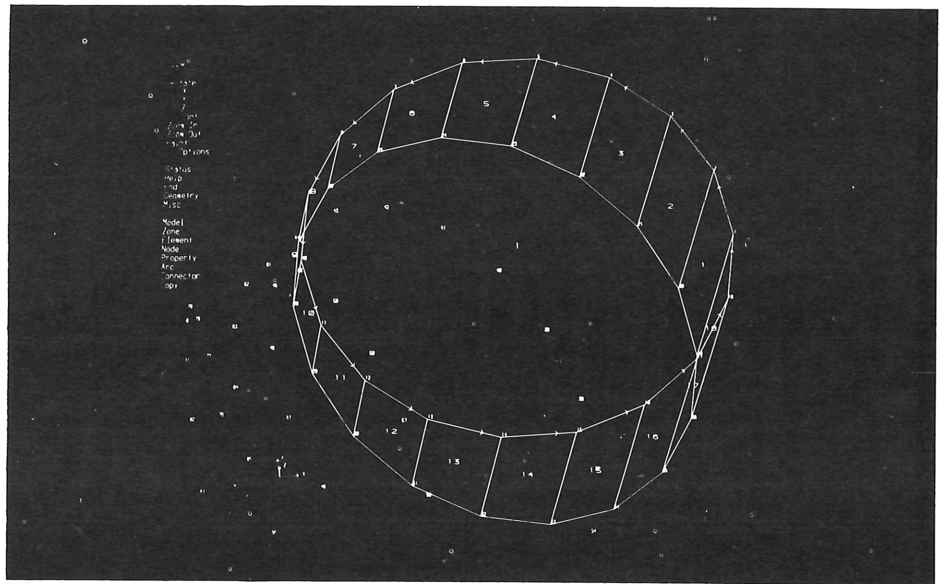


Figure 9. Pipe elbow, element generation.

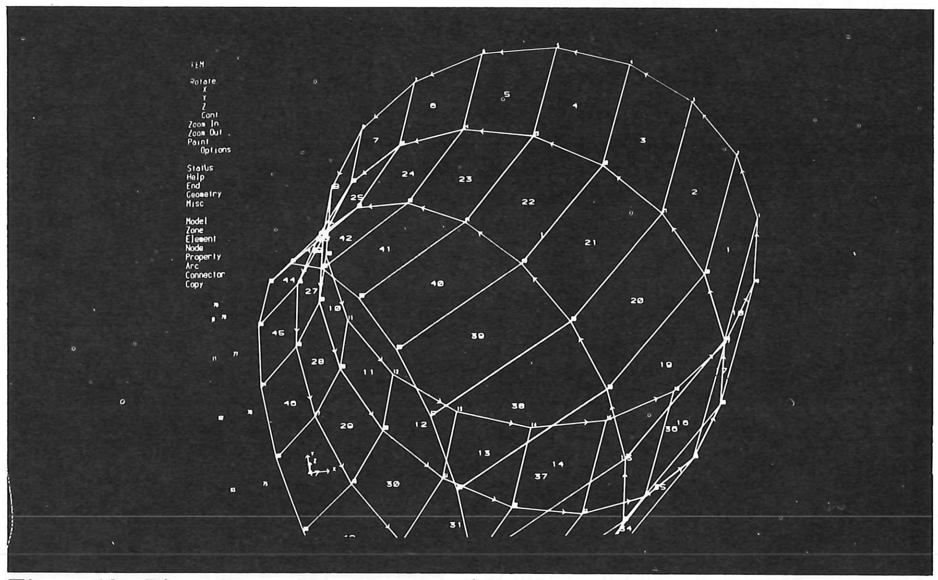


Figure 10. Pipe elbow, element generation.

