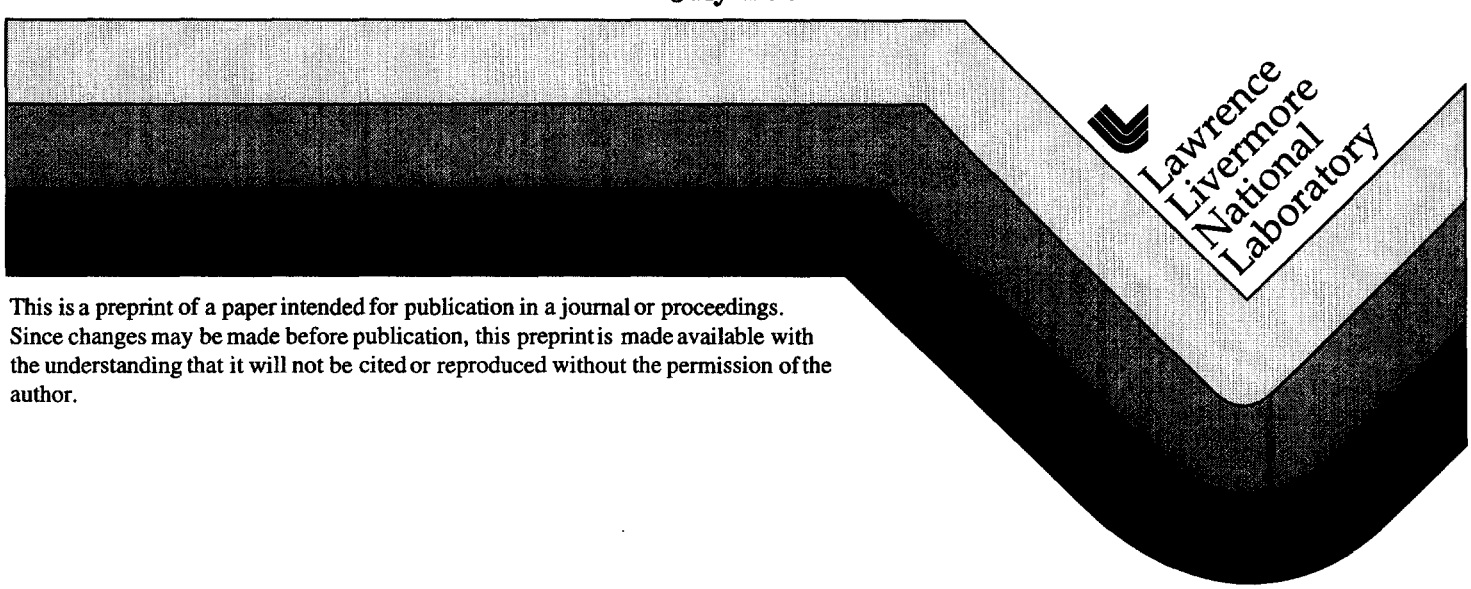
UCRL-JC-127894
PREPRINT

Recent Developments in SAC2000

P. Goldstein
D. Dodge
M. Firpo

This paper was prepared for submittal to the
19th Seismic Research Symposium on Monitoring a CTBT
Orlando, FL
September 23-25, 1997

July 1997



Recent Developments in SAC2000

Peter Goldstein, Doug Dodge, and Mike Firpo
Geophysics and Global Security Division, Lawrence Livermore National Laboratory

Sponsored by the U.S. Department of Energy, Contract number W-7405-ENG-48
Comprehensive Test Ban Treaty Research and Development Program ST482B.

Before discussing recent developments in SAC2000, I will summarize what SAC2000 is/does. SAC2000 is the rebirth and evolution of Lawrence Livermore National Laboratory's (LLNL's) Seismic Analysis Code (SAC) developed during the 1980's for a variety of geophysical applications. Primary funding for the development of SAC2000 has been through LLNL as part of the Department of Energy's (DOE's) CTBT R&D program. The primary development goals for SAC2000 have been to meet the seismic signal processing and analysis needs of the DOE CTB R&D teams and the rest of the CTBT R&D community. SAC2000's strengths include its ability to process a diverse range of data types, its extensive, well documented signal processing capabilities (both on-line and on the web at: http://www-ep.es.llnl.gov/tvp/sac.html), its macro language, and its ability to do both batch and interactive processing. Its extensive usage (> 300 institutions worldwide) has also made it much easier for researchers to develop collaborative research projects. SAC2000's extensive signal processing capabilities include: data inspection, signal correction, and quality control, unary and binary data operations, travel-time analysis, spectral analysis including high-resolution spectral estimation, spectrograms and binary sonograms, and array and three-component analysis.

