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TDNOVA Interactive Graphics

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As computational resources have expanded, the computer codes have kept pace with increased complexity and have grown in sheer volume of output—so much that the millions of numbers are difficult to comprehend without a visualizing tool. A graphical analysis program has been developed to view the huge amount of data produced by the two-dimensional (2-D) NOVA interior ballistics code (TDNOVA).

By using color plots and drawings, the TDNOVA Graphical Analysis Program (TGAP) can display 2-D and 3-D information in four separate, independent windows. Besides the standard interior ballistic (IB) data, such as pressure, temperature, and gas velocity, the TGAP program can also show deformation of the computational grid, movement of propellant increments, and composite gas velocity vectors (radial and axial directions). Three-dimensional drawings of computed IB physical quantities can be rotated, shifted, and sized to produce the desired view for the scientist. Any of the four windows may be chosen for enlargement to full-screen size to make color screen copies or viewgraphs. The windows may show four different types of data from a single TDNOVA calculation, or may be used to display data from up to four completely independent computations.

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1. INTRODUCTION

Over the last 20 years, the spectacular increase in computing power has prompted a similar increase in complexity and detail of interior ballistic (IB) programs. This has resulted not only in expanded capabilities in modeling physics, but also in mountains of printed numbers—whether these numbers actually get inked onto paper, or remain as huge datafiles in computer memory. The human interface has changed little in these same 20 years; a researcher must still organize these mountains of numbers into coherent mental images in order to visualize the physical relationships predicted by the computer model. Sensible organization of the printed numbers on the output page can greatly assist this visualization. But when the computed details are so great as to overwhelm the investigator, then the printed pages have ceased to serve their purpose.

Graphs are excellent tools for showing numerical relationships. Two-dimensional (2-D) plots of breech and base pressures vs. time can bring out features which are nearly indistinguishable as numbers; the concepts of frequency and relative amplitude, for example, are easily understood when graphed. When a third dimension is required, the 2-D graph is inadequate and must be replaced by a three-dimensional (3-D) surface, which is again understood much faster and easier than trying to mentally assimilate a list of numbers.

The two-dimensional interior ballistics code, TDNOVA (Gough 1986), can simulate the IB process from ignition to projectile exit. Its standard output print contains three types of numerical data: tableau (or time snapshots), propellant bag or combustible case information, and a summary of selected data (such as breech pressure) vs. time. An additional output file may be requested, which contains the position of each computational node (at selected IB times) and IB information for each node. TGAP (which is an acronym for TDNOVA Graphical Analysis Program) uses a menu-driven multiwindow environment to display TDNOVA simulations on a color-graphics workstation.

2. TDNOVA

TDNOVA computes two-phase transient IB simulations in two dimensions: from the breech to the base of the projectile, and in a radial direction from the centerline to the tube wall. In this manner, a longitudinal cross section of the gun is formed. It is revolved around the axial centerline to create a 3-D volume representation of the gun.

The initial computational mesh, which does not have to be uniform, may be envisioned as a series of lines in the radial direction and a perpendicular set of lines extending from the breech face to the projectile base (Figure 1). Values for physical measurements (pressure, temperature, etc.) are computed for points at each of the intersections (nodes). Additional values are computed for various boundary points along the inside of the chamber and tube, and for positions describing the rear face of the projectile. As the computation progresses, these points are allowed to move so that the region can expand to the growing volume behind an accelerating projectile, and so that internal boundaries (such as propellant containers) continue to be tracked.

The TDNOVA code uses three sets of equations to model the physically distinct chamber regions. Each increment of the main propellant charge is represented by a system of two-phase macroscopic equations and constitutive relationships to describe the microscopic interactions between the phases due to mass, momentum, and energy transfer. Charge increments may be enclosed in a container (bag or casing) which may be characterized as having reactive substrates on the inner and/or outer surfaces, permitting simulation of combustion on each surface, as well as allowing additional components (such as a basepad igniter) to be attached to the end surface. Immediately adjacent to the main charges are single-phase gaseous regions (ullage) and possible centercore igniter packages—these are modelled by quasi-one-dimensional methods. The remaining volume (ullage not adjacent to two-phase regions) is handled by lumped-parameter equations. At some point during the IB cycle, when propellant within a region has completely burned away and the volume now contains only gases, TDNOVA may alter the method of computation in order to simplify handling of the former two-phase region. Similarly, the quasi-one-dimensional regions may become amenable to computations using lumped-parameter methods.

During IB computation, the TDNOVA code prints tableau information at user-specified intervals. The tableau prints are "snapshots in time" of the computed values at each grid point. A file of plotting information may also be created at specified IB time intervals; each of these intervals contains grid information (where the nodes are currently located), and at each node the values are printed for measurable physical units (pressure, temperature, porosity, gas velocities, etc.).

At the end of the simulation, the code prints a table of IB history data. At time intervals specified in the input deck, values are printed for IB time, breech pressure, mean pressure, projectile base pressure, propellant mass fractions, and projectile travel, velocity, and acceleration. A similar table may be requested for pressure gauge values at specified axial and radial locations.