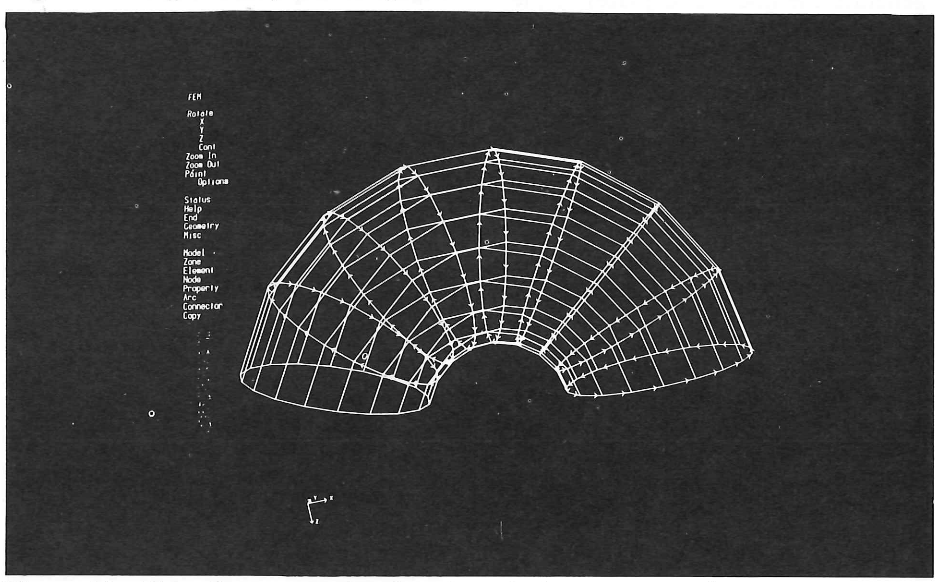


Figure 11. Pipe elbow, completed node and element generation.

INFORMATION SYSTEMS ACQUIRES LASER PRINTER

On July 29, Information Systems (building 55) received its new IBM 3800 Printing Subsystem. This nonimpact, high-speed general-purpose system printer uses a low-powered laser to electrophotographically print on single-ply output paper.

FEATURES

The 3800 prints faster and provides more features than impact printers. It is compatible with user programs that previously used impact printers. The 3800 also provides easy-to-use programming interfaces for its functions and features as follows:

— Character generation storage is provided for printing 255 graphic characters (four character sets) with printing speed independent of the number of characters being used.

— Any two of 18 character sets (including 10, 12, and 15 pitch sets) can be used. These can be changed between data sets or intermixed on a page without operator intervention.

— Graphic character modification allows the substitution or extension of graphic characters in an already defined character set.

— Multiple copies are printed on single-ply paper. Since every copy is an original, there is no need for multiple-ply paper and subsequent separating and stacking.

— Copy modification permits adding or deleting selected data on one or more copies.

— The forms control buffer (FCB) controls the vertical format of pages allowing printing at either 6, 8 or 12 lines per inch, or an intermix of vertical line spacing on the same page.

— Form overlays allow forms and data to be printed at the same time, thus reducing the need for pre-printed forms.

— The *mark form feature* allows the user to mark the horizontal perforations between pages to simplify job separation.

As long as there is sufficient data to print, the 3800 prints at a constant high speed. It can process up to 1000 11-inch long pages in approximately six minutes of continuous printing regardless of the number of lines per page.

HOW THE 3800 PRINTS

The computer transmits data one line at a time to the 3800 where it is stored in an internal page buffer. As each page is completed, it is exposed by the modulated beam of a low-powered laser onto the photoconductive surface of a rotating drum, thereby creating a latent image of the page to be printed.

