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ABSTRACT

Laboratory instruction in engineering disciplines in recent years has been adversely affected by a variety of structural problems making it increasingly difficult to provide students with adequate hands-on lab experience on par with the ever expanding requirements of the technical job market. As a possible approach to deal with some of the underlying issues, this project was concerned with the development of computer integrated laboratory facilities or "laboratory workstations" with capabilities for conducting experiments directly from computer terminals. The objective was to streamline the laboratory delivery process, in addition to improving the effectiveness of hardware utilization and enhancing the overall laboratory experience of the students. The computerized system incorporates data, control signal, and video links with the laboratory facilities, and permits operational control over the hardware functions along with data acquisition and analysis, allowing students to carry out the experimental steps as well as analyze and produce hard copies of their results in different formats from the terminal. Further, through interlinkage with a distributed system of computers via local area networking, it is possible for a single lab facility to serve the experimental needs of multiple users on a quasi-time sharing basis. Includes 27-page "Report of Learner Tryout and Pilot Test Results" (John A. Gretes) summarizing student feedback from the pilot try-outs in the junior lab courses. (SWC)

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ED 461 360

DEVELOPMENT OF COMPUTER-BASED WORKSTATIONS FOR THE OPERATION OF ENGINEERING LABORATORIES

Final Report

Submitted to

The US Department of Education
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July 29, 1994

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FINAL REPORT - SUMMARY

Laboratory instruction in engineering disciplines in recent years has been adversely affected by a variety of structural problems making it increasingly difficult to provide students with adequate hands-on lab experience on par with the ever expanding requirements of the technical job market. As a possible approach to deal with some of the underlying issues this project has been concerned with the development of computer integrated laboratory facilities or 'laboratory workstations' with capabilities for conducting experiments directly from computer terminals. The objective is to streamline the laboratory delivery process by this means, in addition to improving the effectiveness of hardware utilization and enhancing the overall laboratory experience of the students. The computerized systems incorporating data, control signal and video links with the laboratory facilities, permit operational control over the hardware functions along with data acquisition and analysis, allowing students to carry out the experimental steps as well as analyze and produce hard copies of their results in different formats from the terminal. Further, through inter-linkage with a distributed system of computers via local area networking, it is possible for a single lab facility to serve the experimental needs of multiple-users on a quasi-time sharing basis. The design and implementation of the required hardware and software tools to realize the basic project objectives covering three test laboratories have been completed and the computer integrated facilities have been used in the junior laboratory courses on a trial basis. Technical and educational merits of the prototype systems are being evaluated as an integral part of the project activities. A report by the evaluation consultant summarizing the student feedbacks from the pilot try-outs in the junior lab courses is included as part of this report.

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1. Introduction

This project was concerned with the development of tools, techniques and procedures to permit generalized introduction of computers into engineering laboratory courses. Laboratory instruction in engineering disciplines in recent years has been beset by a variety of problems including out-of-date or inadequate lab facilities, lack of trained technical support staff, limited space and insufficient number of equipment set-ups to serve multi-section high enrollment lab classes. Our work generally has focussed on establishing the feasibility of computer based laboratory instruction with provisions for performing the experimental tasks directly from networked computer terminals in a time sharing mode as a way of relieving some of the existing problems, improving the effectiveness of laboratory hardware utilization and generally enhancing the laboratory experience of the students.

Three separate laboratory facilities serving different components of the engineering curriculum and involving instrumentations with fairly distinct characteristics were chosen to demonstrate the feasibility of this approach. These include: 1. Dynamometer/IC Engine Laboratory; 2. Materials Structures Laboratory; and 3. Vibration Laboratory. The project activities were conducted in several overlapping phases as follows:

- Single terminal computer integration of laboratory hardware
- Multi-terminal networking of lab facilities
- Project evaluation and feedback
- Dissemination of results

In the following we provide a summary of the project results covering each of these component activities.

2. Single Terminal Computer Integration

The initial phase of the project focussed on making the single terminal lab stations fully operational so that they may be routinely employed in the laboratory courses. This necessitated the procurement of certain hardware components (which were acquired with local funds provided as part of the institutional contributions to the project) and resolution of specific hardware and software issues for each of the lab facilities. The goal was to computer integrate key hardware components such that equipment control, data acquisition and analysis may be performed from a locally resident dedicated computer terminal. For each of the three laboratory facilities selected for this project the necessary computer interfacing tasks have been completed. The intention is for these facilities to serve as prototypes before more extensive

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hardware integration and software development tasks are undertaken in order to realize a broader computer-based system suitable for delivering complete lab courses. Some specifics of this phase of the work covering each of the labs are provided below.

2.1 Dynamometer/IC Engine Laboratory

This facility, consisting of a 350 HP GM internal combustion engine coupled to a Superflo dynamometer, is intended to provide students laboratory experience on various aspects of the performance of the IC engine conducted under simulated road conditions. Computer based operation of such a system offers considerable advantage over the conventional manual mode of operation by simplifying the labor intensive experimental steps and removing the need for a number of intermediate manual calculations required at different stages of data acquisition and analysis. The computer integration tasks were accomplished by interfacing a dedicated PC using an RS232 bus linking the computer and the dynamometer via a microprocessor controlled I/O port. Provision for simultaneously receiving pressure and piston position data signals from the IC-engine has been made by placing appropriate transducers in the cylinder head of the engine. In addition, it was necessary to develop special hardware boards in order to permit on-line control of the engine throttle and load settings and to synchronize pressure and RPM data. As an additional measure, synchronization of the crankshaft and piston motions will be achieved by having the piston signals converted to a time-marked angular position output using a hybrid hardware/software based approach. With the exception of this last step, the prototype system is now operational and has been successfully tested for instructional use.