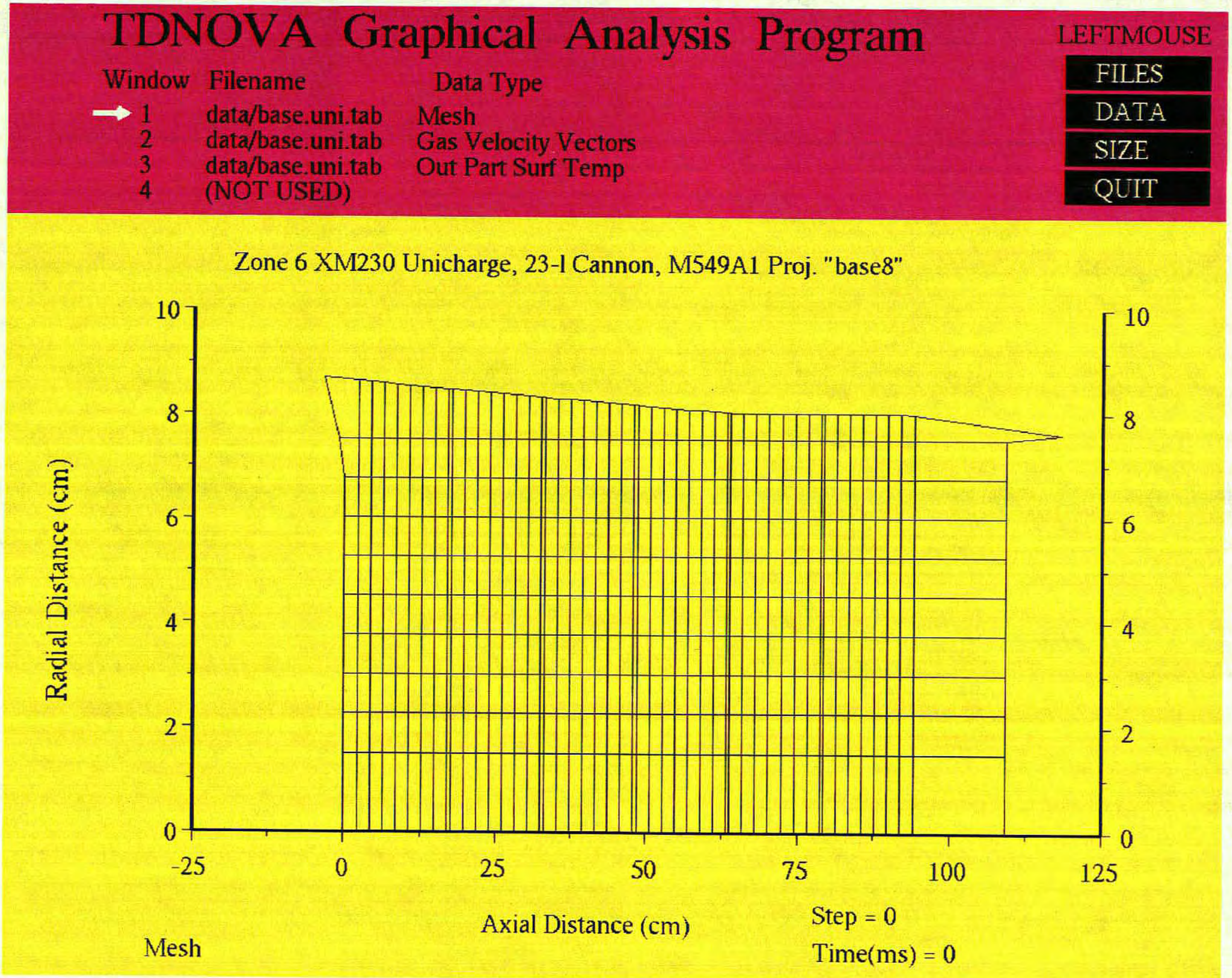

Figure 1. TDNOVA computational mesh.

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3. TGAP

The TGAP code is written in the C language (Kernighan and Ritchie 1978) on a Silicon Graphics Workstation.* IRIX, a proprietary version of UNIX,** is the operating system for the SGI computer. The TGAP program currently contains over 6,500 lines of coding, along with another nearly 1,000 lines of ancillary programs for preprocessing TDNOVA, XKTC (Gough 1990), and IBHVG2 (Anderson and Fickie 1987) output data.

Three broad types of data can be displayed by TGAP: (1) tableau data, (2) bag boundary data, and (3) history data. Though each data type is explained in detail later in this report, a brief overview of the three types will help the reader to understand the motives behind the several initializing steps for the TGAP program:

(1) Tableau data are taken from the TDNOVA plotting file (FORTRAN file 7 from the TDNOVA program). Each tableau is distinguishable by step number and by IB time level. The TDNOVA input deck specifies whether the plotting file is to be generated, how often the plotting information is printed, and which variables are to be written to the file. Grid information is always printed in Z (axial) and R (radial) coordinates; the remaining data types, such as pressure values, are printed as separate arrays where each value (V) tracks one to one with a Z-R coordinate. Using the Z-R-V triplet, this information may be plotted in a 3-D volume (as in Figure 2, showing pressure) or by using the V value as an index for color variation (Figure 3, showing propellant bed surface temperatures).

(2) Bag boundary information is taken from the TDNOVA tableau print, and has three separate values to describe the bag status. The bag is defined to be the structure which contains the propellant material inside the computational volume; in actual artillery situations, this material may be silk cloth, cardboard, nitrocellulose, or even nonexistent (nonbagged). The three types of bag information denote status about permeability, rupture, and combustion (burning). A single line from point-to-point around the bag boundary can convey all three types of information as color, line style (solid, dashed, or dotted), and line thickness (Figure 4).

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* The Silicon Graphics Workstation includes: 4D/70G processor with color monitor, 380MB system disk, keyboard and mouse, dial and button box, and 1/4-in tape drive. For more information, contact: Silicon Graphics Computer Systems, 2011 N. Shoreline Boulevard, P.O. Box 7311, Mountain View, CA 94039-7311.

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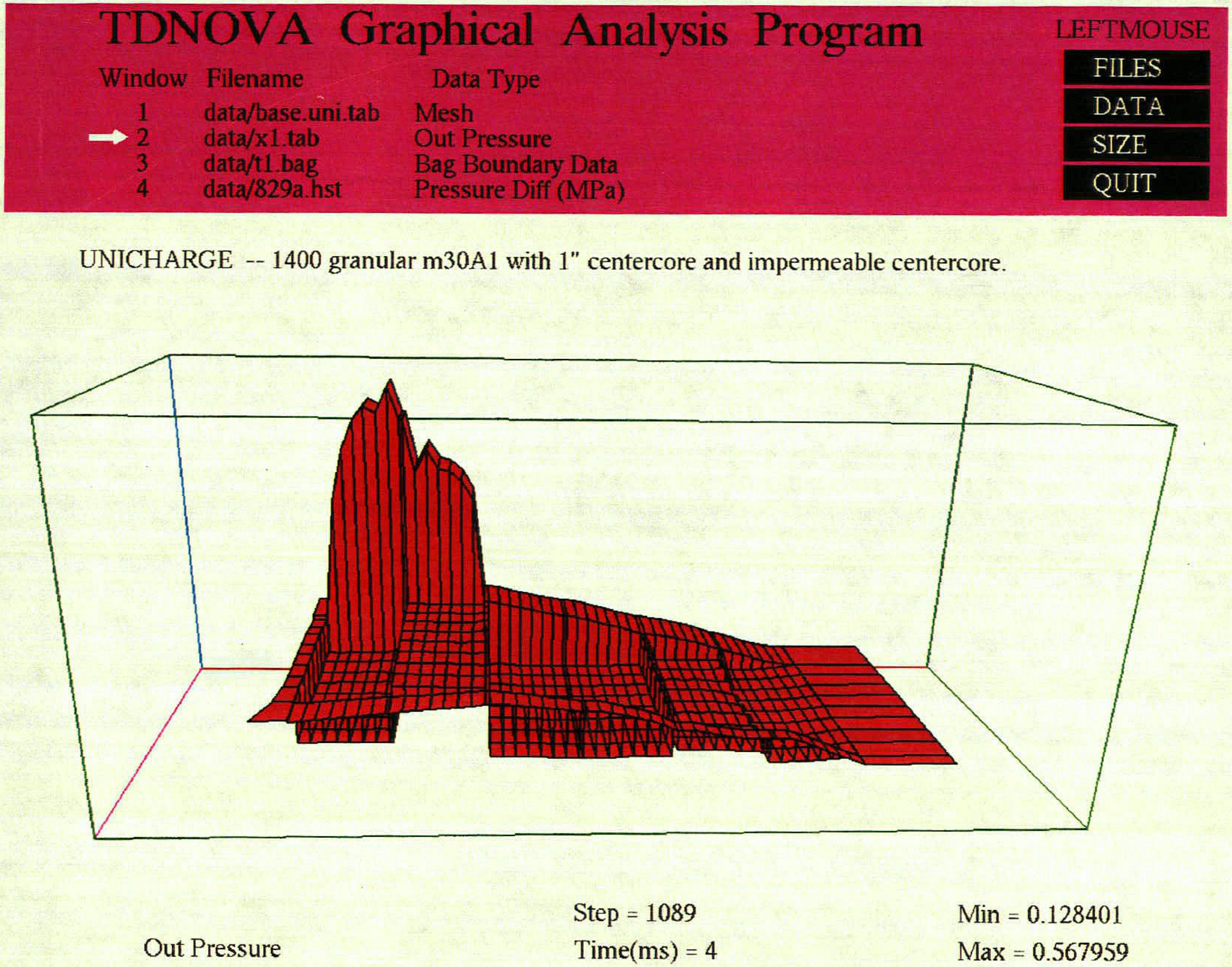

Figure 2. Gas pressure graphed as a three-dimensional surface.