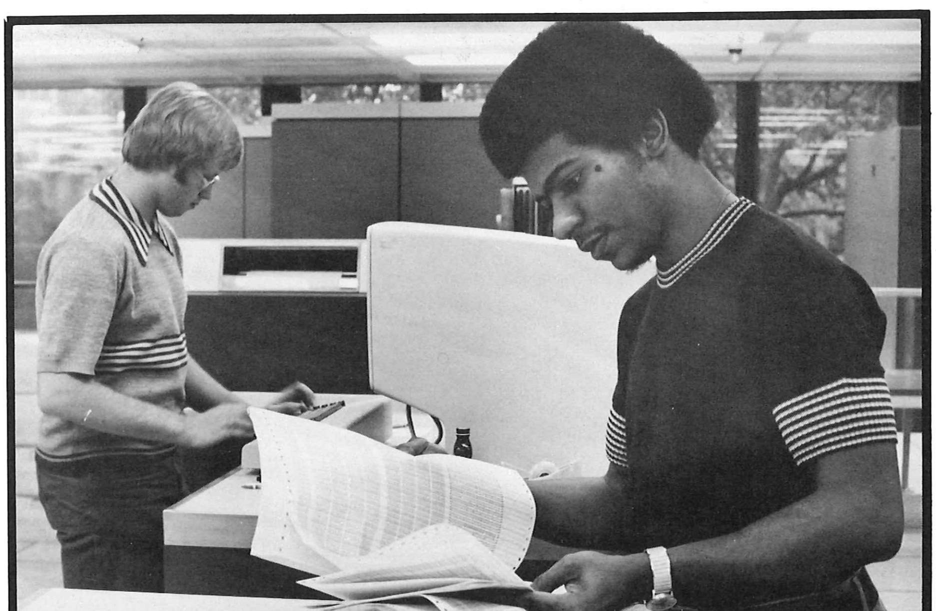
The latent image is coated with toner (a thermoplastic material impregnated with lampblack), and at the transfer station the toned image is transferred from the drum to the paper. The paper then passes through the fuser, which fuses the toned image into the paper. Meanwhile, the surface of the drum is cleaned and reconditioned for following exposures. If there is then enough data in the page buffer to print another page, printing continues without stopping the paper motion. Forms can be printed with the data by flashing the image of a forms overlay negative onto the drum. The forms image passes through the same toner/fuser process for printing.

AVAILABILITY

The printer speeds currently available are:

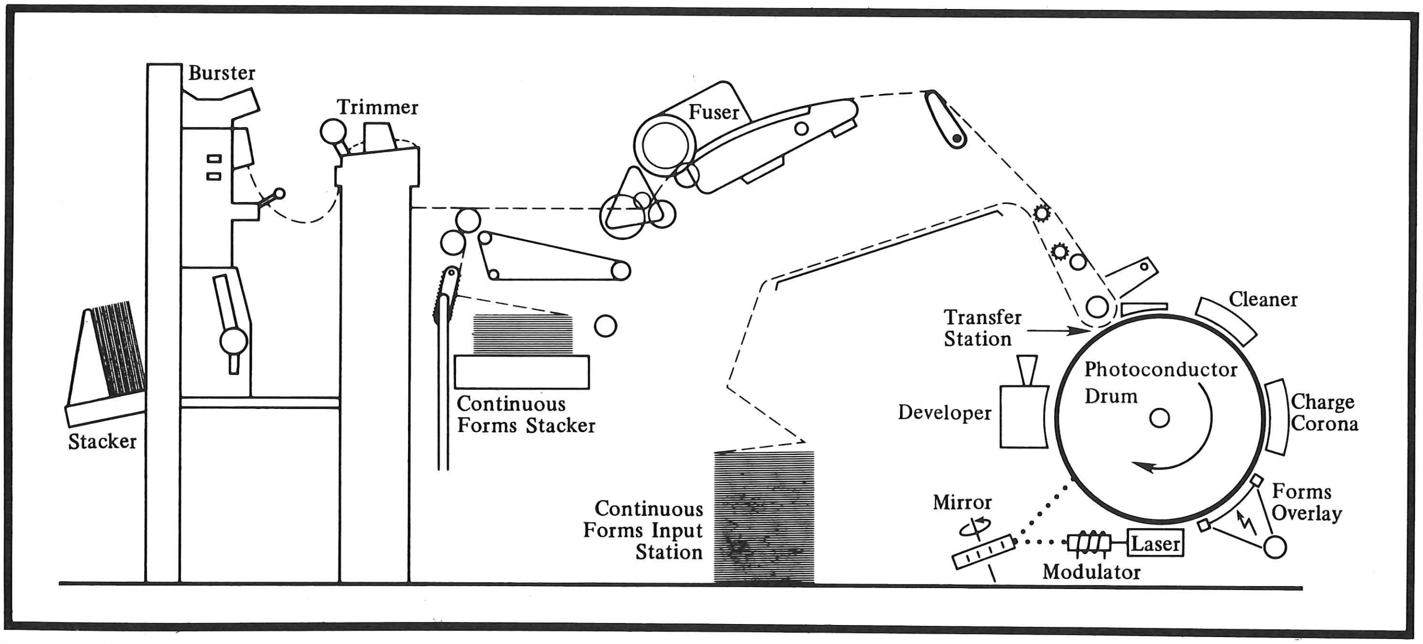
Model	Speed (lines/minute)
1403	1100
3211	2000
3800	20,000