2.2. Material Structures Laboratory

This lab, serving the material science component of the engineering program, houses a complement of x-ray diffraction equipment suitable for conducting experiments on various aspects the atomic structures of materials. The specific goals for this phase of the project were to computer interface the x-ray diffractometers, which are the basic tools of the diffraction measurement system, such that the necessary hardware operations and control may be carried out interactively from the terminal. Since two separate diffractometers with different characteristics and capabilitie were available it was possible to test the feasibility of compute linkage using two different approaches. One of the diffractometer was interfaced with a remote main frame computer using a loca server and Ethernet based LAN facility, while in the second cas a dedicated local PC was linked to the diffractometer. In bo instances the existing diffractometer drive motors were replaced stepping motors and the x-ray intensity measuring instrumentati including radiation detectors. and the signal condition

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components were upgraded or modified to allow serial connections with the computers and plotting devices. The computer based systems have the capabilities for full control of the goniometer scanning functions, selection of the experimental variables from the terminal and sampling of the intensity data as a function of the scattering angle on an interactive basis. Further the systems have provisions for conducting experiments on one or more samples either individually or in a batch mode. Both systems permit data collection at a rate much faster than was possible in the earlier manual mode of operation (typically 1 min or under per sample for routine analysis compared to 15 to 20 min previously) so that it is now possible for students to investigate phase identity and structural parameters of a broader range of material samples in the allotted lab period than was previously possible. Along with the collection of data, analysis of the results is now feasible concurrently on the screen allowing students to rerun an experiment or repeat any measurements as needed (to check an unacceptable result, for example). Furthermore, the system, because of its speed, provides much greater flexibility in studying the effects of various experimental variable on the diffraction patterns which may be set manually or from the terminal. Finally hard copies of the experimental results, including the raw intensity data, diffraction patterns and analytical results may be obtained in graphical or tabular form through dedicated or shared plotters and printers.

2.3 Vibration Laboratory

The purpose of this laboratory is to provide students instruction on the experimental tools and techniques for analyzing the dynamic responses of simple mechanical structures subjected to various modes of forced vibrations. The facility consists of an array of electro-mechanical and signal capturing and processing instrumentations which must be interconnected and manipulated in a prescribed manner in order to run the experiments successfully, making the lab exercises somewhat cumbersome and time consuming in the conventional mode of operation. By utilizing a locally resident dedicated PC and a Heath/Zenith Integrated Workstation a computer integrated facility has been developed which consolidates the various operational steps for running the experiments by allowing computer control of the various hardware functions as well as data collection and analysis from the terminal, thus simplifying the experimental steps considerably. The computerized system permits continuous control of the amplitude and the driving frequency of the excitation platform for the test structures and collection of the strain data simultaneously from multiple strain gages mounted on selected sites on the structures.

Initially, simple 2-dimensional frame structures have been utilized in laboratory exercises. These rectangular frames are multi-level and are constructed with either "fixed" or "pinned" joints. This

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serves to demonstrate the effect of stiffness variation on resulting natural frequencies. Masses can be added to different levels to demonstrate effects of varying mass distribution. In addition, viscous damping can be introduced by means of multiple air jets which can be positioned to oppose vibratory motion. Effects of the positioning of the damping jets at vibratory node or antinode sites can also be observed.

As records of the experimental results, the system provides graphical displays of the strain amplitude vs frequency data both on the screen and in the hard copy format. Resonant frequencies are determined to the nearest 1/10 Hz and relative amplitudes recorded based on the frequency response charts. Students can output tables of raw data or frequency vs. amplitude plots. They can also drive the structures at the various damped or undamped resonant frequencies under amplitude control in order to view the pertinent mode shapes with a strobe light. Because of the modular and open nature of the components and interconnections employed, this facility, more than the others, demonstrates the basic principles of computerized data acquisition, feedback and control in a simple manner in addition to allowing the students to perform the required experimental tasks directly from the terminal.

3. Multi-terminal Implementation

The objective of this phase of the project was to develop a computerized system to allow multiple users to perform experiments by accessing laboratory hardware via computer terminals on a quasi-time sharing basis. For this purpose, it was necessary to develop hardware and software tools for establishing communication between the locally resident lab computers (connected to the lab hardware) and a system of distributed remote computer terminals. Some details of the project activities covering this phase of the work including certain modifications in our original strategy brought about by the installation of new computing facilities in the engineering college consisting of an array of SUN SPARC workstations after this project was initiated are provided below.

Our initial plan for multiterminal implementation relied on a hybrid hardware/software based approach. Very early in the project, from a reconsideration of the networking strategy, this evolved into a largely software based approach relying on the university's VAX 8530-VMS system (which was to serve as the Supervisor/ Scheduler of the system) and the Ethernet based LAN facilities for communication between the laboratory facility (via the dedicated local PC controlling the lab equipment) and a distributed system of PC's serving as remote terminals. The availability of SUN Sparc stations, however, effectively eliminated the need for using the VAX 8530 as the Supervisor/Scheduler for the multi-terminal network requiring a further revision in the plan. Under the new approach, the Supervisor/Scheduler program resides

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in the file server for the workstations. The communication between the workstations and the computer at the experiment site is still done through the Ethernet based LAN facilities as before. The new strategy effectively removes an extra level of hardware (VAX 8530) that could have become a bottleneck in the system. In addition, the SUN workstations also provide the needed graphics capabilities for plotting the experimental results in different formats and also for visual monitoring of the hardware to permit experimentation from remote sites.

The software development work for implementing the basic multi-terminal operation has been completed. The software consists of three modules, a LAN server, a PC server and a User Interface. The LAN server and the User Interface reside on the workstations and the PC server resides on the local PC that controls the lab hardware. User requests are directed to the LAN server which performs the necessary operations based on the user requests and forwards the results. The PC server executes requests from the LAN server for carrying out the experimental steps and sends back the appropriate responses. The LAN server can handle many user requests. However, the PC server responds to the first request from the LAN server and only when the current experiment is finished the next request is considered. The LAN server takes care of supervising and scheduling the requests for experiments and dissemination of the gathered data.

Concurrent with the multi-terminal work, tools and procedures for video monitoring of the lab facilities from remote terminals have also been under development. A video camera installed at a suitable location in the laboratory will capture the image of the active hardware which will then be transmitted digitally via the local PC to the remote site. In the SUN workstation the user can open a window for receiving these images which may be updated periodically to reflect the current status of the equipment. Using a preliminary version of the required software tool completed under this project the feasibility of image capture and transmission has been demonstrated. A second version of this tool, incorporating certain modifications is now under development as part of an extension of this work and is expected to be completed during the current year.