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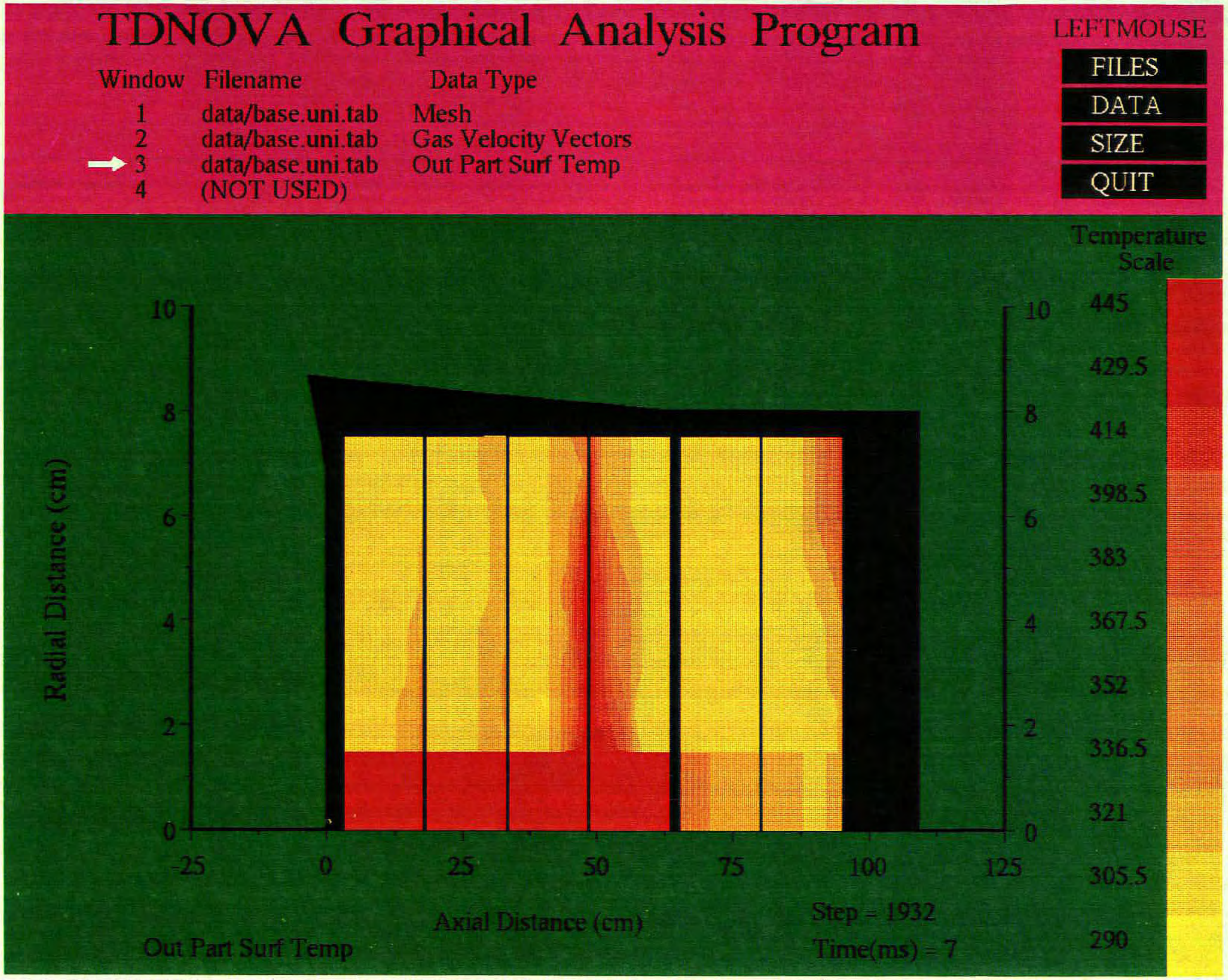

Figure 3. Variations of propellant surface temperatures shown as color gradations.

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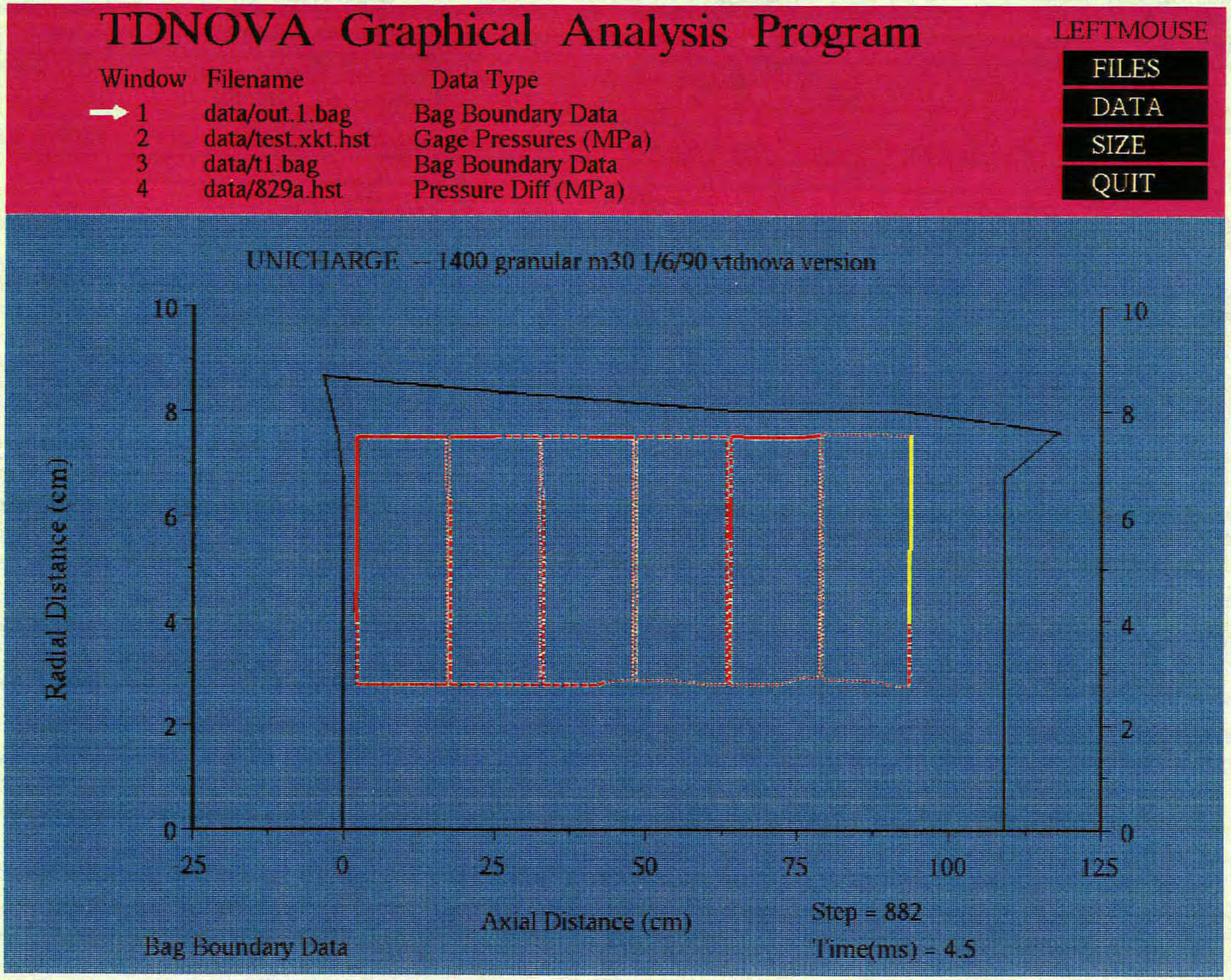

Figure 4. Propellant bag representation.

