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R&DC 265: A TIME-SHARING, BATCH, DATA ACQUISITION COMPUTER SYSTEM

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Summary

The Research and Development Center of the General Electric Company had operational requirements for the following

1. Time-Sharing
2. Batch Computation
3. Acquisition of Scientific and Engineering Data from several sites.
4. Communication of Data to a large batch processing 600 computer at a remote site.

To fulfill these, a GE 235 disc system was upgraded to a GE 265 system where minor hardware changes and major software changes were made from the standard commercial offering. These changes allowed concurrent operation of batch and time-sharing, the serving of experimental systems, and the coupling to special terminals attached to experiments in physical science.

This paper describes many of the unique features of this system, special terminals developed, our operational experiences, and the successes achieved in automating experiments to work with the time-sharing system.

Introduction

The General Electric Research and Development Center conducts basic and applied research and advance development for the General Electric Company. Its staff consists of scientists and engineers covering a wide range of disciplines in various technologies. To fulfill the scientific computational requirements, a batch-oriented General Electric medium-size 225 computer was installed at the end of 1963. In March of 1965, the 225 was replaced by a GE 235 which, for scientific calculations, was five times faster. In 1966 this was modified to a General Electric 265* system potentially capable of handling batch, time-sharing, and data acquisition. The configuration of the latter system is shown pictorially in Fig. 1 and a wide-angle view of the computer room is shown in Fig. 2.

In this paper some of the items described are:

1. the many unique features of the batch, time-sharing, data acquisition system;

2. special terminal devices, with associated software, that gave scientists and engineers increased flexibility in carrying out their technical tasks;

3. the operational experiences that the Center had with this system; and

4. the increased productivity that was realized through automating technical staff calculations and experimental procedures.

It is hoped that this paper will prove useful to others by demonstrating the wide spectrum of potential uses of a medium-size, multipurpose system in a scientific and engineering environment. By describing many of the varied terminal devices, we hope to encourage users to explore similar possibilities at their own installations.

It was thought appropriate to write this paper now that we can present several years of actual experience. In addition, as the equipment was removed from the Center during September 1968, when its

* The GE 265 consists of a GE 235 and a GE DN30. The latter is a stored program communications processor. See Fig. 1.

duties were taken over by a GE 600 system, it represents a completed chapter in the use of computers in our environment.

The system and user experience reviewed in this report represents the work of many of our staff members. Some of them are noted in the acknowledgments. In addition, it should be recognized that almost all users of the system made some contribution to the design, techniques, and procedures described.

Previous Experience: System Objectives and Performance

The design objectives of the Center's 265 system arose in part from our experience with the earlier GE 235 disc system and included the following:

1. the ability to process FORTRAN II scientific calculations using magnetic tapes, paper tape, and line printer, etc.;

2. the ability to handle various scientific or business information systems requiring SORT techniques;

3. the ability to digitalize analog magnetic tape at 10 Kc sampling rates;

4. a requirement to interface experiments in physical science to the computer by use of special data loggers, and interfaces. Some of these experiments required real time response; others could utilize intermediate media such as magnetic or paper tape; and

5. the ability to communicate, via telephone lines at 2000 bps rates, larger scientific problems to a GE 635 computer.

The primary reason for acquiring the original computer was to fulfill the first requirement, i.e., provide short turn-around time batch service. It was recognized that the 16K 20-bit word memory of the 200 series computer would be a serious limitation and a disc was included to mitigate that limitation. It was also planned to provide fast turn-around batch service on a local GE 600 system by means of a remote communication device or station wagon delivery , if necessary. For a variety of reasons the remote batch during the interval we are discussing did not function effectively. The major success was the development of techniques for storing links or segments of a larger program on disc--thus providing the ability to process most of the larger scientific computational requirements of the Center. In general, we had good experience with programs written from the start with the required linking in mind; good experience in reprogramming some packages, e.g., DYNASAR, a large simulation program; and poor experience with other programs that could not easily be re-programmed. On the whole, however, we regularly processed large programs utilizing this technique.

One of the requirements for replacing the 235 by the 265 was that all batch production work previously done on a dedicated basis had to be run as background jobs concurrently with the time-sharing (foreground). In order to retain the ability to run large jobs, a system called MUMPS (Multiple Modular Program System) was implemented that allowed linking and execution of segmented programs to take place on the same disc that contained the time-sharing files.

One of the difficulties in interfacing experiments to the 235 computer was the length of time (usually 6 months to a year) it took a scientist or engineer to automate his experiment to the point at which he could obtain meaningful results from the computer. To overcome and effectively utilize time-sharing, the special hardware and software experimental data acquisition system, to be described, was designed. The success of this endeavor was demonstrated when one of the chemists in analyzing ultraviolet data (which came out as analog voltages from his experiment) complained that it took all of 3 weeks, including his learning some FORTRAN programming, before he got meaningful results. Before the design of the special instrumentation and software, it would have taken at least 6 months to have reached the same point; this estimate considers his programming experience, and the development of special interfacing equipment for his experiment.

While the ability to carry out the remote computational function for large problems described in requirement 5 was achieved on both the batch 235 and time-sharing 265 system, its necessity for use was greatly diminished by the success of linking programs described above.