4. Project Evaluation

Field evaluation of the computer integrated systems has been initiated in accordance with our original plan involving learner tryouts and pilot testing conducted as part of the undergraduate engineering lab courses. A curriculum and instruction specialist from the College of Education serving as the evaluation consultant on this project has been responsible for developing the necessary evaluation tools and in analyzing the student feedback results. Consultant's report summarizing the student responses for one of

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the prototype facilities which has been operational in the lab courses the longest is appended. Both formal and informal feedbacks from the users and observers of the lab facilities have been of help in providing insights into some of the technical and educational issues involved which otherwise may not have been apparent and it is our intention to continue to solicit them as the computerized systems are tested further and become routine tools in the lab courses.

5. Dissemination of the Results

Dissemination of the project activities and results has been achieved through presentations at various professional meetings at the local, national and international levels and the results published in conference proceedings. In addition, the technical aspects of the work have served as the basis for two MS thesis and two senior project reports (one MS and one senior project completed and the remaining two expected to be completed by the end of this year) and has resulted in the award of student prizes. The results of the work were also presented via poster sessions at the (1991 & 1992) FIPSE PD meetings. A summary of the presentations/publications is provided below.

Presentations & Publications

pub.

"Development of Computer Based Workstations for the Operation of Engineering Laboratories", G.P. Mohanty, R.H. Kim, R.D. Peindl, H.M. Razavi and J.A. Gretes, Proc. 9th Intl. Conf. on Technology and Educ., Paris, France, P.378 (1992)

"Remote Multiple-User Access to Laboratory Equipment", H.M. Razavi, V. Varadrajan, G.P. Mohanty, R.H. Kim, R.D. Peindl and J.A. Gretes, Proc. 10th Intl. Conf. on Technology and Educ., Mass. Inst. of Technology, Cambridge, Mass. (1993)

"Managing Multiple-User Remote Access to Laboratory Equipment", H.M. Razavi, V. Varadrajan, G.P. Mohanty, R.H. Kim, R.D. Peindl and J.A. Gretes, Proc. of IEEE Southeastcon, Charlotte, NC (1993)

conf.

"Dynamometer CPU Interface", D. Whisnant, Presented at the Ntl. Conf. on Undergraduate Research, April 14-16, 1994, Western Michigan University, Kalamazoo, Mich. and to appear in the conference proceedings; Also presented at the 91st Annual meeting of the NC Academy of Sciences, Davidson College, Davidson, NC, March 15, 1994. (This paper won second place in the physical science division and has been invited for publication in the NC

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Academic of Sciences journal. D.Whisnant also received 1994 Sigma-Xi undergraduate research award for this work at a presentation ceremony conducted at UNC-Charlotte.)

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REPORT
OF
LEARNER TRYOUT and PILOT TEST
RESULTS

Department of Mechanical Engineering
FIPSE GRANT

July, 1994

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INTRODUCTION

The following report provides an overview of the learner try-out (LTO) and pilot testing (PT) of the workstation access to engineering lab test equipment. The learner try-outs were conducted in December 1991 and January 1992. Analysis of the LTO data was used to make modifications in the software and hardware interface. With the modifications completed, the revised software was pilot tested in February of 1993. The pilot testing was conducted in one of the MEGR 3154 classes with all 19 students in that section of the course. The findinings from this pilot test are also included in this report. Plans call for field testing of the software and hardware with several classes at the end of the summer of 1994.

OVERVIEW AND ANALYSIS OF LEARNER TRY-OUT FINDINGS

During the months of September through December of 1991, three mechanical engineering undergraduate majors were asked to serve a learner tryout subjects using a computer workstation and prototype software to analyze samples on the x-ray diffraction test equipment in the lab. The three students were selected as a representative sample of engineering students in the undergraduate program at the third year level. They had all completed the lab using the conventional process on manual sample identification and thus were in a good position to compare the use of the workstations to the traditional lab method.

The purpose of the Learner Tryout process was to gain information from the target audience about utility of the lab process, workstation performance, and software functions and operation. This information was seen as important to the project so that modifications to the process and software could be made before the pilot testing continued in the next phase with several classes of students. Anticipation of process and software problems might increase efficiency and effectiveness of the pilot testing phase.

Each student was asked to complete the Learner Tryout Feedback Form found in Appendix A of this report. The following findings are based on an analysis of the student comments and responses.

1. The software should calculate relative intensity.
2. The software should proved a hard copy of the values.
3. An example simulation before the student starts the actual analysis of the material was seen by all three students as important to make students feel more confident about the process of analyzing the sample an making more efficient use of the time on the workstation.
4. All three students agreed that the graphing functions of the software were easy to use. One suggested that a grid be provided on the screen to ease reading the graphs.
5. The students saw no advantage to the software in teaching graphing functions over the manual method used in the conventional lab.
6. Pull down menus or clear listings of software functions were suggested by the students as functions that would add to make the software easier to use.
7. All students agreed that the background information provided in the lab guide was helpful.

8. The "computer use" section of the lab guide, students agreed needed clarification, simplification and explanation.

9. The "procedure section" of the lab guide was easy to follow overall. One student suggested that instruction to the user to calculate Irel and dspacing values should be added to the procedure.

10. All three students suggested the addition of an On-Line Help function to the software package.

11. Suggestions were made to mask non specific functions from the user. There were too many functions available, many were not needed to complete the lab analysis and only distracted the user.

12. The workstations allowed more rapid completion of the lab task.

13. The students saw no need for a video image of the test equipment to be provided. In fact they said that they could see the test equipment because it was next to the workstation. When pilot testing begins, students may use the test equipment from a remote site and this issue should be addressed again. Not being next to the test equipment may cause problems with larger groups.

14. More information needs to be provided to the user in the form of task cards for using the workstation and the software.

15. User friendliness of the software needs to be increased.

16. A Mouse or arrow key interface would increase the effectiveness of the software.

As a part of the learner tryout process, these findings have been provided to the engineering faculty involved in the project and to the computer science graduate assistant who is programming the software interface for the test equipment. Specific revisions and additions will be made to the software before the pilot study begins with full classes of students.

INDIVIDUAL STUDENT RESPONSES TO THE Learner Tryout Feedback Form

1. Did the workstation and software help you better understand the lab concepts?

YES? NO?

STUDENT RESPONSES:

YES - By allowing the computer to do all the work so the user can concentrate more on the lab fundamentals.