Recent developments in SAC2000 include: enhanced compatibility with the CSS3.0 database schema, complete compatibility with the widely used SEED data format instrument responses, map making capabilities via an interface to GMT, a new three component polarization and phase identification tool, an external interface that allows users to define their own commands, and an interface to MATLAB that allows the user to use MATLAB commands and scripts on SAC data from within SAC2000. We have also implemented a number of commands to enhance user efficiency and numerous improvements and enhancements to many individual sac commands.

Current developments in SAC2000 are motivated by the need for easy and efficient access to, and processing and interpretation of large amounts data. We are also driven by the need to communicate results from SAC2000 to our database and other programs. Based on these needs, we have begun developing a new data structure for SAC2000. This new structure will be completely compatible with the standard SAC format but will also allow us to access, modify, and output all the information in CSS3.0 based oracle databases or CSS3.0 flat files. Given the variety of data types that are currently possible in SAC2000 and other programs, and the likelihood that additional data types or parameters will be needed in the future, we are designing SAC2000's new format to be easily extendable and anticipate incorporation of significant extensions to the CSS3.0 schema.

Key Words: Seismic, Data, Signal Processing, Software

Objectives

We are continuing the development of SAC2000 to provide the signal processing and analysis capabilities needed for comprehensive test ban treaty research and development. These efforts are utilized by a broad community of researchers and institutions including the federal government, academia, and companies (Figure 1). Our current efforts include the development of a new data structure that will allow us to access, modify, and output all the information in CSS3.0 based oracle databases or CSS3.0 flat files. These new capabilities are essential for effecient processing and analysis of the large amounts of data that are being collected as part of DOE's seismic regionalization and identification R&D efforts. We have also focussed part of our effort on implementing state-of-the-art signal processing capabilities that allow researchers to process and interpret data more accurately and efficiently. We describe a few selected developments in the next section and provide a more extensive summary in an appendix.

Research Accomplished

Three Component data analysis tool

We have developed a new tool for interactive and batch mode analysis of 3 component seismic data. This tool will improve a users ability to detect and identify seismic phases, especially secondary phases. It has also helped us process data and identify problems with data such as incorrect sensor orientation information.

This tool has a number of capabilities including: graphical data selection and filter design, automatic backazimuth and incidence angle estimation, interactive, graphical, three-component particle motion analysis, and maximum-likelihood probability estimates of selected wavetypes.

Figure 2 displays a selected example of the interactive version of this three-component data analysis tool. Interactive data/window selection, phase picking, and signal rotation are done in the main window. Popup windows are used to: filter the data (no windows shown), interactively analyse particle motions (Particle motion module), and compute maximum-likelihood probabilities for selected wavetypes (ML-polarization analysis module).

Easy to use MATLAB interface

We have developed an easy to use interface to MATLAB from SAC2000. This interface automatically loads all the data in SAC2000's internal memory into a set of well organized, easy to use MATLAB data structures. This interface allows the user to apply both MATLAB and SAC2000 commands to data from within SAC2000. Users now have the opportunity to use both SAC Macros and MATLAB scripts for both interactive and batch processing. As an example use of this capability we developed a data inspection tool (Figure 3) that plots the SAC data and documents the MATLAB data structures using pull-down menus.

Access to Oracle and Flat File CSS3.0 Databases

We are developing a new data management module in SAC2000 that will provide convenient and intuitive access to both Oracle databases and flat files. This module includes a new data format that is completely compatible with the standard SAC and CSS3.0 formats but more flexible and easily extensible. The development of this new module is essential for efficient access and processing and updating of data. A schematic illustration of the new SAC data management module and its relation to the rest of SAC2000 is indicated in Figure 4.