The high-speed digitalizing requirement

was originally satisfied by dedicating the 235 to this task. On the 265 this digitalizing was done while time-sharing was taking place. A special interface unit (Fig. 3) was connected to an analog digital converter. This unit, along with the digital magnetic tapes, could be run from either the 235 or the DN30 via a peripheral switch. For the digitalizing these units were put on the DN30. After the DN30 had put the digitalized information on magnetic tapes, these were switched to the 235 and standard FORTRAN programs were utilized to carry out as a background job, the computing of correlation functions, spectra, or other data analysis required. Thus, vast amounts of data could be analyzed effectively without disturbing the time-sharing users of the system. Figure 3 shows this digitalizing system which consisted of the special interface, Analog to Digital Converter, and an analog tape system.

Properties of System

The preceding has given some of the requirements placed on the 265 system and how these were satisfied. The system properties of the time-sharing, background, and data acquisition will now be described in greater detail.

Background

The necessity of doing batch production work while time-sharing was taking place, along with some of the additional requirements that arose after the system was installed, resulted in many background system programs being implemented. Some of these were:

1. a batch-oriented FORTRAN II that had subroutines for generating CalComp plots which were plotted in real time on the system;

2. FORWARD-SORT-MERGE-GENERATOR for data processing applications;

3. various Assemblers for the GE 235, DN30, and GEPAC 4020 (a process computer that was being installed for data acquisition as part of the future 600 system);

4. WISP, a list processing language;[1] and

5. Peripheral to Peripheral Programs, e.g., card to printer, tape to printer, etc.

Because of the small size core, the first four types of activities were swapped into core, run for several seconds, and then swapped out. The background throughput varied from almost 100% (of that attainable on a 235) when no users or a few time-sharing users, who did not require much 235 processor time, to 25% when 17 or 18 time-sharing users were doing extensive calculations. The fifth activity only required a small part of core and resided there permanently when required. The program drove the peripherals at full speed and there was almost no degradation of time-sharing service.

Time-sharing Services

Numerous languages were available to the users, many of which were obtained from Dartmouth College [2] and used with no alterations. Some of these languages were:

1. BASIC

2. ALGOL

3. TIME-SHARING DATA ACQUISITION FORTRAN. This allowed users to process data entered through the data acquisition system that is described below as well as doing standard FORTRAN II type programs

4. String Edit Functions

5. TSAP which allowed 235 machine language programs to be run interpretatively

6. LISP

The first four languages were very similar to those available from the General Electric commercial 265 time-sharing service. Since description of these languages is covered in the literature, no further comments will be made about them here.

Data Acquisition

Because of the large amount of experimental scientific work being carried on at the Center, considerable thought and effort were given to automatically acquiring data from experiments in a form amenable for computer processing. Originally general-purpose portable data loggers were put together by the Design Engineering Group at the Center that would readily collect data from instruments, e.g., digital voltmeters,electronic counters etc. The data were punched out either on paper tape or placed on an incremental magnetic recorder. To encourage the use of data loggers of this type, they were available from the Center's instrument pool, and special programs were written to allow users to process the data with FORTRAN programs. Unfortunately, as indicated earlier, considerable time was required before the scientist achieved meaningful results.

When the 235 system was updated to a 265 system, a special data logging system was designed to work simultaneously with time-sharing and background processing. This is shown in Fig. 4. It could handle both digital data that came in at 110 baud rate through telephone lines, or analog data that came to the computer room on hard wires from various laboratories or from remote locations through analog modems.

In conjunction with this system special terminals were designed to readily allow digital data to be transmitted to the computers from experiments. This is shown in Fig. 5. The terminal consisted of integrated circuitry built in the back of a model 33 TTY that readily interfaced to instruments. The distributor of the teletype was used for transmitting the data to the computer. The teletype printer could be used for monitoring the data as they were transmitted, and the paper punch on the TTY could punch a backup tape in case the transmission was interrupted or the computer failed during the experiment. Initially one of these terminals was constructed to evaluate its properties and placed in the instrument pool. Seven of these terminals have now been built for various staff members. The analog system consisted of a 10-line scanner and an analog-to-digital converter that sampled each line 10 times/sec.

To accommodate the data acquisition system, modifications were made to the 265 command language system and in the DN30 software. An additional set of commands was introduced to give the status of the various digital channels and allow the user to assign himself a channel. The user manual for this system is listed in Reference 3. When the command DIGIT or ANALOG was given all eight-bit characters from remote digital terminals or the A/D converter were placed on special areas of the disc with additional bits for identification. This continued until a special eight-bit character (007) was received; then the DN30 would respond to the normal command system, and the teletype returned to use as a conventional time-sharing terminal.

The experimental data could be processed using routines in the background FORTRAN language or from the terminal with time-sharing FORTRAN. The former would allow more sophisticated processing of the data to take place and give the user the ability to plot his data on the CalComp plotter. The latter allowed the scientist to utilize the advantages of conversational time-sharing to experiment with the data and develop algorithms for finding peaks in the data, integrate area under curves, etc. Figures 6 through 8 show some of the experimental areas where these data logging techniques were employed. Figure 9 shows schematically how data from human shock patients were processed on the Center's 265. This was a joint program with Albany Medical College, Rensselaer Polytechnic Institute, and the GE Research and Development Center.

Figures 10 and 11 show some of the typical savings in manpower and time that occurred by employing the techniques described above.