NO - NO COMMENT

NO - The software does not make the comparisons of the I and 2D values apparent. Using the published data it is easier to see how these values are used to determine material identity. A hard copy of the pattern would make it easier to see where 2D and I values come from.

2. **Do you see the need for additional calculation functions in the software?**
YES? NO?
Please provide examples in the comments section.

STUDENT RESPONSES:
NO - Too many calculation options could make the program difficult for the inexperienced user.
YES - It would be nice if the software calculated the relative intensity
YES - The I values are difficult to determine from the screen a hard copy of the pattern would facilitate more accurate readings and subservient Irel values, if these values are not given by the computer.

3. **Did you feel rushed when using the workstation?**
YES? NO?
Why?

STUDENT RESPONSES:
NO - I was given no time limit. The computer program makes the lab move quicker, so I don't think students will feel rushed.
NO - NO COMMENT
NO - The procedure in the lab is straight forward and easy to follow and therefore it does not take long.

4. **When using the workstation, did you interact more or less with the lab assistant? That is did the workstation help reduce reliance on the lab assistant?**

STUDENT RESPONSES:
Initially, I required the assistance of the lab assistant, but after I became familiar with the program I could more or less operate on my own.
We had to interact more with the lab assistant do to the program halting or "freezing up".
No, I had some questions about what needed to be put into the computer at some places.

5. **Would an example simulation or two before you use the workstation to conduct the experiment with the test equipment have helped you better use the test equipment software?**
YES? NO?

STUDENT RESPONSES:
YES - This is a good idea. It would reduce reliance on the lab assistant
YES - Previous exposure is always helpful.
YES - It would help if the lab assistant first obtained a hard copy using the original set up and explained how to obtain Irel and 2D values and for what peaks and explained about how some peaks are caused by -----?

6. **Would an example simulation or two before you use the workstation to conduct the experiment with the test equipment have helped you feel more confident about using the workstation to run the test equipment?**
YES? NO?

STUDENT RESPONSES:
YES - It would reduce the reliance on the lab assistant.
YES - NO COMMENT
YES - It would make the procedure that is written in the lab manual more clear.

7. **Were the Graphing Functions of the software easy to use?**
YES? NO?
How could they be improved?

STUDENT RESPONSES:
YES - They allowed the user to view the results of the scan immediately. IDEA: fix program so that invalid peaks are not displayed on the plot.
YES - NO COMMENT
YES - A grid on the screen plot of the diffraction pattern would make intensities easier to read from the screen.

8. **Did the Graphing Functions of the software help to teach you more than the manual lab experiment?**
YES? NO?
How might they be improved?

STUDENT RESPONSES:
NO - NO COMMENT
NO - NO COMMENT
NO - Obtaining a hard copy of the pattern for students to label with 2D and I values would facilitate their understanding of how the pattern is used.

9. **Are there additional software functions you would add to make the software easier to use?**
YES? NO?

STUDENT RESPONSES:

NO - Too many options would make the program cumbersome and difficult to understand for the inexperienced user.
YES - Pull down menu's or better listings of options would make the software user friendly.
YES - It would be easier to use if it could print out a list of the 2D, I, and Irel and dspacing values.

10. **Did you need additional analytical capability not included in the software?**
YES? NO?
If so what? How would you have used it?

STUDENT RESPONSES:
NO - NO COMMENT
NO - NO COMMENT
YES - I calculated Irel and dspacing values because it was not done by the computer.

11. **Were the screen configurations used in the software easy to use?**
YES? NO?
What could you add to the screens to improve them?

STUDENT RESPONSES:
YES - NO COMMENT
YES - As mentioned before, vertical lists would be easier to read.
YES - NO COMMENT

12. **Was the background information provided in the lab guide helpful?**
YES? NO?
How could it be improved?
Did it help you more easily complete the analysis task?

STUDENT RESPONSES:
YES - Background information is very important. Preferably, the user should understand the lab fundamentals, and how the program is being used to achieve results.
YES - NO COMMENT
YES - It was helpful in understanding how the diffraction of the x-rays occurs. It would also be helpful if there was some information on why peak intensities vary.

13. **Was the "computer use" section of the lab guide easy to follow?**
YES? NO?
How could it be improved?

STUDENT RESPONSES:
NO - Sometimes I felt as if I was blindly entering the listed commands. A list of the commands and an explanation of each would be helpful.
NO - Could use more explanation. I didn't feel like I really understood what was going on in each step.
YES - It needs to include how to input dspacing and Irel values for the search. It should also inform students as to when the 2D and I values are listed on the screen and that these values should be recorded if a hard copy is not obtained.

14. Was the "procedure" section of the lab guide easy to follow?
YES? NO?
How could it be improved?

STUDENT RESPONSES:
YES - NO COMMENT
YES - NO COMMENT
YES - It should include instructions for the students to calculate the Irel and dspacing values if this is not done by the software.

15. Would you have used an ON-LINE HELP FUNCTION if it were available?
YES? NO?
At which point could you have used an ON-LINE HELP FUNCTION?

STUDENT RESPONSES:
YES - At the main menu and at subsequent "sub-menus" to help me decide which command to choose.
YES - At various points throughout the command sequence to help with question # 13.
YES - It would be nice if when an error message or some other message appears that halts the procedure, a help message could be obtained that gave suggestions for correcting the problem or more detail on what the problem was.

16. As you used the software, were you confused by all of the options available?
YES? NO?

STUDENT RESPONSES:
YES -
YES -
NO -

Would it be easier to use if it only allowed you to use that portion of the software that was needed for the Lab?
YES? NO?

STUDENT RESPONSES:
YES - I think that the inexperienced user would better understand what was going on if only allowed to use the pertinent portion of the program.
YES - NO COMMENT
NO - The lab procedure eliminates confusion as to which command should be used at any point in the program.

17. When you used the workstation did that help reduce the time used in sample preparation? How much?

Time Saved? = ____________

STUDENT RESPONSES:
- I'm sure that total lab time will be reduced.

- The workstation has tremendous time saving capabilities if you can get all the bugs out.
- The only place time is really saved is in obtaining possible material identities through the computer search, but it still takes time to determine which possibility is the correct material identity if it is not the first material listed.

18. **How many samples did you test?**
Samples = ____________

STUDENT RESPONSES:
1
1 We were going to test more but the software "froze up". We tested chalk, silicon and Al2 O3.