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(3) History data is plotted as a 2-D graph with time as the horizontal axis. Since TDNOVA and XKTC both have history tables of very similar construction, TGAP has been programmed to allow either IB program's history data to be plotted. These plots are the conventional IB information: pressures (breech, mean, and base), projectile values (position, velocity, and acceleration), and mass fraction of each charge. History tables may also be written for gauge pressures since both XKTC and TDNOVA allow pressure data at nodes along the gun tube and projectile base to be stored during the computation and printed when the simulation is finished. TGAP can plot these pressures as a series of lines in a pressure vs. time graph. Each line is defined by color and line style (Figure 5). IBHVG2 trajectory data can also be plotted as history data, using either the default IBHVG2 values or other physical data (such as gauge pressures) which the user may require.

4. PROGRAM EXECUTION

4.1 Preprocessing TGAP requires that its input data (files of data to be plotted) be formatted in one of five ways: tableau files, bag boundary data files, and history data files in TDNOVA, XKTC, or IBHVG2 formats. The plotting information from TDNOVA file 7 (TGAP's tableau data) need not be postprocessed for use in the TGAP display. When the TDNOVA program has finished printing its file 7, this need only be renamed as *filename.tab* where *filename* is the user's choice of a descriptive name.

Bag boundary data for TGAP are created by postprocessing the TDNOVA standard output file. Bag information is collected by the *bag_data* program. *bag_data* is written in the C language, and filters the TDNOVA standard output file for position and status of the bag boundary datapoints. This information is then printed in *filename.bag*, where again the *filename* is chosen by the user.

History data, unlike tableau and bag boundary values, require no position information. The information from TDNOVA and XKTC history tables and from the IBHVG2 trajectory print is printed with respect to computational (IB) time, and is positioned at the end of the standard output for each program. The postprocessor called "sort.hist" is a UNIX shellscript program which gathers and reformats the history tables. The history datafiles are created as *filename.hst*, where *filename* is supplied by the user. Since TDNOVA outputs use metric units and XKTC uses English units, the postprocessor converts XKTC information to units which match the TDNOVA data.

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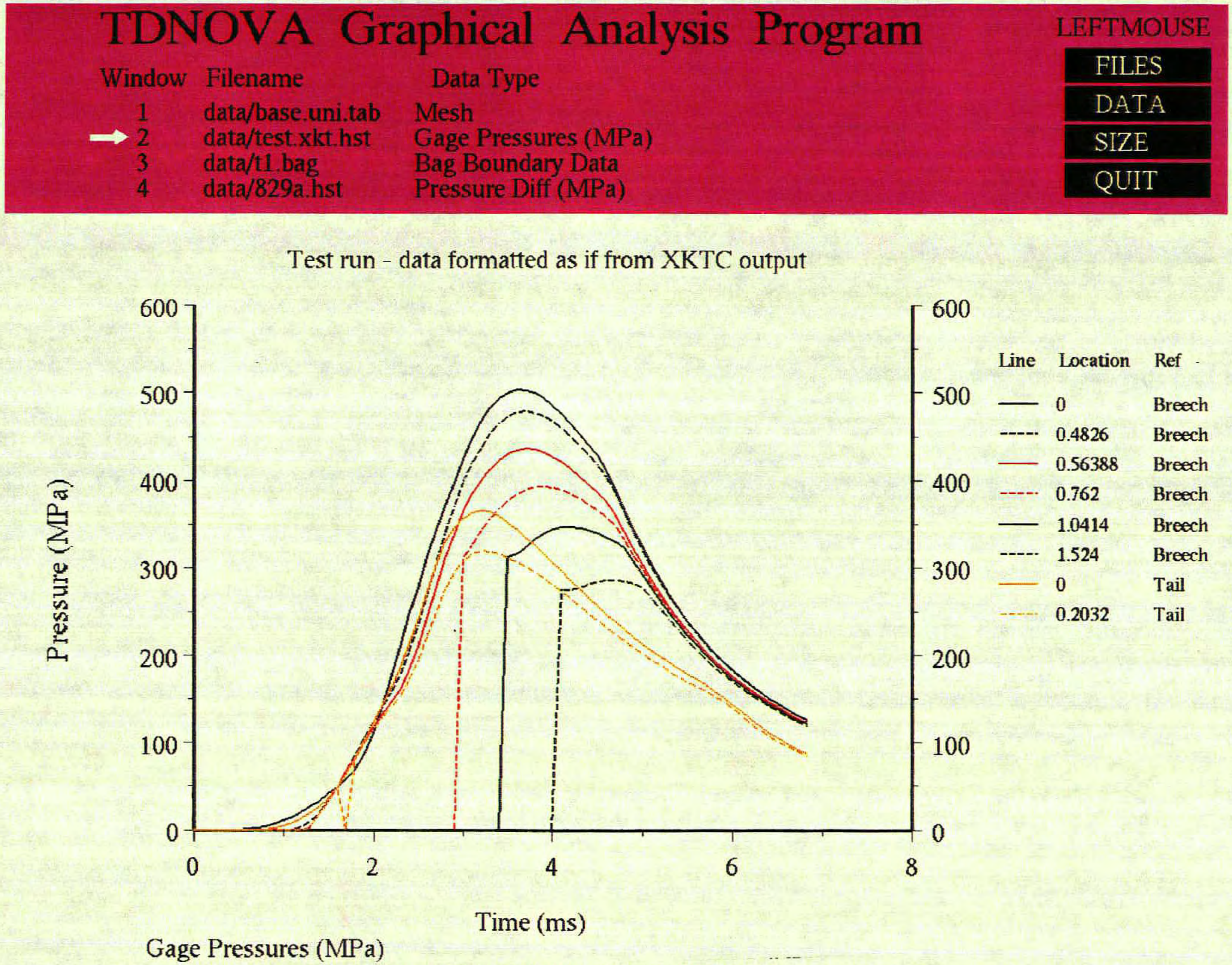

Figure 5. Time history plot - pressure gages.

A single TDNOVA simulation may provide data for all types of TGAP files—tableau, bag boundary, and history. When several simulations are computed, such as for a study of gun parameter variations, the number of TGAP files can increase rapidly. For this reason, it is usually best to have the *filename* identical for any TGAP data created from a single TDNOVA computation.