Foreground to Background Systems

Also developed on the 265 system were special systems that allowed data files to be built from time-sharing terminals and then be processed with background techniques. One of these was a program that allowed files that were created by the time-sharing FORTRAN to be plotted on the CalComp plotter in the computer room.

However the most effective system developed allowed system programmers to type in the machine language coding for the operating system for the Center's new 600 computer. Several hundred of these files would be linked and placed on magnetic tape once or twice a day. This tape contained the equivalent card images for a GE 600 GMAP assembly program. Because of the size of the assembler, this tape had to be processed on a 600 machine. However, the flexibility of using teletypes rather than keypunches, and the ability to use the time-sharing edit package for making corrections, insertions, etc., allowed the system programmers to do their own coding conveniently and resulted in far more comments and descriptions in the listings than would have ever occurred in conventional keypunching of these programs. It is estimated that this technique cut down the time for coding the operating system for the 600 by at least a factor of two.

Special Remote Terminals

Aside from the development of special terminals for data logging other special remote devices were engineered.

To allow the staff to work conveniently at their desks or at home, a special "portable" teletype with an acoustical coupler was developed as shown in Fig. 12. This resulted in increased evening and weekend use of the computer. Devices working on the same principles have since become commercially available from several vendors.

Another remote device was the plotting system shown in Fig. 13 that allowed the user to get rough plots on the X-Y recorder or on the memoscope at the 110 baud rate. Special modifications were made in the DN30 and time-sharing FORTRAN software to accommodate this device. The same equipment was also packed in a suitcase as shown in Fig. 14 and scientists would borrow it for off-premise use. One scientist even quipped that with the remote plotter and teletype there was no need for him to come to work.

Several unique applications were put on the Center's 265 system. One of these was the Student Response System. One such system was implemented by an R&DC team at Syracuse University. Each student in a classroom had available to him a set of buttons shown in Fig. 15 by which he could make a multiple choice answer to a set of questions. The question would be part of an examination or an indication to the lecturer of how well the student was understanding the material being presented. The lecturer could automatically tell from averaging meters the response of the students, or the system could feed in real time the individual responses to the computer in Schenectady. The instructor could then get arbitrarily detailed analysis of the responses to date on a teletype as shown in Fig. 16.

Another project was worked out with one of the local elementary schools which had classes for autistic children. A standard teletype terminal was installed and special programs were written by the teachers to stimulate the children's interest in mathematics, spelling, etc. While the project is still highly experimental, the teachers working with the children are enthusiastic about the potential of this method of training children afflicted with this problem. One of the authors experimented on his own young children, who are not in these courses, with the programs created, and was unable to pry them away from the teletype for 3 hours.

There have been many other interesting, special or unique projects carried out on the time-sharing computer such as keeping the scores of the athletic events of the Center's social club, or arranging papers, rooms, and times for a Magnetics Conference. Undoubtedly other clandestine, interesting projects were being done at the remote terminals that were not reported to the Computer Operation Management.

Operational Experience

The operation of a developmental combined background time-sharing data acquisition computer system is far different from that of running a simple batch service, and many things were learned during the first year of operation--unfortunately some of them the hard way.

Developing of new techniques or software had to be done far more carefully and with adequate warnings. Unlike batch, which can disrupt one user, when a time-sharing system goes down, 15 or 20 people may have several hours of painstaking work ruined.

When the 265 was first installed, extensive modifications were made to the operating system originally obtained from Dartmouth College. That, coupled with the new hardware, resulted in the system's failing every few hours. After some months, about one failure every 2 days would occur and before the system was removed it would run 1 or 2 weeks without any serious failures disrupting service.

For the last year the system was left on

7 days a week, 24 hours a day. Time-sharing was only taken off at 6 p.m. to 7 p.m. weekdays to take dumps of the time-sharing files on magnetic tapes; 6 p.m. appeared to be the optimum time to perform this task since it forced the scientist to go home to his waiting wife and supper. At midnight or during early morning hours several of the scientists were often using the system. Operator coverage was supplied from 8:00 a.m. to 11:00 p.m. weekdays. At other times the system was left unattended. The staff could come in and, if they had a few hours of training, do their background processing "open shop."

Operationally we learned that a high quality of service had to be given to the time-sharing user. Many of them had little previous computer experience. However, it did not take long for them to become familiar with the time-sharing techniques. Along with system reliability and uptime was the requirement to maintain the files as the user last left them. On rare occasions users would tolerate files being restored to an earlier date. This occasionally happened when the disc had catastrophic failures. If this happened too often, as was the case when software modifications were made in the DN30, then users and their managers would rightly complain.

Because the background work deteriorated the time-sharing response, and vice versa, it was desirable to run low priority production background in the evening rather than during the day. An effective way of achieving this was to charge according to the time a "batch" job was in the system. During the day, the much slower throughput caused many background users to request their jobs be run in the evening. On the other hand, for debugging or when it was important to get answers to meet deadlines, results (at a higher cost) could be obtained with fast turn around.

Because of the various other activities that the DN30 performed (including handling 3 GE DATANET 760 displays) the number of remote terminals the system could handle was reduced from the normal 40 on a commercial GE 265 system to 21. During a typical month about 1700 hours of contact hours from about 60 terminal devices would be logged as well as 200 hours of background processing.