19. **How much time did it take you to complete the test on one sample?**
Time = ______________

STUDENT RESPONSES:

(20 - 30 minutes)
(20 minutes) The time would decrease with more use.
(25 minutes) It took about 25 minutes from beginning to end if there were no problems with the software.

20. **Were you able to complete sample testing faster with the workstation? Faster than in the manual mode during a regular lab?**
YES? NO?

STUDENT RESPONSES:
YES - NO COMMENT
NO - If the software package had not failed, it would have been much faster than the manual method.
YES - The time on the computer could be shortened if the software calculated Irel and dspacing values and a hard copy was obtained.

21. **Would it have helped you to be able to see a video image of the test equipment working while you were using the workstation software?**
YES? NO?
Why?

STUDENT RESPONSES:
NO - Too many options are unnecessary
NO - The equipment can plainly be seen through the glass doors and digital read outs of the angle is already given.
NO - The test equipment was next to the workstation. It might be helpful if the software could plot the pattern on the screen as it is being done, similar to the way the old setup produces a hard copy as the machine is working.

22. Given your experience at completing the lab assignment without the use of the workstation, how does that compare with the lab experiment with the workstation? Be as specific as possible in your response, and feel free to use the next page as well as the extra space on the back of this form if needed.

STUDENT RESPONSES:

- I think this program will be a great improvement over the "manual lab". PROS: 1. The lab moves along more quickly allowing the user to spend more time on fundamental concepts rather than looking up data in a book. 2. The use of the computer may generate more interest in the lab. Students would rather use the computer than look up things in a book. CONS: 1. The students do not learn how to use the Hanawalt Index and other reference books since the computer does all the work. However, students soon forget how to "manually" identify a sample anyway. IDEAS: 1. Get rid of the bugs in the program. We were not able to finish the lab because the program locked up. 2. When plotting peaks, delete all invalid peaks so that only valid data is displayed. 3. On-Line help function at main menu and sub-menues. 4. Give each user a listing of commands with a thorough explanation of each. Also give each user a copy of the "menu-tree".

- The software package has very strong capabilities and could greatly reduce the amount of time in testing samples. It is definitely faster than having to read values off a hardcopy plot and looking values up in the diffraction manuals. This only remains true as long as the software is running. I do not know if fault lies in the software itself or the VAX-VMS system. When it did run, I liked it.

  The procedure for using the software package was very weak. I disliked being guided through a program without explanations of the functions that are available. The only other complaint I have is the lack of USER FRIENDLINESS. This could greatly be helped with menus and a help key. What would be extremely nice is having a system that would allow you to use a mouse or at least arrow keys.

  Even though I have listed a lot of complaints, I still think this software package is a definite plus over the manual method. Just get all the bugs out of the software.

- The lab without the workstation makes some of the concepts more apparent, such as, how are 2D and I values obtained from the graph and how are the dspacing and Irel values used to search through published data to find the material identity.

SUMMARY OF COMMENTS AND SUGGESTIONS FOR REVISION:

I would suggest using the workstation and the old method simultaneously. A group of students could # use the workstation to obtain the diffraction pattern on both the screen and paper. Then obtain a hard copy of the 2D and I values given by the software. While the next 2 or 3 groups each get on the computer and obtain similar output, the first group could label their diffraction pattern and calculate dspacing and Irel values and use the published data to determine the material identity. When the last group has obtained their data, the groups could confirm the material identity with the software, if time allows.

OVERVIEW AND ANALYSIS OF PILOT TEST FINDINGS

Based on the feedback from the learner try-out, a pilot test was conducted in the Spring of 1993. The pilot test was conducted with one section of the engineering lab with 19 students. These students were selected because they had all completed the labs in the traditional manner with out the use of the computer workstations. The 19 students ware asked to use the workstations (with the software revised based on feedback from the leaner try-out) to complete the labs so that the project might gain insight into the students comparison of the lab with and without the assistance of computer technology. Appendix B contains a copy of the feedback sheet used to collect the data presented below.

Some 79% of the pilot test group reported that the workstations and software helped them better understand the lab concepts. When asked if there was a need for additional calculation functions in the software, some 68% reported that there was no need to modify the software.

When asked if they felt rushed using the workstations to conduct the lab, 63% reported no. Some 74% of the pilot test group reported interacting more with the lab assistants when they used the workstations. One hundred percent of the pilot test group reported that the graphing functions of the software were easy to use. About 95% suggested that the addition of one or two simulations provided before the lab would have helped them conduct the lab with the software and would have increased their confidence.

Regarding the functions contained in the software, 63% reported that no additional functions were needed to simplify the use of on the workstations. Many, 74%, reported that the screen configurations were easy to use. As far as the background information provided in the lab guide, 74% reported these materials were helpful in the completion of the lab. About 79% reported that the computer use section and the procedure section of the lab guide were easy to use. Reactions to the on-line help functions of the software were mixed. Some 58% reported not being confused by the number of options provided by the software, while 42% reported being confused. Regarding the amount of time needed to complete the lab, 68% reported a reduction of time needed compared to that of the traditional lab. The majority of the students, 90%, reported completion of from 1 to 4 samples during the lab (see response to question # 18. for more specific information. The average time need to complete one sample using the workstation was reported by students as taking 10 minutes or less (90%). About 85% reported being able to complete sample testing faster with the workstation.

In reference to addition of a video image along with the software and the workstation, 58% reported that video would not have helped in the completion of the lab.

Based on the pilot test data, for the field test to be conducted in the late Summer or early Fall of 1994, the following modifications to the software and documentation are recommended:

1. No video image need be added to the workstation capability.
2. One or more simulations of sample tests be added to the software for students to view before they begin the lab process.
3. A reduction in the number of software provided options for sample testing be reduced for the field testing.
4. A review of the lab guide be conducted and/or specific questions regarding the lab guide be increased on the filed test feedback form.