continued

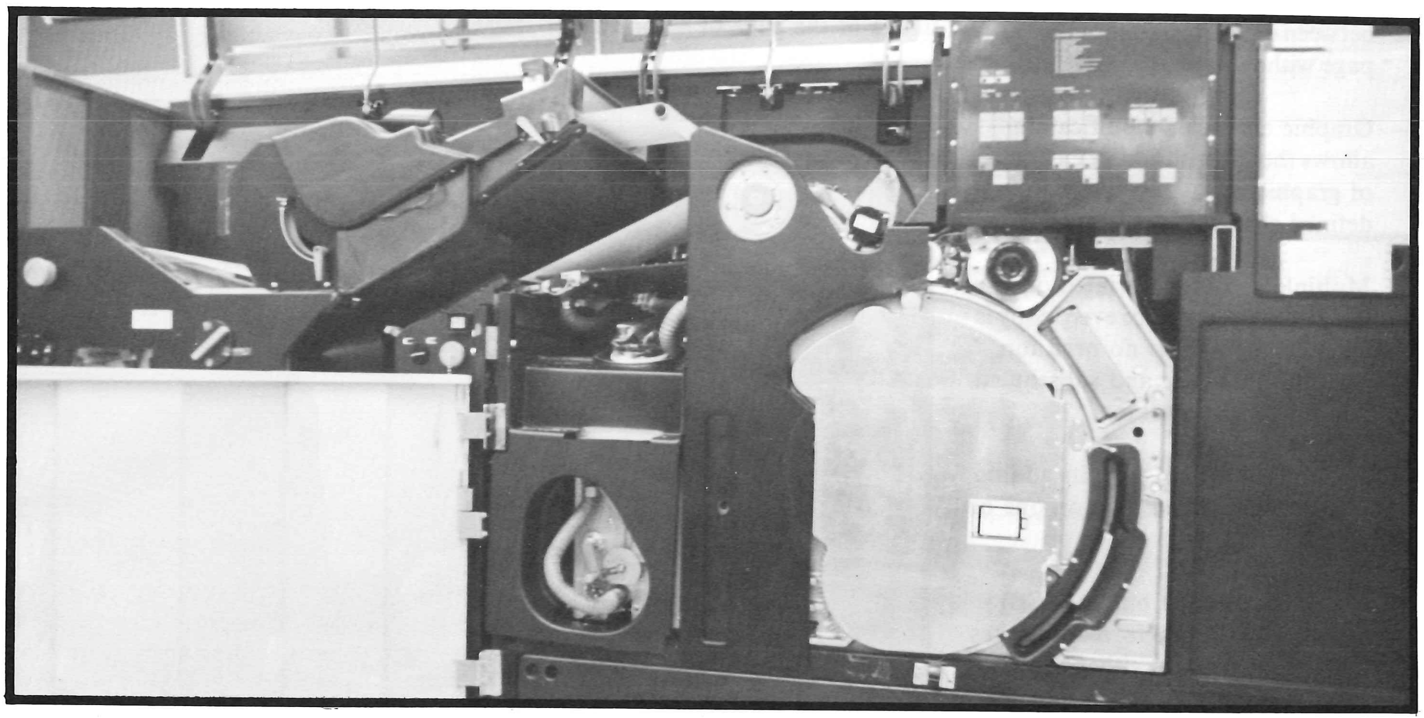


The IBM 3800 printer is located in building 55. Working with the printer are Todd Hendrickson, computer operator, and Fred Long, test coordinator (both work in Computer Operations, part of Information Systems).