Conclusion

The GE 200 series computers installed in the Center had a dual purpose of providing computational services and educating the technical staff in new techniques for performing their scientific and engineering tasks. During the initial phases of batch service and the time-sharing services there was skepticism by some of the staff and management as to the effectiveness of these techniques. However, when the system was finally turned off, its performance and its effect on technical work had transcended the most optimistic expectations of all concerned. Many of the staff had become completely dependent on the computer to perform even their routine daily tasks.

Prior to its removal, the 265 system was overloaded and incapable of the sophisticated work that will be required in the future. For these reasons, it was replaced by a GE 600 series system that includes a GE 4020 process computer and other suitable machines. However, many of the staff members, including the authors, still feel great gratitude to the 265 system described in this report for its performance and the experience it provided. It also was satisfying to watch an experimental system that was up only a few hours at a time become a production-oriented system with many services that became almost as dependable as a utility.

Acknowledgments

As indicated earlier, the work described in this report is the contribution of many people. The system was evolved from the executive systems and languages obtained from Dartmouth College. Some of the programmers who made contributions were R.W. Benway, G.D. Detlefsen, P.W. Edmonds, M.G. Hoogeboom, and V.P. Scavullo, all of whom suffered many hours of anxiety until system performance became acceptable. Other engineering efforts on the computer hardware and remote terminal devices were made by J.S. Sicko and E.C. Underkoffler, and others in the Center's Designing Engineering Group. Without efforts of these and many other Center personnel, the Center would not have had a computational system that was worth writing about.

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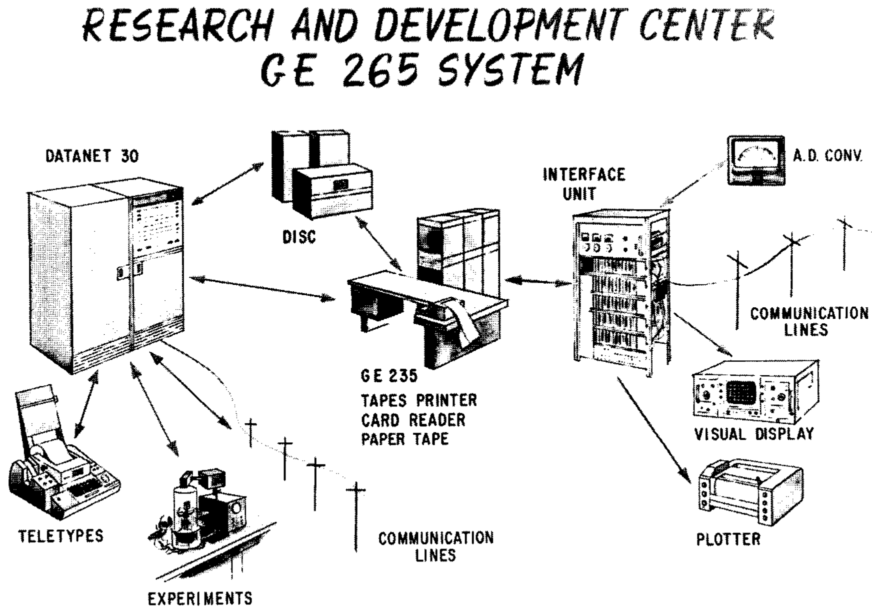