INDIVIDUAL RESPONSES TO THE PILOT TEST FEEDBACK FORM (N=19)

1. **Did the workstation and software help you better understand the lab concepts?**

RESPONSES:

YES		NO	
#	%	#	%
15	79%	4	21%

The concepts of this lab are in the analysis of the data. We analized the data ourselves.
The software was primarily used for gathering data and not used for a conceptual analysis.
How to set up diffraction, limit angles.
By having the equipment which provide an accurate measurement.
The lab workstation allowed us to see what the writeup was taking about.
It helped to understand how the diffractometer performed and ---
Parameters
Parameters used
Did the complex measurements and calculations and gave understandable results.
How the machine works.
How the material was evaluated.
Everything was already prepared, this we did not experience the usual way.
Got to change parameters.
The many different options contained on the software's menus made me aware of the assortment of possible analysis procedures, in my opinion.
It made the objective clearer and more accurate results.
Set-up of diffractometer

2. **Do you see the need for additional calculation functions in the software?**

RESPONSES:

YES		NO	
#	%	#	%
6	32%	13	68%

The calculations could be used in a professional environment outside the scope of the lab.
Find 3 highest peaks and perform necessary calculations to determine the composition
Sometimes, they asked us to calculate for some parameter but the formula for that is not given in the manual book.
Calculate the intensity of the peaks.
Sin2 0 ratio - Index
The software already performs more calculations than I fully comprehend.
No, provided you have time to use the software to do calculations

3. **Did you feel rushed when using the workstation?**

RESPONSES:

YES		NO	
#	%	#	%
7	37%	12	63%

Because the equipment wasn't operating properly until about 45 minutes into the last session.
We are always short on time in labs.

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Yes, everybody was to use the equipment.
The station temporarily broken down which decreased the amount of lab time available.
We always have to be careful and follow the pre-cautions in conducting the experiment.
Yes, because everyone was waiting to use it.
I had another class.
Everyone was understanding.
We were each alloted about 10 min. to perform our test.
Initializing the program to use for the first time took 1 hr.

4. **When using the workstation, did you interact more or less with the lab assistant? That is did the workstation help reduce reliance on the lab assistant?**

RESPONSES:

YES		NO	
#	%	#	%
14	74%	5	26%

Yes. The computer prompts the user for all of the necessary info.
No, I didn't know exactly what the commands meant, <o I had to rely on the assistant.
No difference. Had to ask which buttons to push.
The workstation increased time associated w/lab assistance. Software operation explanation.
I interacted to make sure I was doing right, but was less dependant than usual.
I interact more with the lab assistant. We need the lab assistant to provide the information about the workstation and equipment.
The workstation was pretty much self-explanatory after the initial explanation.
Not completely, there were some steps I couldn't remember.
Yes, somewhat
Yes, made understanding easier
More, because they understood the commands.
Yes, after understanding the equipment, need for T.A. minimal.
No, in a way to get familiar w/the program
Yes, the procedure was self explanatory.
Yes, all we needed to do is select from a few choices, on the computer, and the workstation did all the mechanical work.
Less because of easy-to-follow menu of program
The workstation made me less reliant on the lab assistant.
Yes, after understanding the equipment.
More. Yes

5. **Would an example simulation or two before you use the workstation to conduct the experiment with the test equipment have helped you better use the test equipment software?**

RESPONSES:

YES		NO	
#	%	#	%
18	95%	1	5%

There were example simulations.
We had an example and it didn't help.
Would have learned how to operate the equipment.
Could see the actual operation of the equipment.
More user friendly
We need an example about the use of workstation so that we can see clearly how to operate on these equipment.

Wouldn't have taken longer to perform
List on how each subroutine works (manual w/software)
We were given a helpful demonstration.
Examples are always helpful.
We did.

6. **Would an example simulation or two before you use the workstation to conduct the experiment with the test equipment have helped you feel more confident about using the workstation to run the test equipment?**

RESPONSES:

YES		NO	
#	%	#	%
18	95%	1	5%

There were simulations
Same as #5.
Same as #5.
As I stated above, an example will help me a lot in operating the equipment and this make me become more confident to run the test.
Same as above
I may have already explained this, but examples are always helpful.

7. **Were the Graphing Functions of the software easy to use?**

RESPONSES:

YES		NO	
#	%	#	%
19	100%	0	0

Autoscaling
No improvement noticed.
So far I got no problem in using the graphing function. They could be improved if we were given the latest software which easier to operate.
Less menus
Write steps in manual.
Appears to do the job.
The menu make things easier.
Provide a manual
Get a new printer!

8. **Did the Graphing Functions of the software help to teach you more than the manual lab experiment? How might they be improved?**

RESPONSES:

YES		NO	
#	%	#	%
18	95%	1	5%

Autoscaling
The graphics were more accurate resulting in better data.
By having the graphing function software, they help us to figure out how the output of the experiment will looks like.
We did not refer to the manual.
Don't know

9. **Are there additional software functions you would add to make the software easier to use?**

RESPONSES:

YES		NO	
#	%	#	%
7	37%	12	63%

Pull down menus

Not that I can think of.

More user friendly

I'm not very expert about software functions. anyway, I'm sure there are some which can help us easier in using the software that we have now.

More explanations of commands

Yes, do the actual calculations and spit out the results to the lab.

Instructions

Don't know if needed

I believe that the software should incorporate a library of metallogical data which would provide the identity of each sample as well as all the answers I might need to include in my report. Further, an additional software function I would find useful is one which actually writes the lab report for me.

10. **Did you need additional analytical capability not included in the software? If so, what? How would you have used it?**

RESPONSES:

YES		NO	
#	%	#	%
5	26%	14	74%

Calculations for b, d, h & l, etc.

So far, the software that we're using now is considered good for this lab.

Calculated depacing

We had to calculate lines of angles.

I don't feel that I should have to write comments for each and every question.

Sin20, sin20 ration, Index, to figure the lattice type

Peak comparisons

11. **Were the screen configurations used in the software easy to use? What could you add to the screens to improve them?**

RESPONSES:

YES		NO	
#	%	#	%
14	74%	5	26%

The default values for the menus were not clear enough.

Organization of commands could improve.

Add more information on what the screen displayed.

Nothing. They are fine as is.

Have pre-printed instruction in lab manual.

A quick reference manual was needed.

Nothing else needed.

The menus should be layed out in column form instead of row form.

12. **Was the background information provided in the lab guide helpful? Did it help you more easily complete the analysis task?**

RESPONSES:

YES		NO	
#	%	#	%
14	74%	5	26%

Include a sample diffraction pattern.
There was no info in the lab manual.
More and charts
Easier to read
Provide more example and details explanation. Add course yes.
The instructor and T.A. helped.
Somewhat. It really didn't help in the computer setup.
Don't see the necessity for improvement. Yes, it matched up with what actually occured.
Very good
It was helpful but inadequate to prepare me to perform the experiment.