4.2 Initialization. Currently, the executable TGAP code is named *2d*. To run the display program, a user must enter the command "**2d** *directory*" to supply the name of a UNIX directory containing TGAP datafiles. TGAP will check for existence of *directory*, then check to see if any files with extensions *.tab*, *.bag*, or *.hst* are resident in that directory. If either of the above conditions are not met, TGAP will exit with a descriptive error message. If the directory and TGAP datafiles are present, a graphical display will be generated on the screen (Figure 6). The display shows a list of the available filenames, information about which kind of data is available under each *filename* (three columns labeled "TAB," "BAG," and "HST" contain either "Y" or "N" after each *filename* to show existence of the three types of datafiles), and a small rectangular figure divided into four regions with a number in each region. Next to the figure is a table with four numbered lines—initially, each line contains a number and the phrase "*(not used)*".

A menu will appear on the initial screen, allowing the user to select which files to display in each of the four graphical display areas. The SGI input mouse and the rightmost mouse button are used to choose from the menu of *filenames*, as well as to choose from *.tab*, *.bag*, or *.hst* data (if present). The **Previous Menu** option allows the user to correct a mistake when choosing a *filename*. As the filenames and data types are chosen, the numbered lines next to the rectangular figure are overwritten with the respective *filename*. A graphical area may be skipped during the initialization by choosing the option **Leave Blank** instead of a *filename*.

After the datafile (or blank) options have been chosen for the four regions, the TGAP program searches through the appropriate files and creates data queues for tableau or bag information (or will read a *.hst* file in its entirety). Data queues are lists of positions in a file where successive time steps begin, and are required because tableau and bag boundary data files are sometimes too large to fit in program memory. TGAP uses the queue information when gathering data prior to plotting a graph. As the datafiles are searched and the queues are formed, a dark blue rectangle appears on the screen with "Creating Queues" and the filename printed in white letters.

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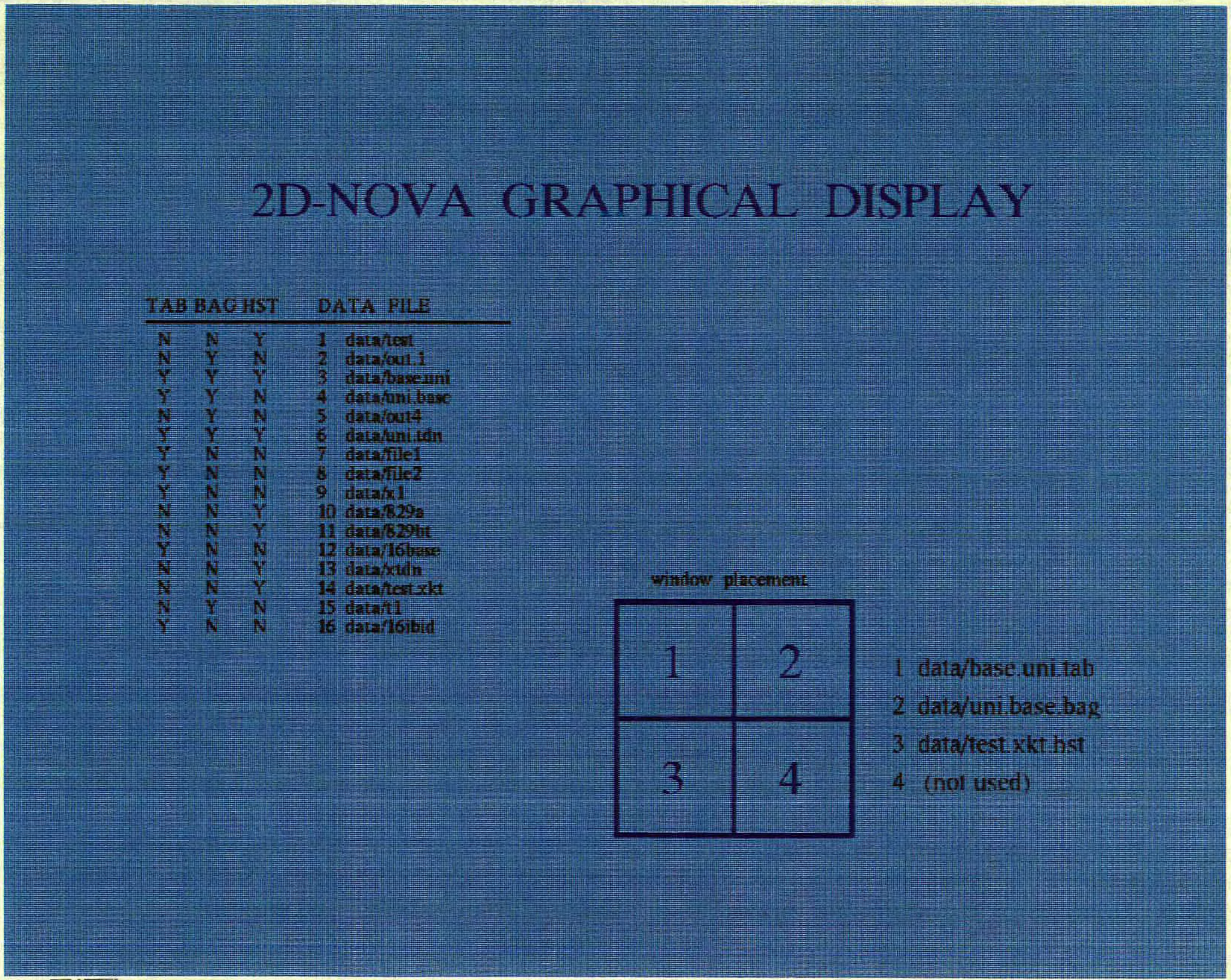

Figure 6. TGAP shows available filenames and data types.

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When queue creation is finished, the initial screen will be replaced by an "overhead" window and by the four graph regions (Figure 7). The overhead window contains "TDNOVA Graphical Analysis Program" written in large letters, a table of numbers and filenames corresponding to each region, and (on the right-hand end) a set of function boxes. Before each of the four graphical regions is drawn, another menu asks the user which of the physical properties is desired to be graphed. From the previous queuing activity, TGAP has determined which of the properties are contained in each datafile. If a particular property is not present, such as particle surface temperatures in a *filename.tab*, it will not be an option in this menu. A list of possible properties for *.tab* and *.hst* files is in Table 1. Since bag boundary data is plotted as a single graph, there is no menu presented when a *filename.bag* has been chosen. As each data property is chosen to be graphed, the property name is written after the appropriate filename in the overhead window.

Table 1. Data Types Printed in TDNOVA, XKTC, and IBHVG2 Output Files

TDNOVA Tableau Data	Time History Data (TDNOVA and XKTC)	Time History Data (IBHVG2 default)
Axial Position	Time	Time
Radial Position	Breech Pressure	Projectile Travel
Pressure	Base Pressure	Projectile Velocity
Bed Stress	Mean Pressure	Projectile Acceleration
Axial Gas Velocity	Propellant Mass Fractions	Breech Pressure
Radial Gas Velocity	Projectile Travel	Mean Pressure
Axial Grain Velocity	Projectile Velocity	Base Pressure
Radial Grain Velocity	Projectile Acceleration	Mean Temperature
Porosity	Gauge Pressures	Propellant Mass Fractions
Gas Density		
Gas Temperature		
Particle Surface Temperature		
Pyrolysis Product Mass Fraction		