Fig. 1 GE's R&DC 265 system; schematic view

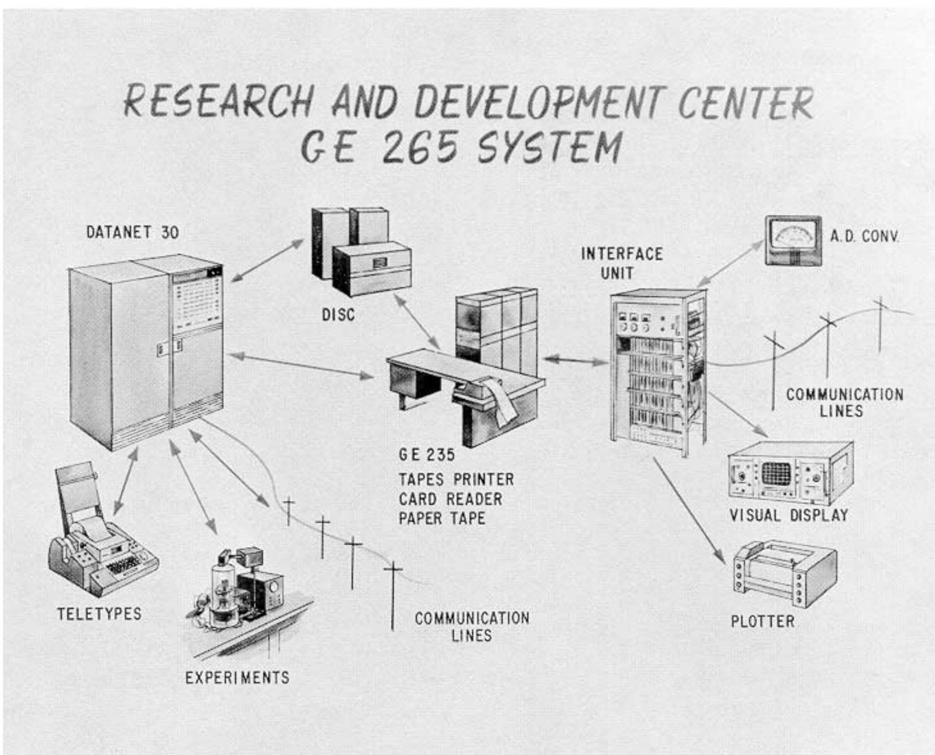


Fig. 2 GE's R&DC system; wide-angle view of computer room

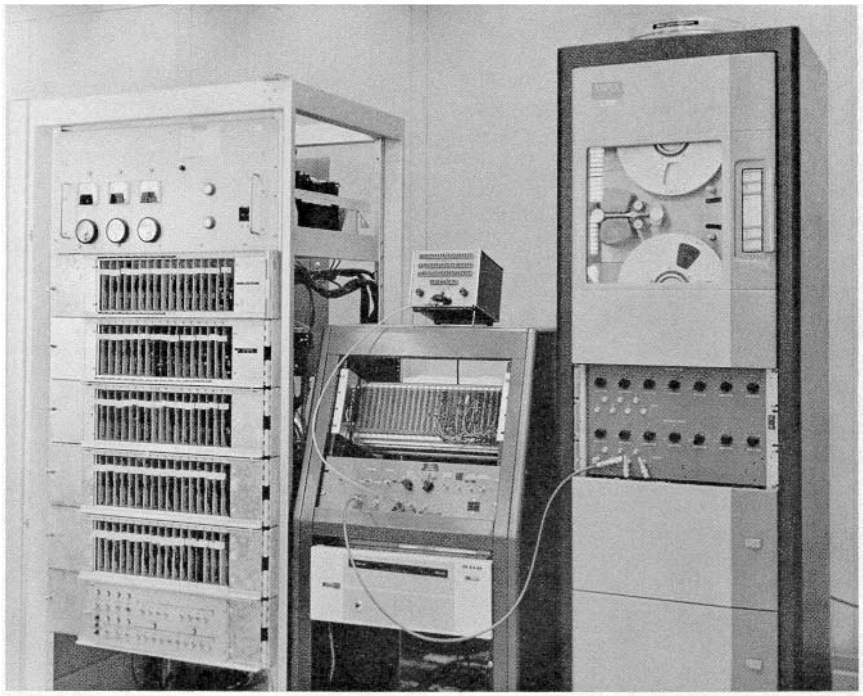


Fig. 3 Special interface unit (left) of the GE 265 system, connected to an analog digital converter (center) and analog tape drive (right).

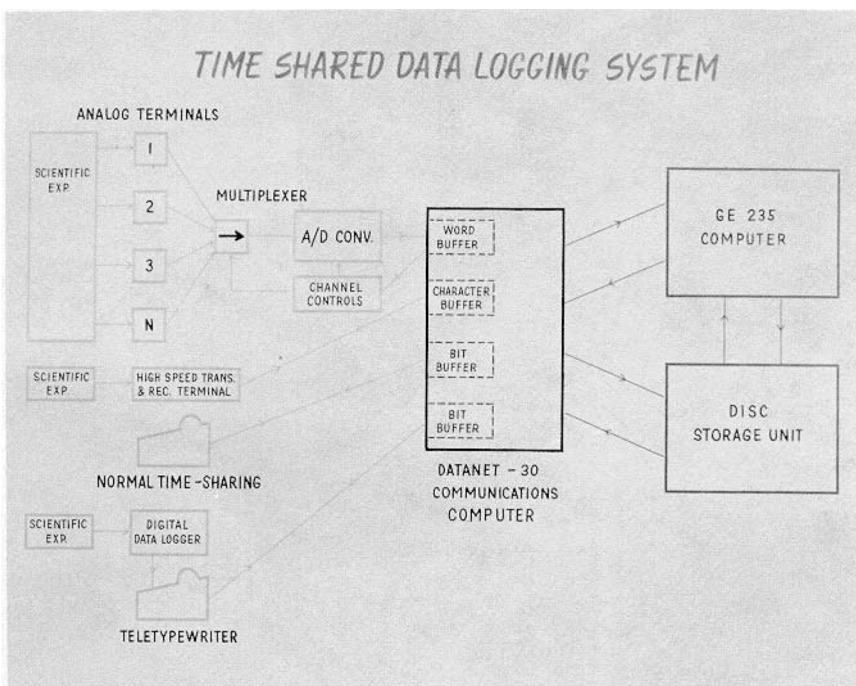


Fig. 4 Data logging system of the GE 265, designed to work simultaneously with time-sharing and background processing.

Fig. 5 Special terminals readily allow digital data to be transmitted to GE 265 computers from experiments.

Fig. 6 An infrared experiment in which data logging techniques are employed with the GE 265.

Fig. 7 X-ray diffractometer in which data logging techniques are employed with the GE 265.