Efficiency enhancements

We have implemented a number of enhancements that will improve user efficiency. These include the ability to use unix commands from within SAC2000 and a HISTORY command, similar to the unix history command, that allows the user to inspect and repeat previously entered SAC2000 commands. DELETECHANNEL is a recently implemented data selection capability that can be used with the FILENUMBER commands to identify and remove unwanted data from SAC2000's internal memory. A more extensive list of enhancements is given in the appendix to this paper.

Conclusions

We have implemented a number of new processing capabilities and enhancements in SAC2000 that will improve users efficiency and their ability to acurately interpret data. We are also developing a new, flexible data structure for SAC2000 that will allow us to access, modify, and output all the information in CSS3.0 based oracle databases or CSS3.0 flat files. These new capabilities are essential for effecient processing and analysis of the large amounts of data that are being collected as part of DOE's seismic regionalization and identification R&D efforts.

Appendix: Summary of New Comands and Capabilities in SAC2000

The following is a very brief summary of some of the recent enhancements to SAC2000. SAC2000 commands are indicated by by words with all capital letters. More extensive documentation of these features can be found on-line by typing:

help "command name".

One of our newer features the MAT command is an interface to matlab that will allow you to run matlab scripts from within SAC2000 on data in SAC2000 memory. This interface is still undergoing development but a preliminary version is available in the latest version of SAC2000. Type, "help mat" for more information.

Processing enhancements:
MAP or GMAP: High Quality Maps using a command line interface to GMT.
Arraymap can be used to plot array configurations.

external_interface: Make your own sac commands using fortran or c subroutines.
LOAD: Loads your external commands.

MAT: Allows users to run their matlab scripts from within sac.

evalresp option in TRANSFER: Transfer has been modified to incorporate/utilize SEED style responses.

TRAVELTIME: Calculates travetimes based on the iasp91 model.
PLOTRECORDSECTION: new version with a default portrait mode that can also
plot iasp91 travel times on record sections and automatically
displays travel time picks.
It is also possible to zoom in and out and it is no longer
necessary to specify a timewindow with this command.
ADDSTACK, CHANGESTACK, LISTSTACK: begin and end time can now be specified.
DELETESTACK now works properly

SPECTROGRAM: High resolution spectrograms with properly registered seismogram.
SONOGRAM: High resolution sonograms and binary sonograms.
IMAGE: image plots of 3-D data
LOADCTABLE (lct): a selection of 17 colortables to use with 3-D images
(e.g., spectrograms, fk, etc...)

BBFK and BEAM: Use lat and lon in headers or user7, user8, user9, to
compute relative station locations.
BBFK: Wavenumber and azimuth at maximum power are writen to blackboard variables
CORRELATE: output timing made consistent with conventional applications.
CONVOLVE: convolves a master signal into itself and a number of traces.
Timing is now consistent with conventional applications.
FUNCGEN: Generates a new function consisting of a string of impulses.
LINEFIT: Fit a straight line to data
WIENER: filters data using filter design based on a window of noise.
This routine has significantly improved stability and error
checking is done to make sure the noise window is within the data.

Input and Output
READCSS: read CSS2.8 and CSS3.0 data into sac.
Recent enhancements include a station selection option,
(e.g., readcss my.wfdisc station AAA).
Shift on or off to set the origin time to reference time (default is on)
Scale on or off to scale the data by the calib constant (default is off)
Added GSE3.0 format.
WRITECSS: write CSS3.0 data from sac (Minimal functionality, still under development)
WRITE: Write to xdr format for tranformation to linux version.
kstcmp option uses to kstnm and kcmpnm to define file name.
The kstcmp option is most useful with css data that has multiple
waveforms in a single wfdisc.
READ: Read from xdr format. (see write).