Information Systems' heavy use of the 3800 printer to support Tektronix business systems precludes unscheduled use of the printer at this time. If you have any questions about the 3800, call John Patton on ext. 7363.



Information Systems' IBM 3800 Printing Subsystem uses a low-powered laser beam to expose data onto the photoconductive surface of the rotating drum. At the developer, the data image is coated with toner and then the toned image is transferred to paper at the transfer station. Next the toned image is fused to the paper, and the paper itself is trimmed and stacked.



A close-up of the printer, showing the photoconductive drum in the lower right. Paper is passing through the fuser near the top of the printer.

SAFETY CERTIFICATION TAKES TIME . . . and sometimes a lot of it.

Customer demand is pulling Tektronix closer and closer to third-party safety certification for all of its products. An increased corporate commitment to safety certification will require greater effort and time from each participant in the certification process.

In the concept phase of new product introduction, engineering must carefully consider product use and misuse and the resulting safety implications. Product Safety Engineering will provide guidance for engineering in testing designs for safety features, and formatting the documented test data for the certifying agency. And, finally, manufacturing has a continuing responsibility to build products according to safety standards and to control approved materials.

CUSTOMER DEMAND

The primary cause of rising customer demand for third-party certified products is the customer's desire to meet newly enforced OSHA (Occupational Safety and Health Act) requirements. Another component of the demand is the desire to comply with state and municipal codes. In the last few years, state and municipal governments have been more rigorously applying established codes.

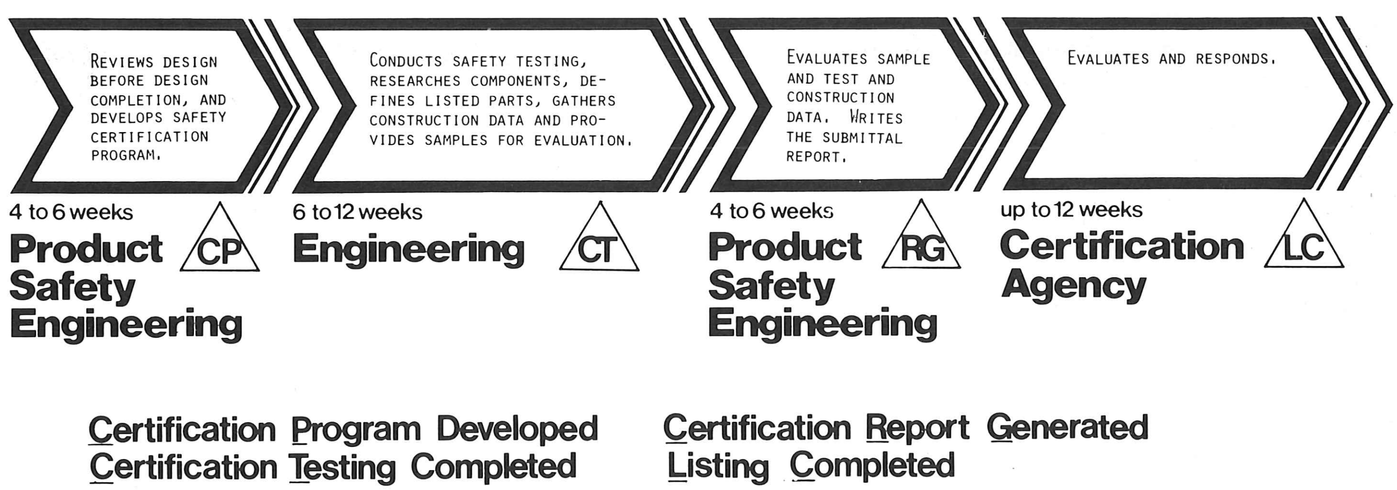
PSE Umbrella

Product Safety Engineering (PSE) plays an overview role in acquiring third-party certification for Tektronix instruments. PSE's activities include reviewing the initial design for safety features, supporting engineering efforts to test design for safety requirements, formatting test data for submission to the certifying agency, and supporting follow-up inspections of product manufacture.