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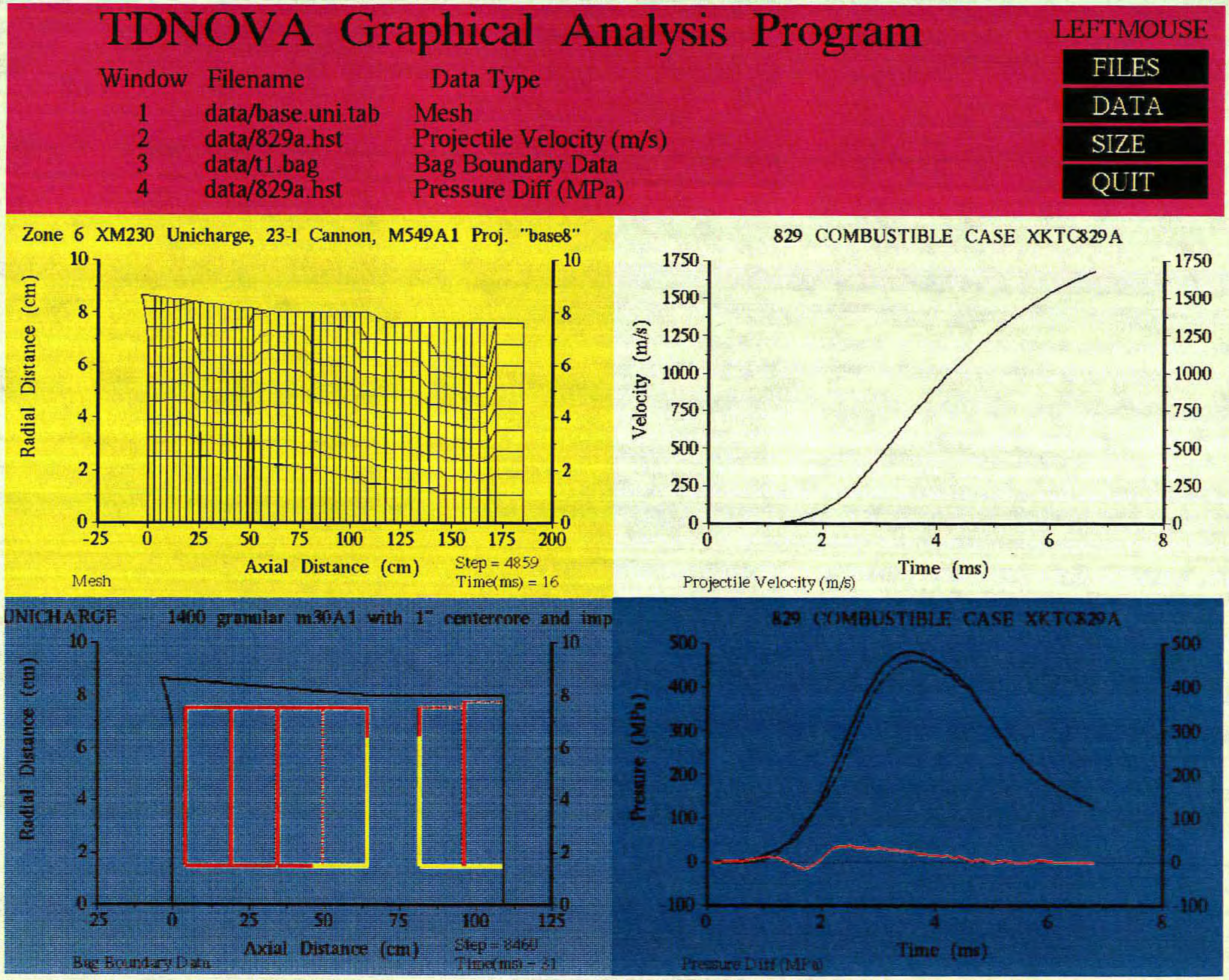

Figure 7. Multi-window display of interior ballistic data.

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5. GRAPHS

There are several distinct types of graphs drawn by TGAP, depending on which physical property is to be displayed. Mesh information, bag boundary data, and time history graphs all are drawn as 2-D figures where position and line attributes (style, color, and width) may convey additional information. Composite gas velocity plots are drawn inside a chamber-wall boundary, and contain vectors to represent gas direction and relative speed. For the remaining graphs, a third dimension is created by adding a third axis (the conventional 3-D plots) or by using color gradients. All drawings are labeled in the lower left-hand corner of the graphics window.

5.1 Mesh Graphs. A mesh plot is a graph showing the TDNOVA computational grid. Figure 1 and display region 1 of Figure 7 contain mesh plots. The former figure shows an initial time step (IB time of 0.0 ms). The horizontal graph axis corresponds to the gun centerline, and the vertical axis represents distance from the centerline in a radial direction (toward the chamber wall). Units of measurement are centimeters, but the axes are not proportionately drawn; as the projectile moves, the horizontal axis will rescale itself and always display the entire distance covered by the TDNOVA computational mesh, as shown in Figure 7 (same simulation, but later in IB time).

Initially, all interior nodes are defined as intersections of straight lines. Boundary (wall, breech face, and projectile base) points are individually defined. After the computation begins, the interior nodes are allowed to move when regions expand or when internal boundaries (such as propellant bags) are shifted due to the forces during the IB cycle. Then, the lines may no longer be straight or parallel, but each intersection remains a computational point.

At certain times within the TDNOVA computation, the mesh may be restructured. Some node points may be discarded when they no longer have reason for existence. For example, when a propellant has completely burned and the region contains only product gases, the computational method may change from two-phase to lumped-parameter equations. The many nodes which originally defined bag boundaries may then be restructured to form a lesser number of single-phase regions.

Mesh plots display the TDNOVA run title above the graph, the data-type description "Computational Mesh" below the figure on the left side, and the current IB time and computational step number below the graph.

5.2 Bag Boundary Graphs. A bag boundary plot shows the position and status of an interior propellant container; Figure 4 is an example of such a plot. A propellant bag can be defined in TDNOVA with a variety of attributes: strength, permeability, internal energy, etc. The bag may consist of silk cloth, cotton fabric, combustible case (nitrocellulose based), or one of many other materials. The bag structure may play an important role during the IB process, since these internal boundaries affect the placement, movement, and access to propellants. For these reasons, the TDNOVA code tracks bag boundaries as long as the bag plays a nontrivial role in the simulation.

The four variables shown in a bag boundary plot are: position, permeability, rupture, and burning status. In the graph, each datum corresponding to a bag boundary point is connected to its neighboring point by a line; the line represents the position of that bag boundary. Other line qualities are used to display the remaining bag information - color corresponds to burning status: yellow = inert, red = burning, black = all burnt; line style shows rupture status: solid = intact, dashed = rupturing, dotted = ruptured; line width conveys permeability information: thick = impermeable, medium = partially permeable, thin = fully permeable. An outline of the chamber is drawn as a thin black line to aid in viewing placement of the bags within the computational region.

Bag boundary plots also have an overhead title (from the TDNOVA run), the axes correspond to axial and radial distances as in the mesh graph, and IB time and computational step number are again printed below the graph. Region 3 in Figure 7 shows a bag boundary plot after the bags have been distorted.

5.3 Vector Plots. Relative velocities are shown by drawing vectors inside a boundary line. Gas (and solid particle) velocity vectors, available only when axial and radial velocities are present in the tableau datafile, are computed through vector addition of the two velocities (where negative axial and radial directions are toward the breech and centerline, respectively) into a single directed-vector form. The base of the vector is drawn as a black dot at the location of the computational node (always an intersection of grid lines when shown on a mesh plot), and the direction and relative size of the vector are represented as a red arrow emanating from the black dot. The largest arrow size (40 pixels long in a full-scale drawing) corresponds to the largest-valued vector for that particular drawing; a full-sized arrow and the value (in meters per second) are drawn in the lower right-hand corner of a vector plot when in full-screen mode. Figure 8 is an example of a full-screen vector plot displaying gas velocities.