Documentation
HELP: on-line help contains all the sac documentation. Type help for instructions.
Web page: http://www-ep.es.llnl.gov/tvp/sac.html

Ease of use and efficiency related enhancements:
UNIX: Any unix command except rm can be specified at the command line.
HISTORY: view commands or reissue with unix style !"command number"
(e.g., !2 to rerun the second command issued in the current sac session).

sacnfiles (an automatically generated blackboard variable):
The number of files in memory is now listed as a blackboard variable.
CHNHDR: selectively change individual file headers.
READ: can now handle path names with wildcards and very large directories
SETMACRO: Added a new option to add more macro directories and increase maximum number of macro directories to 100.
LISTHEADER: You can now see all the header variables with the inclusive option. Even ones that aren't defined.
FILENUMBER ON|OFF: When this command is on the filenumbers are displayed next to the traces.
DELETECHANNEL (dc): combined with filenumber, it allows the user to remove unwanted channels from memory.
PLOTPK: a new option to turn the bell on or off: e.g., ppk bell off. (default is on).

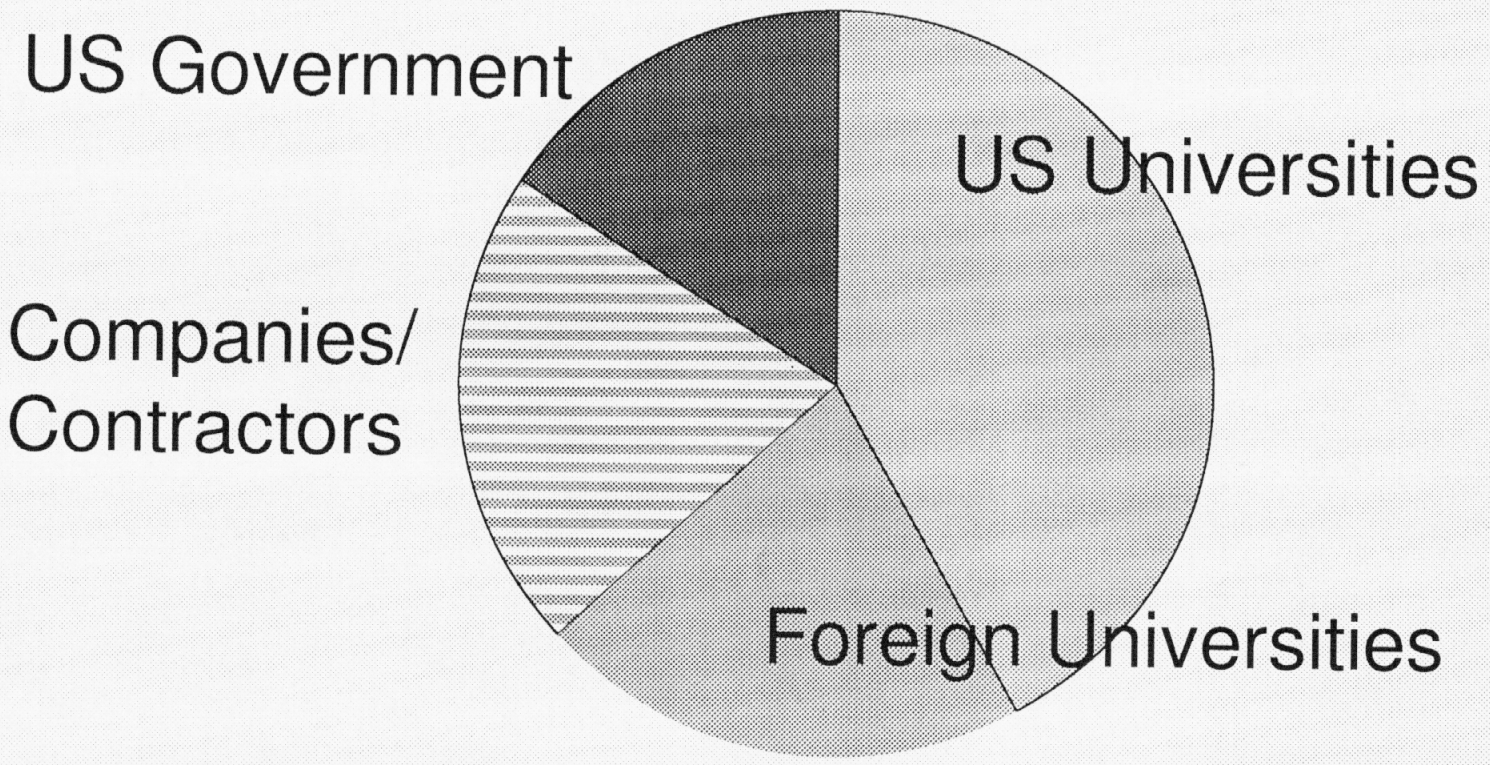


Figure 1. Pie chart indicating the types of institutions that use SAC2000. SAC2000 is Used Extensively by the Seismological R&D Community. It is used at more than 300 institutions by thousands of researchers. We have provided copies of SAC2000 to more tha 200 institutions in the last year and the number of requests has continued to grow.