PSE also plays an important educational role bacause product safety engineering is a new discipline and few engineers have received any formal training in designing for safety. So, PSE communicates certification requirements to design engineers and is determined to impress them with the fact that seeking certification can add a lot of time to the new product introduction schedule (especially if the device has to be redesigned to include neglected safety features.)

continued

SAFETY CERTIFICATION PROCESS



The product engineering group begins the product certification process by giving careful consideration to product safety and certification requirements during the concept phase of new product introduction. Product Safety Engineering's role is to support engineering efforts to provide test data and to give that data (in the proper format) to the certification agency. In some product categories, the certifying agency has delegated full responsibility for certification to PSE whereby PSE performs all the agency activities and supplies all the paperwork and product samples for verification of performance. Work goes on even after the selected agency certifies the product...manufacturing continues to be responsible for building to standards and for controlling approved materials and parts, and Product Safety Engineering and the certifying agency conduct unannounced inspections of the product on the production line.

THE BEGINNING

Safety features should be considered at the beginning of the new product proposal. In the concept phase, designers need to incorporate safety features in their design; in their project plans they need to include time for safety testing and time for review by the certification agency (which can take as long as 12 weeks).

PSE, available for consultation at any point in new product introduction, is qualified, in some cases, to act for the certifying agency.

DESIGN REVIEW

Once the product has been designed, Product Safety Engineering reviews the initial model. At that time, PSE helps the project manager determine which third-party certification (there may be more than one) will be required for the product. As soon as that decision has been made, PSE will begin to assist in developing the safety certification program for that product.

The safety certification program outlines the information that must be supplied for each certification submittal. Every certification submittal has three main segments:

— description of some of the components in *unlimited circuits* (circuits in which there is a voltage higher than 42.4 volts peak, or in which the available power exceeds 150 watts, or in which the maximum current exceeds 8 amperes).

— physical description and identification of materials used, with special emphasis on flammable insulation systems.

— test results.

DOCUMENTED TESTS

Engineering groups are responsible for testing their own designs for safety features, but PSE does provide support for these efforts. Engineering control of the tests ensures the quickest turnaround for the test data, and thus shortens the certification schedule. Engineering collects the test results onto data sheets for PSE's review.

Unlike many other tests that evaluation and design groups perform, safety tests must be fully documented. Everything must be written down...procedures as well as results.

PSE PUTS IT INTO SHAPE

Product Safety Engineering combines the test data and procedure specifications with component research and construction data and puts them in the format required by the certifying agency.

There are three main certifying agencies that Tektronix regularly deals with today, and each has its own format requirements. Some agencies also require samples of the instrument for evaluation.

PSE has responsibility for all Tektronix products. Its headquarters is in building 58, but there are representatives in Wilsonville. PSE is responsible for mods as well as new instruments.

AGENCIES AND MORE AGENCIES

Most of us think of "UL" when we think of safety certifying agencies. But Underwriters Laboratories isn't the only agency Tektronix regularly deals with. Other certifying agencies include the Canadian Standards Association (CSA), and the City of Los Angeles. UL, CSA and the City of LA are all third-party certifying agencies.

Other safety standards and groups include the IEC (the International Electrotechnical Commission), ANSI (the American National Standards Institute), BRH (the Bureau of Radiation Health), FDA (the Food and Drug Administration), BPO (the British Post Office), and VDE (the Verband Deutscher Electrotechniker).

UL's standards are by far the most inclusive, stringent and notable of North American standards, but the IEC standard holds first place worldwide. The IEC, however, does not certify instruments as a third party.

Most designers (or project managers) choose UL for certification of their instruments because it will satisfy all USA market demands.

FOLLOW-UP

Work doesn't stop even after we have received certification for the instrument. UL and CSA make unannounced inspections of Tektronix manufacturing and testing facilities to check for compliance with the original submittal. For the City of LA, we annually submit a current sample for their review. Manufacturing has a continuing responsibility to make sure all required warning labels are attached and to maintain control of all approved parts (unapproved substitutions may void the certification).