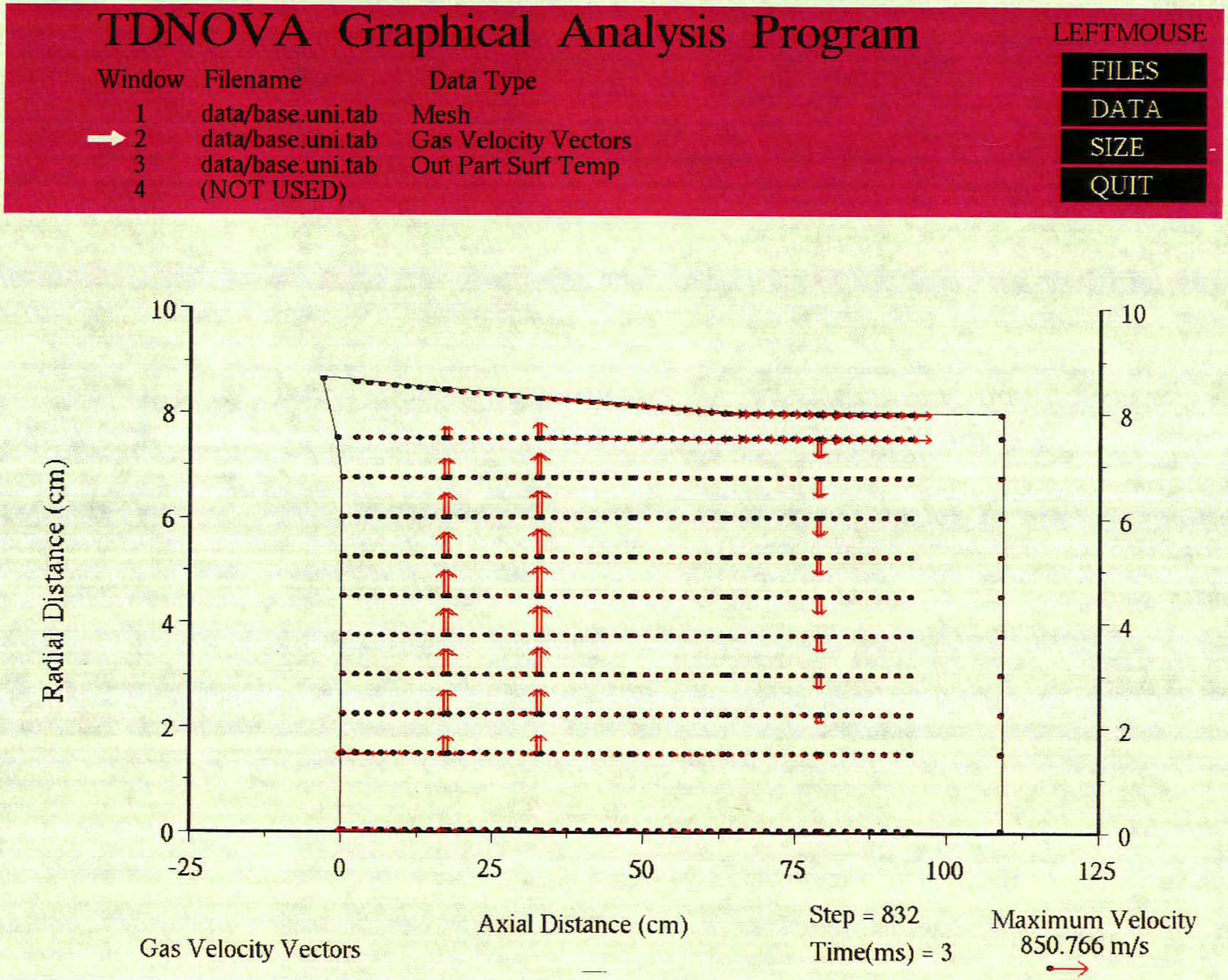

Figure 8. Vector representation of axial and radial gas velocities.

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5.4 Carpet Plots. The most common 3-D graph is one in which three mutually perpendicular axes are drawn, with datapoints located within the defined volume. A series of interconnected points creates a surface of information resembling a "flying carpet," hence the name "carpet plot."

TDNOVA computations are made for points which are defined in two axes. If the third axis is used for the values of pressure, density, or any of several other properties in the TDNOVA tableau logouts, then a carpet plot is a natural form of displaying the computed information. Figure 2 is an example of the TGAP carpet-type graphical displays. The TGAP default view of carpet plots is from inside the chamber, looking out toward the chamber wall. This view, where the breech face is on the left-hand end of the carpet, and the projectile base is on the right, is the most common representation of IB drawings. TGAP shows the projectile (base) moving from left to right as the simulation progresses. The axes are automatically scaled to fit whatever minimum and maximum data values need to be drawn within the defined volume.

The carpet plots do not have labeled axes, but the three major axes are colored differently. For best interpretation, the user should know that the "near lower" axis is the gun centerline (red); the "lower left" axis is radial distance from centerline toward chamber wall (violet); and the "near left vertical" axis (blue) corresponds to property value. Other axes are drawn in green, so that the graphical outline is shown as a rectangular volume. The TDNOVA computational grid intersections create three- or four-sided polygons which are colored red during the graphics process. In a primitive form of hidden-line algorithm, only the polygons whose upper side faces the viewer are colored; drawing the polygons sequentially from the "far" corner allows the foreground figures to overwrite the background. Also, the polygon edges are drawn with black lines so that the overall effect is one of texture and undulation rather than just a solid mass of color.

The TDNOVA run title is printed overhead as in previous graphs, and the graph type, IB time, and computational step are printed below the graph. Two additional values are printed below the graph—a minimum value and a maximum value for the current display. In Figure 2, for example, pressure minimum value is 0.1014 MPa and maximum value for the plotted carpet is 0.815035 MPa.

5.5 Color-Grid Plots. Color may be used instead of position in order to create a third dimension. Figure 3 shows a display of temperature values in a gun chamber during a TDNOVA computation of an ignition sequence. A color band chart is drawn along the right-hand edge of the display in single-window mode; the bottom color corresponds to the lowest temperature, and successive shading leads to the highest color representing the hottest temperature in the display. For the highest, lowest, and several steps in between, the corresponding temperature is printed alongside the color chart—yellow is the coldest temperature, and red is the hottest. Theoretically, any variation in color could be used for color-grid plots, but yellow-to-red was chosen for particle surface temperatures. A black-to-white scheme was defined for gas temperatures and for porosity, with shades of gray as intermediate steps. The title, graph type, IB time, and step values are also printed as in the mesh and bag boundary plots.

Currently, only gas temperatures, grain surface temperatures, and porosity graphs are drawn as color-grid figures. At time step 0, the computational mesh is drawn over the color values; this gives the viewer a better idea of where the internal components are located, rather than presenting merely a single-colored chamber cross section.