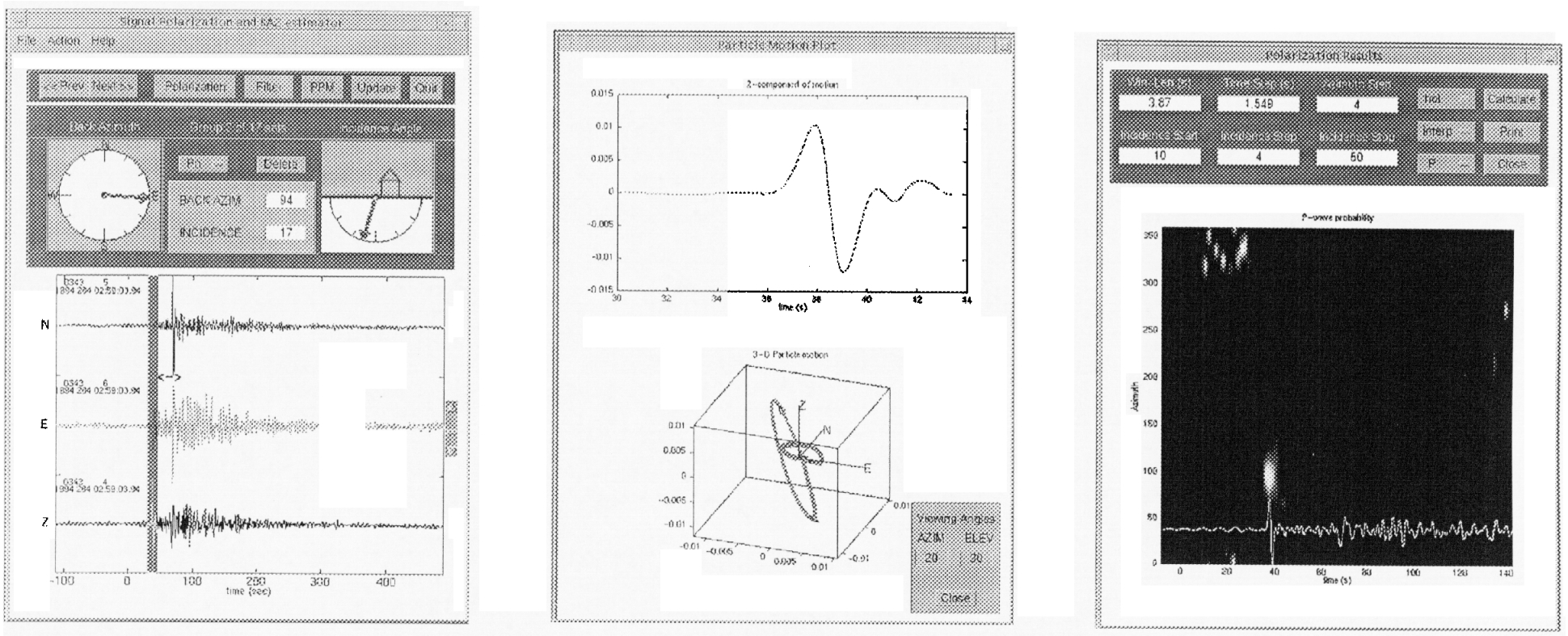


Figure 2 Interactive version of SAC2000's three component data inspection and analysis tool. The leftmost panel illustrates the main winodw where window, picking, and processing selections are made. The center panel indicates the vertical component window of the data and the corresponding three-dimensional particle motion. The particle motion perspective can be changed interatively by dragging on the axes of the particle motion plot or by changing the values in the text box at the lower right. The panel at the right indicates the ML probability estimate of the polarization for this window.