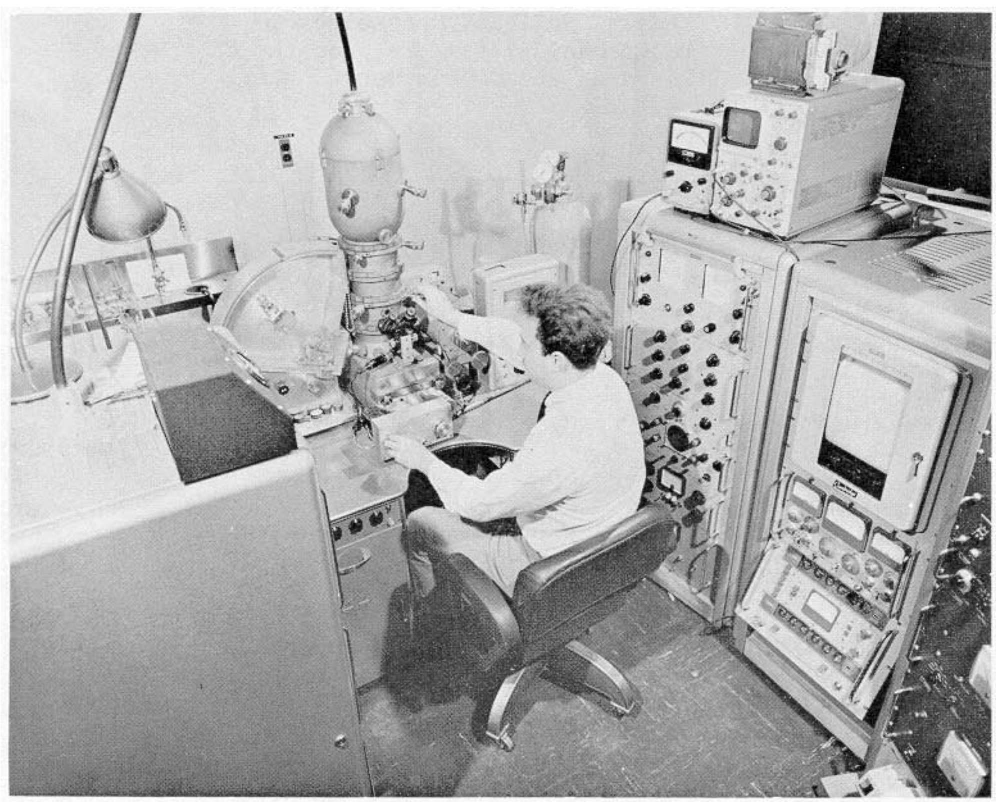
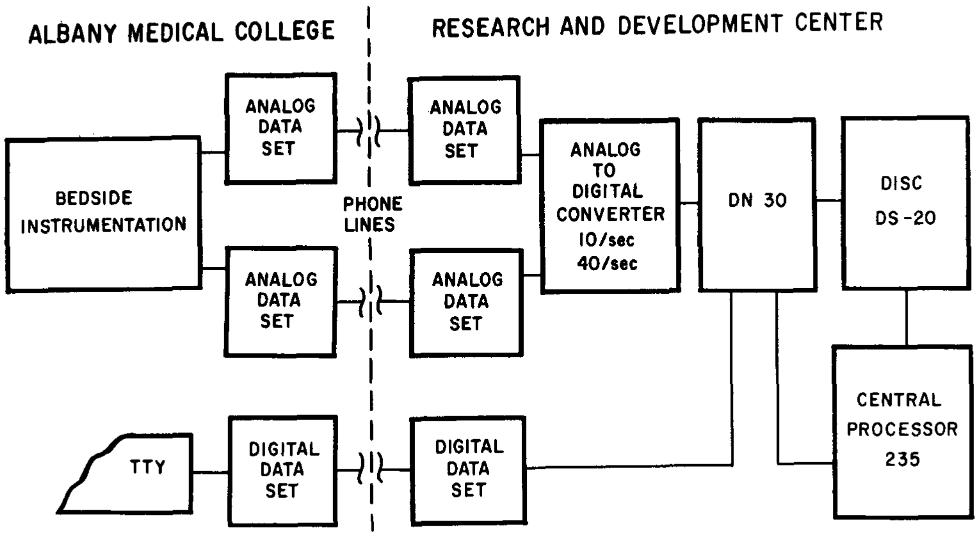


Fig. 8 Electron microbeam probe in which data logging techniques are employed with the GE 265.



ON-LINE COMPUTER STUDY OF THERAPY FOR HUMAN SHOCK PHASE I

Fig. 9 Schematic of on-line computer study of therapy for human shock a joint program with Albany Medical College, Rensselaer Polytechnic Institute, and the GE Research and Development Center.

EXPERIMENT	MANUAL	AUTOMATED	REMARKS	SCIENTIST
MASS SPECTROMETER* PLATE ANALYSIS	16 HRS.	4 MIN	DIRECT INPUT FOR COMPUTER ANALYSIS 40% TO 50% ACCURACY IMPROVEMENT	KENNICOTT (GEN PHY)
ELECTROCHEMICAL ● EXP. DATA ANALYSIS	25 HRS.	30 MIN	PAPER TAPE RECORDING COMPUTER ANALYSIS	BREITER (CHEM SYSTEMS)
X RAY DIFFRACTION EXPERIMENT	10 WEEKS	1 WEEK	PAPER TAPE CONTROL PAPER TAPE RECORDING COMPUTER ANALYSIS	KASPER (MET & CER)
ELECTRON BEAM ●* MICROPROBE	6 MO.	1 WEEK	TTY DATA LOGGER COMPUTER ANALYSIS	LIFSHIN HANNEMAN (MET-CER
JET ENGINE ●* SIMULATION CHAMBER	7 HRS.	2 HRS	TTY DATA LOGGER COMPUTER ANALYSIS 25% IMPROVEMENT IN RESULTS	LIPSTEIN (MECH TECH)
PIEZO REFLECTIVITY●	8 HRS.	30 MIN.	PAPER TAPE RECORDING COMPUTER ANALYSIS FEWER ERRORS	TIEMANN (GEN PHY)
ELECTRO CONDUCTIVITY ● OF GLASS	1 HR.	30 MIN.	PAPER TAPE RECORDING COMPUTER ANALYSIS MEANINGFUL RESULTS ONLY WITH AUTOMATION	WAGSTAFF (MET & CER)