5.6 Time History Graphs. Time history plots are 2-D graphs of the values printed as "Summarized IB Data" and "Summarized Pressure Data" at the end of the TDNOVA or XKTC standard outputs. These plots always use IB time as the horizontal axis; each of the other variables may be graphed individually as shown by the projectile velocity curve in Region 2 of Figure 7. Summarized pressure gauge data, however, is plotted on one graph where each curve is defined by gauge position—a table of line styles and line colors differentiates each gauge's pressure values by printed reference point. (TDNOVA references a gauge by centerline or wall location; XKTC defines gauges by distance from the breech, or by distance from the projectile base when gauges are located on the tail boom.)

Pressure-difference graphs are available when two or more pressure gauge positions are contained in the history tables. A menu of gauge positions allows the user to choose the initial- and subtracted-gauge pressures before the graph is drawn. Both gauge pressures are drawn in black, while their difference is a red line (an example is in Region 4 of Figure 7).

IBHVG2 trajectory prints are also graphed as time histories. Units are not changed from the original outputs - IBHVG2 series "400" codes use English units, while versions "500" and above use metric units. If the user changes the trajectory variables from the default group, TGAP will still graph the resulting data, but the user will be responsible for putting computational time in the first column, and data titles and units will be graphed as provided through the IBHVG2 "TDIS" decks. For example, the user may define gauge positions along the tube, force IBHVG2 to print pressure values for each gauge (through the "TDIS" decks) during the IB cycle, and multiply the computed value by some factor in order to get nonstandard units (such as *kpsi* rather than the default units of *psi* in the earlier "400" code versions).

Since time history data spans the life of the computation, there is no need for IB time or step number to be printed. The run title, again, is printed above the graph, and the graph type is printed below the right-hand corner of the figure.

6. FUNCTIONS

Several functions are available to the TGAP user by means of keyboard buttons, input dials, and specialized screen areas which can be activated by the mouse buttons. TDNOVA tableau information can be cycled sequentially backward or forward in IB time; carpet plots may be moved, rotated, or expanded on the screen in order to gain a better perspective of the graphed values. Files, or the data within a file, may be exchanged within TGAP so that different graphs can be explored during a single graphics session.

6.1 Arrow Keys. The left- and right-arrow keys on the SGI keyboard control cycling of TDNOVA tableau information backward or forward in IB time. RIGHTARROW causes the current display (one window) to be replaced by a drawing of the same property in the next chronologically higher tableau. LEFTARROW makes a step backward in IB time to the previous tableau. If the display is in four-window mode (Figure 7), whichever display contains the mouse pointer (small red arrow) will be cycled. As tableau plots change, the IB time and step number are updated. The minimum and maximum data values printed with carpet plots also change to remain current with the displayed figures.

6.2 Dials. The SGI workstation includes a set of eight dials, named S0 through S7, as input devices to the software. Two columns of four dials are located on a small metal box; the bottom two dials are S0 and S1 (left and right, respectively), the next row contains S2 and S3, and so on.

When a program enables these dials, they send numerical values back to the program describing the amount of dial rotation from an initial position. The TGAP program uses this information for three types of functions—rotation, magnification, and translation. Only carpet plots are affected by the dials, and only when the carpet plot is designated by positioning the red pointer arrow within the display region.

Dials S0, S1, and S2 control rotation in the three planes of the display volume. The picture may be rotated so that any portion of the carpet is visible from above, below, or from any angle side-to-side.

Dial S3 controls magnification of the carpet by defining a viewpoint at a variable distance from the display volume origin. This effectively can put the "user's eye" very close to the carpet surface, and it is possible to "overrun" the carpet by putting the viewpoint between the carpet surface and the origin.

Dials S4 and S5 position the display volume horizontally and vertically on the screen. Dials S6 and S7 are not currently used by the TGAP program.

6.3 Function Boxes. On the right-hand side of the overhead (information) window are four special areas which are activated by the left mouse button. The word "LEFTMOUSE" is printed above the function area to remind the user to select with the leftmost mouse button. (There are three mouse buttons—the right button is used for all other mouse-pointing; the middle mouse button is currently unused in TGAP.) Each function area is designated by a black rectangle with a keyword printed inside; the keywords are "FILE," "DATA," "SIZE," and "QUIT." (Examples can be seen in Figures 1–5, 7, and 8.)

The FILE function allows the user to choose a new or different *filename* for any one of the four display regions. Note that Figure 7 contains information from three different files. After FILE is activated by the LEFTMOUSE (press the left mouse button while the pointer arrow is within the FILE black rectangle), a menu appears to enable the user to choose which window is to be changed. Display control then passes back to the initialization window, where the user may see which datafiles are available. After the *filename* choice is made, TGAP creates new data queues and readies internal pointers for displaying the new information. If the new file is tableau or time history data, another menu appears with choices for the physical property to be graphed. After a new file and data type are chosen, the list in the overhead window is updated to print current information.

The DATA function area should be chosen whenever the user wants to display information from the same datafile, but change the graph to be a different physical property. Within a *filename.tab*, for example, a switch could be made from displaying a pressure carpet plot to displaying a gas temperature color-grid figure. After DATA is chosen, the user must choose which window is to be changed. Then a menu of available properties appears; the user may select any one of these data types. The new picture will be drawn in the same region, and will be at the same level of IB time. Since *.bag* datafiles contain only bag boundary information, the DATA function is not valid for any region where *.bag* files are currently displayed.

The SIZE function allows the user to change from the four-region display mode to where one graph is shown at twice its scale and covering all four regions. Again, after the SIZE function is chosen, a menu appears for selecting which of the four regions to enlarge. If the display is already in large mode, no menu appears and the four-region display mode is enabled.

The QUIT function is just as the name implies—exit the TGAP program. All graphical displays created by the program are released to the operating system, and control is regained by the user in UNIX mode.

7. REVIEW

TGAP can create images from TDNOVA, XKTC, and IBHVG2 output files. These images are displayed in a multiwindow mode on a Silicon Graphics Workstation using 2- and 3-D techniques to enhance the visualization of the physical processes simulated by the IB computations.

The four-region display mode can present up to four different types of information; the data in each independent window may be retrieved from a separate input file. During the graphics session, data files and the types of data within each file may be exchanged with current displays. When choosing a new file, TGAP lists onscreen the available datafile names and whether the files contain tableau, bag, or history information.

Tableau information can be cycled backward and forward by the use of the keyboard, and 3-D volume images may be rotated, enlarged, or moved across the screen by using dial functions. Temperatures and porosity are displayed as color-scale plots, where the data values are indexed by color. At any time, one of the four windows may be regenerated to fit the entire four-region area, so that graph details are much easier to inspect.

8. PREVIEW

There are many possible features to be added to TGAP, including:

- Comment Strings - enter character strings to be used as overhead titles, axes titles, and one or two lines of comments below the graph area.

- Scaling Option - limit rescaling so that independent plots may be more easily compared.

- History Plot Animation - sequential plotting of history information, along with a tube/projectile drawing as a means of describing the current physical situation.

- Hardcopy - a menu option or button defining a printer interface for creating a hardcopy picture of current screen display.

- Animated Sequence - an option to automatically cycle through the entire IB time sequence of tableau, bag, or history information in one or more windows.

Other options and features may be added as TGAP matures. TGAP allows the researcher to quickly and thoroughly inspect a TDNOVA, XKTC, or IBHVG2 simulation. The future options will make this process easier and available to additional IB programs.

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