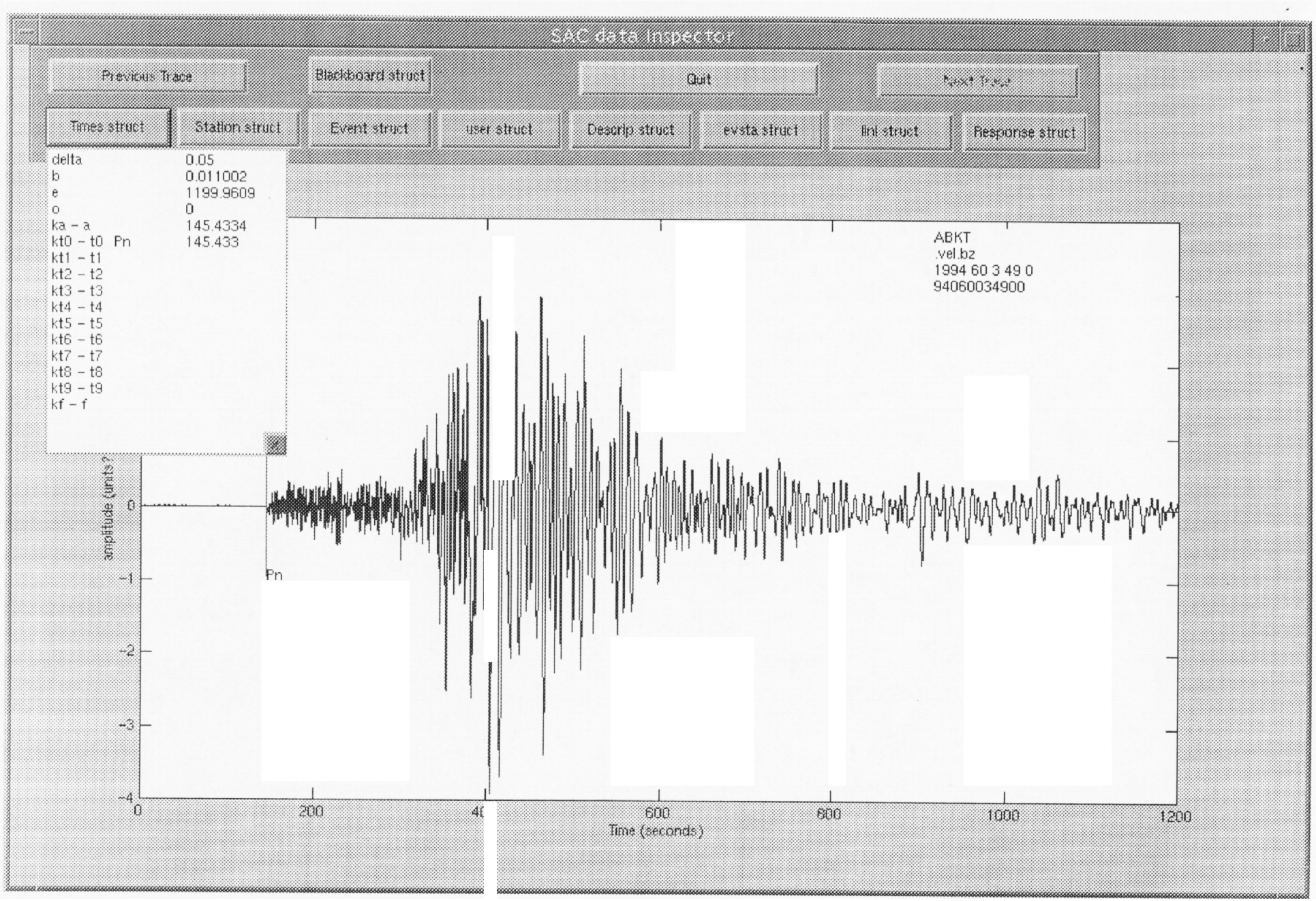


Figure 3. MATLAB based graphical user interface to data in SAC2000. Pulldown menus indicate the available data structures and data values currently in memory.