13. **Was the "computer use" section of the lab guide easy to follow?**

RESPONSES:

YES		NO		No Response	
#	%	#	%	#	%
15	79%	3	16%	1	5%

No lab guide.
More detail
So far, I think it is okay.
Easier to understand
Need to work with it further in order to recognize any.
Dr. Mohanty gave the needed instructions in lab lecture.

14. **Was the "procedure" section of the lab guide easy to follow?**

RESPONSES:

YES		NO		No Response	
#	%	#	%	#	%
15	79%	3	16%	1	5%

There was no procedure given.
Illustrations
Provide the diagram which shows how the equipment is arranged before starting the test/experiment.
Writer longer explanations
Not necessary
It could be written from more of a layman's point of view.

15. **Would you have used an ON-LINE HELP FUNCTION if it were available? At which point could you have used an ON-LINE HELP FUNCTION?**

RESPONSES:

YES		NO		No Response	
#	%	#	%	#	%
10	53%	8	42%	1	5%

It should be available at any point in the program.

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Show what commands were in each directory.
When come to the dangerous - experimenter such as involves explosion or radiation test.
During diff. run.
All the way through
No, because TA knew how to help.
In the beginning
On-line help was provide by lab assistants.
To find out needed parameters.

16. **As you used the software, were you confused by all of the options available?**
RESPONSES:

YES		NO	
#	%	#	%
8	42%	11	58%

Would it be easier to use if it only allowed you to use that portion of the software that was needed for
the Lab?
RESPONSES:

YES		NO		No Response	
#	%	#	%	#	%
14	74%	4	21%	1	5%
8	42%				

The program options need to be explained.
I had no idea what some of the options were.
Was not confused b/c of the assistance by the professor.
Wouldn't get confused as easy.
This help me not to confuse and do the test smoothly.
That would help indeed.
When there is only one option, it is generally easier to decide which one option to choose.

17. **When you used the workstation did that help reduce the time used in sample preparation?**
RESPONSES:

YES		No Response		NA	
#	%	#	%	#	%
13	68%	5	27%	1	5%

How much?

The responses indicated that students saved about one hour.
Was prepared before class
Much faster and easier.
Just for this experiment
The whole lab took about 3 1/2 hrs. last time, when it was similar MEGR 3153.
Actually, we did not prepare samples. We prefered to sit idly and watch others perform their analyses.

18. **How many samples did you test?**
RESPONSES:

# of Samples Tested	# Students Testing	% Students Testing
1	5	28%
3	6	34%
4	5	28%
6	1	5%
7	1	5%

For this experiment x-ray diffraction we use 6 different samples of materials.
We tested 3 samples.

19. **How much time did it take you to complete the test on one sample?**
RESPONSES:

Time	# Students	% Students
Less tan 5 Minutes	3	16%
5 Minutes	4	21%
10 Minutes	10	53%
More than 10 Minutes	2	10%

20. **Were you able to complete sample testing faster with the workstation? Faster than in the manual mode during a regular lab?**
RESPONSES:

YES		NO		No Response	
#	%	#	%	#	%
16	85%	2	10%	1	5%

We could not get the plotter to work, so the lab took much longer.
Didn't have to measure everything.
As I said, workstation can save you time and provides better result.
Only by a small amount.
This would illustrate the process being done.
Because it gave the correct 20 values
Because gave 20 values.
That manual mode is bogus.
But, after the software is more familiar to the users it would speed up the process considerably.

21. **Would it have helped you to be able to see a video image of the test equipment working while you were using the workstation software?**
RESPONSES:

YES		NO		No Response	
#	%	#	%	#	%
6	32%	11	58%	2	10%

It is always useful to visulize what is happening.
I don't know, perhaps.
So far, we never saw a video image of the test equipment. Just see the given diagram in the manual book.
It wouldn't have made it any easier.
To let the user know what is going on and when to proceed.
All moving parts are hidden by their enclosure.

I enjoy watching television images in the interest of education.
The test equip. was beside of us.

22. **Given your experience at completing the lab assignment without the use of the workstation, how does that compare with the lab experiment with the workstation? Be as specific as possible in your response, and feel free to use the next page as well as the extra space on the back of this form if needed.**

The computer made the experiment easier because all of the manual commands did not have to be known.

The diffractometer before the workstation was easier because the results were plotted immediately. I realize that the workstation does much more analysis, but x-ray diffraction analysis is not that difficult to begin with.

Get more accurate data.

By using the workstation, it gives me a better understanding of the experiment that we have done.

This time was slightly faster aside from the equip. failure.

The lab with the workstation was much easier and straightforward. It allowed results to be obtained quicker.

The use of workstation made processing of data quicker, but menus are so vague that if you don't know what you were looking at, you were lost.

The workstation made it much easier because it gave you exact values for 2θ.

The workstation gave us 2θ where as we had to find it before this saved us much time and reduced our error.

Much faster but needs an on line help function or quick ref. manual to supplement the software.

This lab was just quicker and a little easier to understand.

Last time (MEGR 3153) it was horrible, the lab took 3 1/2 hrs. and sorting out the mess brought upthe total time to complete this lab to about 15 hrs. I anticipate it will take about half that time from start until I turn in the report.

On a scale of 1 to 10, the lab without the workstation is a 2 while the lab with the workstation is higher. Perhaps a 4 or a 5. The commands necessary for the non-workstation lab were not exactly intuitive. with the new setup, I think I could probably figure out most of this stuff using the menus, given enough time.

The workstation provided more accurate results than hard calculations.

Using the workstation hardware speeds up the process considerably.