*IS COUPLED DIRECTLY TO COMPUTER
●UTILIZES R&DC BUILT PORTABLE DATA RECORDER

Fig. 10 Typical savings in manpower and time by employing the techniques of the GE 265 System.

EXPERIMENT	MANUAL	AUTOMATED	REMARKS	SCIENTIST
TENSILE TESTING	--	24 HRS	CONTROL OF TEST ON PAPER TAPE. IMPOSSIBLE TO DO EXCEPT BY AUTOMATION	D. LORD (M&C LAB)
POLE FIGURE DETERMINATION	20 HRS	2 HRS	USES INSTRUMENT POOL TTY DATA LOGGER BETTER RESOLUTION	OSIKA (M&C LAB)
HUMAN SHOCK EXPERIMENTS	--	10 MIN	ANALOG INPUT TO COMPUTER THROUGH TELEPHONE LINES USED TO MODIFY TREATMENT OF PATIENTS	RIVEST AND POWERS (ISL) (AMC)
FAR INFRA-RED	6 HRS	1 HR	PAPER TAPE TO TIME SHARING MEANINGFUL RESULTS ONLY WITH AUTOMATION	ROBERTS (G. PHY)
THIN FILM THERMISTOR	2-3 DAYS	2-3 MINUTES	TTY DATA LOGGER	ROHLING (E. P.)

Fig. 11 Typical savings in manpower and time by employing the techniques of the GE 265 system.

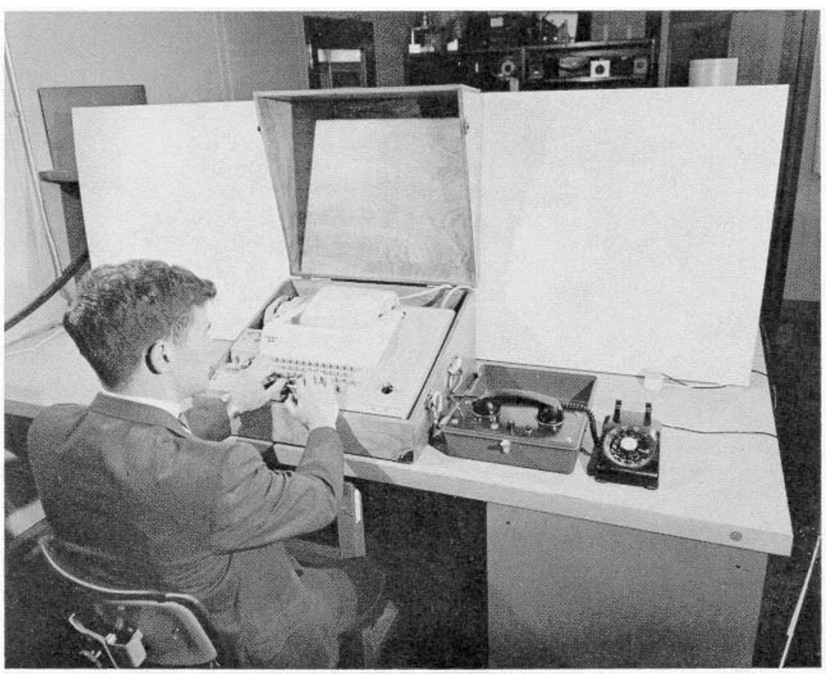


Fig. 12 Special "portable" teletype with acoustical coupler for conversational use with GE 265 system.