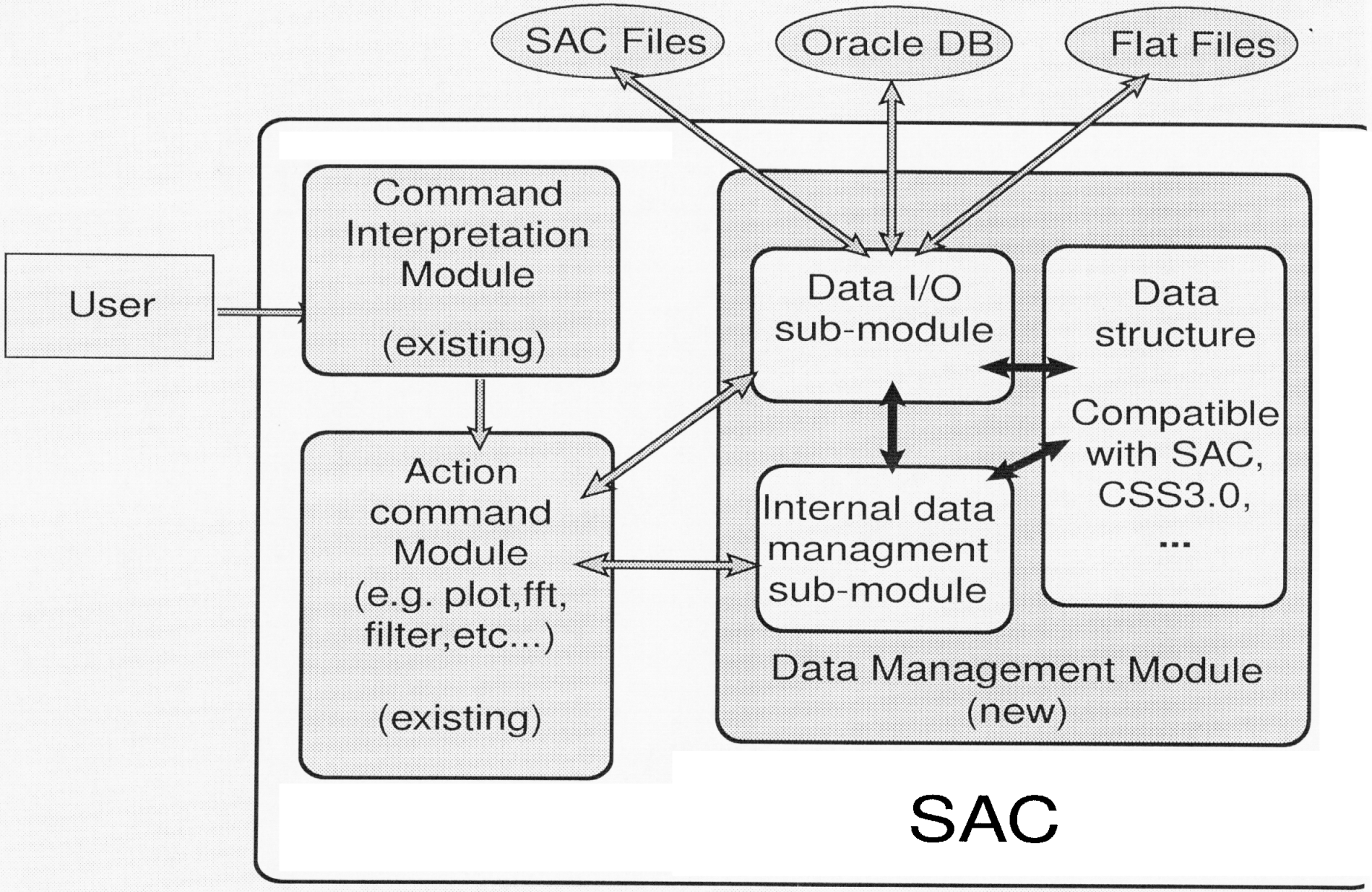


Figure 4. Flow chart illustrating the new SAC data management module and its relation to the command interpreter and processing commands.

Technical Information Department • **Lawrence Livermore National Laboratory**
University of California • Livermore, California 94551