APPENDIX A

LEARNER TRYOUT FEEDBACK FORM

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Learner Tryout Feedback Form

Student Name ____________________ Date ________________
Lab Course ______________________
Test Equipment Used ____________________________________
Analysis Conducted:

1. ____
2. ____
3. ____
4. ____

1. Did the workstation and software help you better understand the lab concepts?
   YES? NO?
   How? Which concepts?
   COMMENTS:
   ____
   ____
   ____

2. Do you see the need for additional calculation functions in the software?
   YES? NO?

   Please provide examples in the comments section.
   COMMENTS:
   ____
   ____
   ____

3. Did you feel rushed when using the workstation?
   YES? NO?
   Why?
   COMMENTS:
   ____
   ____

4. When using the workstation, did you interact more or less with the lab assistant? That is did the workstation help reduce reliance on the lab assistant?
   COMMENTS:
   ____
   ____
   ____

5. Would an example simulation or two before you use the workstation to conduct the experiment with the test equipment have helped you better use the test equipment software?
   YES? NO?
   COMMENTS:
   ____
   ____
   ____

6. Would an example simulation or two before you use the workstation to conduct the experiment with the test equipment have helped you feel more confident about using the workstation to run the test equipment?
YES? NO?
COMMENTS:

7. Were the Graphing Functions of the software easy to use?
YES? NO?
How could they be improved?
COMMENTS:

8. Did the Graphing Functions of the software help to teach you more than the manual lab experiment?
YES? NO?
How might they be improved?
COMMENTS:

9. Are there additional software functions you would add to make the software easier to use?
YES? NO?
COMMENTS:

10. Did you need additional analytical capability not included in the software?
YES? NO?
If so what? How would you have used it?
COMMENTS:

11. Were the screen configurations used in the software easy to use?
YES? NO?
What could you add to the screens to improve them?
COMMENTS:

12. Was the background information provided in the lab guide helpful?
YES? NO?
How could it be improved?
Did it help you more easily complete the analysis task?
COMMENTS:

13. Was the "computer use" section of the lab guide easy to follow?
YES? NO?
How could it be improved?
COMMENTS:

____

____

____

14. Was the "procedure" section of the lab guide easy to follow?
YES? NO?
How could it be improved?
COMMENTS:

____

____

____

15. Would you have used an ON-LINE HELP FUNCTION if it were available?
YES? NO?
At which point could you have used an ON-LINE HELP FUNCTION?
COMMENTS:

____

____

____

16. As you used the software, were you confused by all of the options available?
YES? NO?
Would it be easier to use if it only allowed you to use that portion of the software that was needed for the Lab?
YES? NO?
COMMENTS:

____

____

____

17. When you used the workstation did that help reduce the time used in sample preparation? How much?
Time Saved? = ____________
COMMENTS:

____

____

____

18. How many samples did you test?
Samples = ____________
COMMENTS:

____

____

____

19. How much time did it take you to complete the test on one sample?
Time = ______________
COMMENTS:

____

____

____

20. Were you able to complete sample testing faster with the workstation? Faster than in the manual mode during a regular lab?
YES? NO?
COMMENTS:

___

___

___

21. Would it have helped you to be able to see a video image of the test equipment working while you were using the workstation software?
YES? NO?
Why?
COMMENTS:

___

___

___

22. Given your experience at completing the lab assignment without the use of the workstation, how does that compare with the lab experiment with the workstation? Be as specific as possible in your response, and feel free to use the next page as well as the extra space on the back of this form if needed.
COMMENTS:

___

___

___

___

___

APPENDIX B

PILOT TEST FEEDBACK FORM

ERIC

Pilot Test Feedback Form

Student Name ____________________ Date ________________ Lab Course ______________________
Test Equipment Used ____________________________________
Analysis Conducted:
1. ____
2. ____
3. ____
4. ____

1. Did the workstation and software help you better understand the lab concepts?
YES? NO?
How? Which concepts?
COMMENTS:

____
____
____

2. Do you see the need for additional calculation functions in the software?
YES? NO?
Please provide examples in the comments section.
COMMENTS:

____
____
____

3. Did you feel rushed when using the workstation?
YES? NO?
Why?
COMMENTS:

____
____
____

4. When using the workstation, did you interact more or less with the lab assistant? That is did the workstation help reduce reliance on the lab assistant?
COMMENTS:

____
____
____

5. Would an example simulation or two before you use the workstation to conduct the experiment with the test equipment have helped you better use the test equipment software?
YES? NO?
COMMENTS:

____
____
____

6. Would an example simulation or two before you use the workstation to conduct the experiment with the test equipment have helped you feel more confident about using the workstation to run the test equipment?
YES? NO?
COMMENTS:

____
____

7. Were the Graphing Functions of the software easy to use?
YES? NO?
How could they be improved?
COMMENTS:

8. Did the Graphing Functions of the software help to teach you more than the manual lab experiment?
YES? NO?
How might they be improved?
COMMENTS:

9. Are there additional software functions you would add to make the software easier to use?
YES? NO?
COMMENTS:

10. Did you need additional analytical capability not included in the software?
YES? NO?
If so what? How would you have used it?
COMMENTS:

11. Were the screen configurations used in the software easy to use?
YES? NO?
What could you add to the screens to improve them?
COMMENTS:

12. Was the background information provided in the lab guide helpful?
YES? NO?
How could it be improved?
Did it help you more easily complete the analysis task?
COMMENTS:

13. Was the "computer use" section of the lab guide easy to follow?
YES? NO?
How could it be improved?
COMMENTS:

14. Was the "procedure" section of the lab guide easy to follow?
YES? NO?
How could it be improved?

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COMMENTS:

15. Would you have used an ON-LINE HELP FUNCTION if it were available?
YES? NO?
At which point could you have used an ON-LINE HELP FUNCTION?
COMMENTS:

16. As you used the software, were you confused by all of the options available?
YES? NO?
Would it be easier to use if it only allowed you to use that portion of the software that was needed fdhe Lab?
YES? NO?
COMMENTS:

17. When you used the workstation did that help reduce the time used in sample preparation? How much?
Time Saved? = ____________
COMMENTS:

18. How many samples did you test?
Samples = ____________
COMMENTS:

19. How much time did it take you to complete the test on one sample?
Time = ______________
COMMENTS:

20. Were you able to complete sample testing faster with the workstation? Faster than in the manual mode during a regular lab?
YES? NO?
COMMENTS:

21. Would it have helped you to be able to see a video image of the test equipment working while you were using the workstation software?
YES? NO?
Why?
COMMENTS:

22. Given your experience at completing the lab assignment without the use of the workstation, how does that compare with the lab experiment with the workstation? Be as specific as possible in your response and feel free to use the next page as well as the extra space on the back of this form if needed.

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