MORE INFORMATION?

Contact Pete Perkins (Product Safety Engineering manager) with any questions about the safety certification process here at Tektronix. You can reach Pete on ext. 7374 or by dropping by 58-262.

CERTIFYING AGENCIES

UL (Underwriters Laboratories). A non-profit corporation independent of government and industry, UL writes its own standards which are recognized throughout the United States. Many cities and states, as well as OSHA (the Federal Occupation, Safety and Health Agency) have regulations requiring UL listing of products.

CSA (CANADIAN STANDARDS ASSOCIATION). The principal Canadian standards writing group, acts as a secretariat for industry-funded and industry-staffed standards committees. CSA certification is recognized throughout Canada and the northern U.S.

IEC (INTERNATIONAL ELECTROTECHNICAL COMMISSION). An international secretariat for groups interested in electronic standards, the IEC does not certify products, but does privide standards for other groups to use in certifying products.

CITY OF LOS ANGELES (THE LOS ANGELES DEPARTMENT OF BUILDING SAFETY). Evaluates products for compliance with city codes and third-party standards. It is recognized throughout Los Angeles county and Southern California.

FM (FACTORY MUTUAL ENGINEERING CORPORATION). An independent certification agency chartered to certify factory equipment, but not recognized by Los Angeles and Chicago. FM certifies products for compliance with ANSI and other standards.

Certifying agencies with which Tektronix seldom has contact:

3VDE	Verban Deutscher Electrotechniker, Germany.
BSI	British Standards Institution, United Kingdom.
KEMA	Kevring van Elektrotechnischer Materialen, Netherlands.
SEV	Schwizerischer Elektrotechnischer Velein, Switzerland.
SAA	Standards Association of Australia, Australia.
CEBEC	Comite Electrotechnique Belge, Belgisch Elektrotechnisch Comite, Belgium.
DEMKO	Danmarks Elektriske Material Kontrol, Denmark.
NEMKO	Norwegian Board for Testing and Approval of Electrical Equipment.
SEMKO	Swedish Institute for Testing and Approval of Electrical Equipment.
ETL	Electrical Testing Laboratory, New York. Certifies electrical products and their installation for safety code compliance. All electrical products offered for sale within New York City must be labeled by ETL or UL.
	The Electrical Inspectorate, Finland.

TERMINOLOGY

FIRST-PARTY CERTIFICATION. Self-certification. Whether a product is in compliance with a standard is determined by the manufacturer of the product. Tektronix did this until a few years ago.

SECOND-PARTY CERTIFICATION. Product compliance with a standard is determined by the purchaser (at Tektronix, by the Incoming Inspection Office).

THIRD-PARTY CERTIFICATION. Compliance with a standard is determined by a group not connected with either the manufacturer or the purchaser. Underwriters Laboratories is an example.

TEST RECORD. This is the test data either gathered by the manufacturer or performed by the certifying agency, to determine if the product meets the selected standard. At Tektronix, design engineering departments are responsible for gathering this data.

PROCEDURE/CONSTRUCTION REPORT. A physical description of the construction required to maintain a safe device.

COMPONENT REPORT. A part number description of the components required to maintain certification.

CSA CATEGORY CERTIFICATION. Delegation of authority by the Canadian Standards Association to a manufacturer who has demonstrated possession of inspection facilities equivalent to CSA's, and who has shown that product safety employees are independent of manufacturing, sales and design functions. The manufacturer is allowed to perform all the tests and keep all the records that the CSA would perform and keep. The CSA conducts quarterly inspections of records and products to make sure the requirements have been met.

EMULATE OR SIMULATE?

In Steve Dum's article (**In circuit Emulation Using the Target Microprocessor**) in the last issue of EN, there was a brief discussion of emulation and simulation. Steve Rosenthal, a free-lance writer working with Marketing Communications, further defines those concepts.

SIMULATION

A simulator takes representations of a system's inputs, and predicts the outputs of the simulated system.

EMULATION

An emulator takes representations of a system's inputs, and produces an exact duplicate of the output of the emulated system.

SIMULATION

Simulation is a more general term than *emulation* which is a specialized subcategory of simulation. Simulation includes all modeling systems which are intended to predict the actions of a modeled system. The simulating system may take the original inputs or a representation of the original inputs, and process them to show what the output of the original system would be. Figure 1 emphasizes the relationship between simulation and emulation.

A computer program which attempts to show what would have happened if you had built a rocket ship, voted for a Republican, or turned the rudder to the left is a *simulation program.* An analog or digital system that performs such modeling behavior is a simulator and the process involved is a simulation.

If a computer program (generally part of an operating system) takes a user program and pretends to execute it, but prevents the object program from actually taking its usual degree of control of the computer resources, then it is simulating execution. The operating system program that does this is a simulation program. At the actual hardware level however, nothing is being simulated—it is all reality. Therefore, the microprocessor or CPU involved is not being simulated, although the software execution is.

EMULATION

By contrast, emulation is a form of imitiation. Emulation systems, like all simulation systems, attemp to provide the same outputs as the original system would have provided if given the same inputs. An emulation system, however, may run slower or faster than the original system, and may utilize any combination of software or hardware to get the job done. Table 1 summerizes the attributes of both emulation and simulation.

Designers emulate the operation of a system to get the same work out as the original system would have produced, possibly learning more about the original system on the way. Emulation's main application is to use one CPU or computer to imitate the operation of another one.

Most often, emulation is needed when a computer is changed or upgraded, and the effort required to change the old software is prohibitive or the time available is too short.

Emulation allows the new CPU to run old software. Theoretically, no changes need be made to the soft-ware, but in practice it is not uncommon for some changes to be required with commercial emulators.

A common example of emulation is a designer's use of a bipolar chip set to imitate the operation of a MOS microprocessor either to allow system operation at a higher speed than the original system would allow, or to make internal data accessible to the designer.

It is also possible to emulate the operation of one microprocessor on another, but this is rarely done.

AREAS OF CONFUSION

Many of the "emulation modes" used on most microprocessor development aids (MDA) are actually simulation modes. Their objective is either to show what would have happened if the program had been run, or to run the program while keeping track of external data. If the same microprocessor is used in the simulation as the system being simulated would have used, then no *chip-level* emulation is involved.

Emulation is involved, however, when a complete development system is being utilized to imitate the operation of a target microprocessor while external data is being collected or the system is run for verification. In this case, the *whole* MDA emulates the target CPU (meaning that the MDA takes the same inputs and produces the same outputs), but the CPU in the MDA is not doing any emulating at all if it is the same type as the target microprocessor.

Note also that if the microprocessor system is providing the memory, input/output, or operating system, then it may be either simulating or emulating these parts of prototype operation depending on whether it is supplying exact replacement signals or providing the user with representations of what would have happened.

Comments from readers are invited. Mail your comments to **Engineering News,** D.S. 50-462.

	INPUT	OUTPUT	OBJECTIVE
SIMULATION	representation of original system's input	representation of original system's output	accurate prediction of output of original system
EMULATION	actual input of original system.	actual output of original system.	exact duplication of output of original system.

Figure 1. Emulation is a subset of simulation.

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Why EN?

Engineering News serves two purposes. Long-range, it promotes the flow of technical information among the diverse segments of the Tektronix engineering and scientific community. Short-range, it publicizes current events (seminars, new services available, and notice of achievements by members of the technical community).

Contributing to EN

Do you have an article or paper to contribute or an announcement to make? Contact the editor on ext. 5468.

How long does it take to see an article in print? That is a function of many things (the completeness of the input, the review cycle and the timeliness of the content). But the *minimum* is three weeks for simple announcements and about five weeks for articles.

The more important step for the contributor is to put his message on paper so that the editor will have something to work with. Don't worry about problems with organization, spelling or grammar. The editor will take care of those when he puts the article into shape for you.