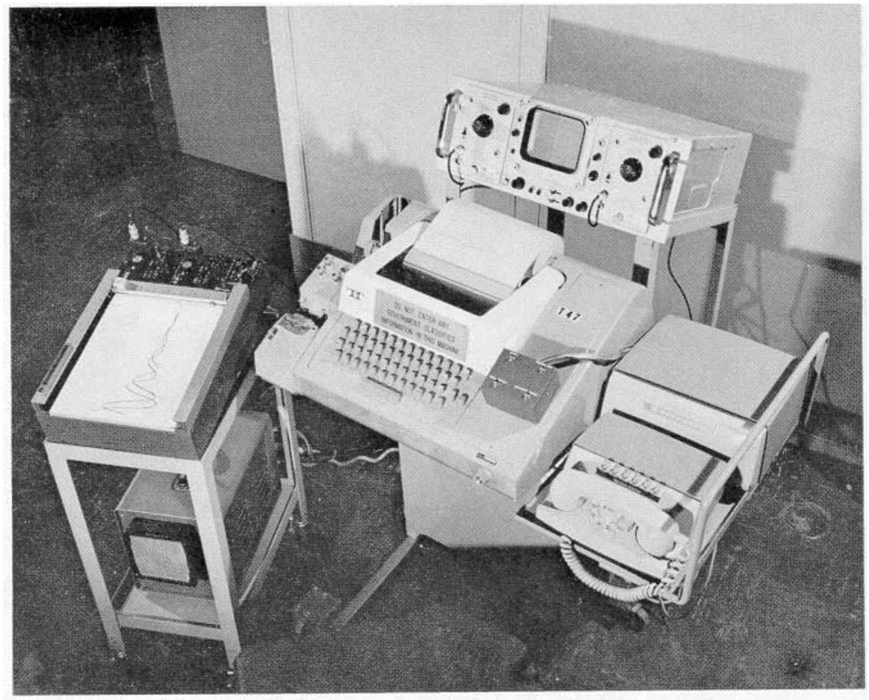


Fig. 13 A remote plotting system with X-Y plotter and memoscope.

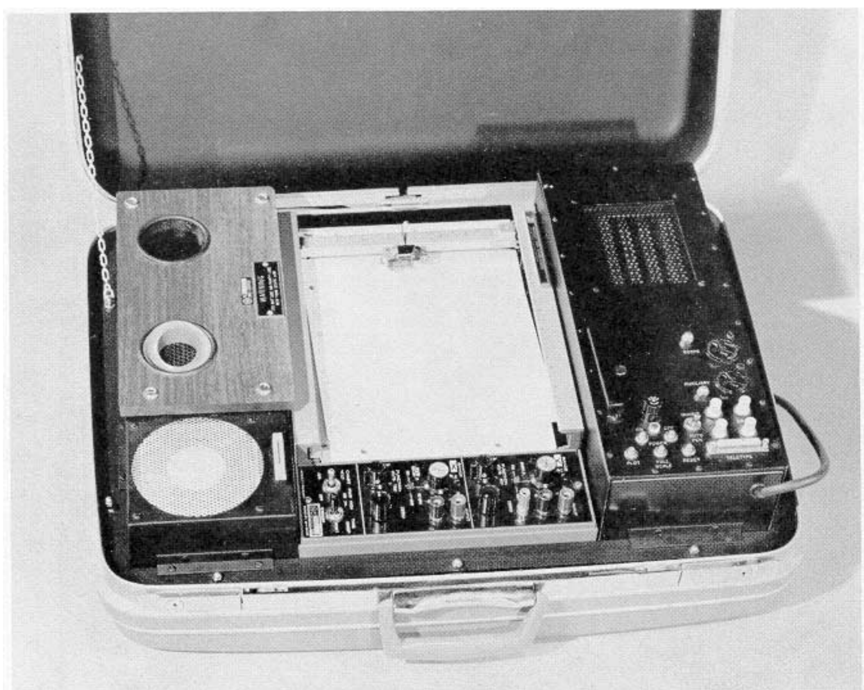


Fig. 14 Remote device packed in a suit- case for off-premise use. See Figs. 12 and 13.

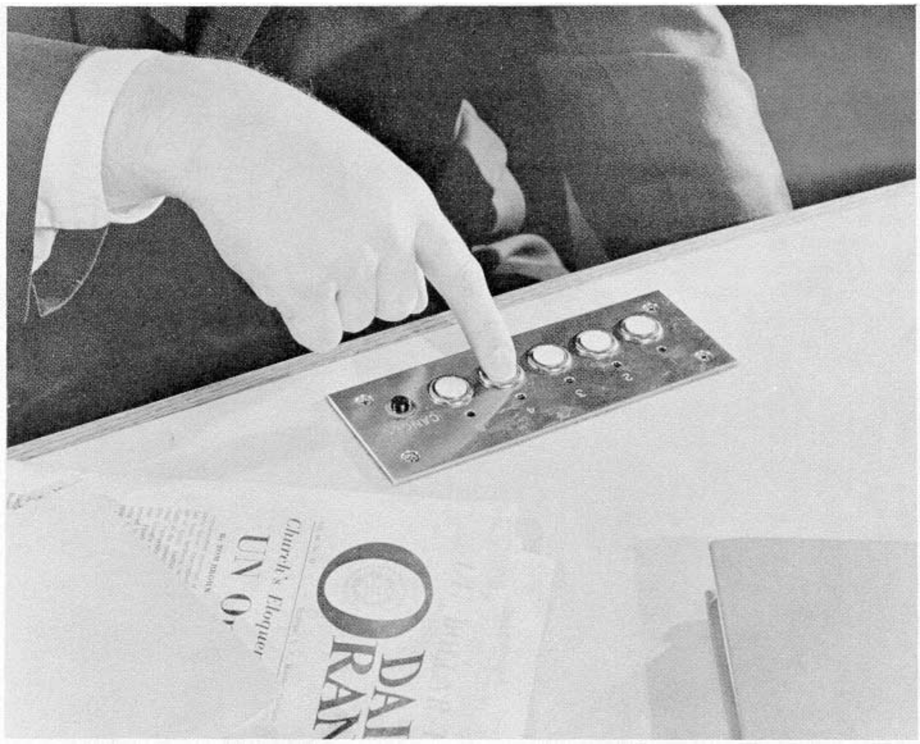


Fig. 15 Student Response System for classroom use. Buttons shown are for recording answers.

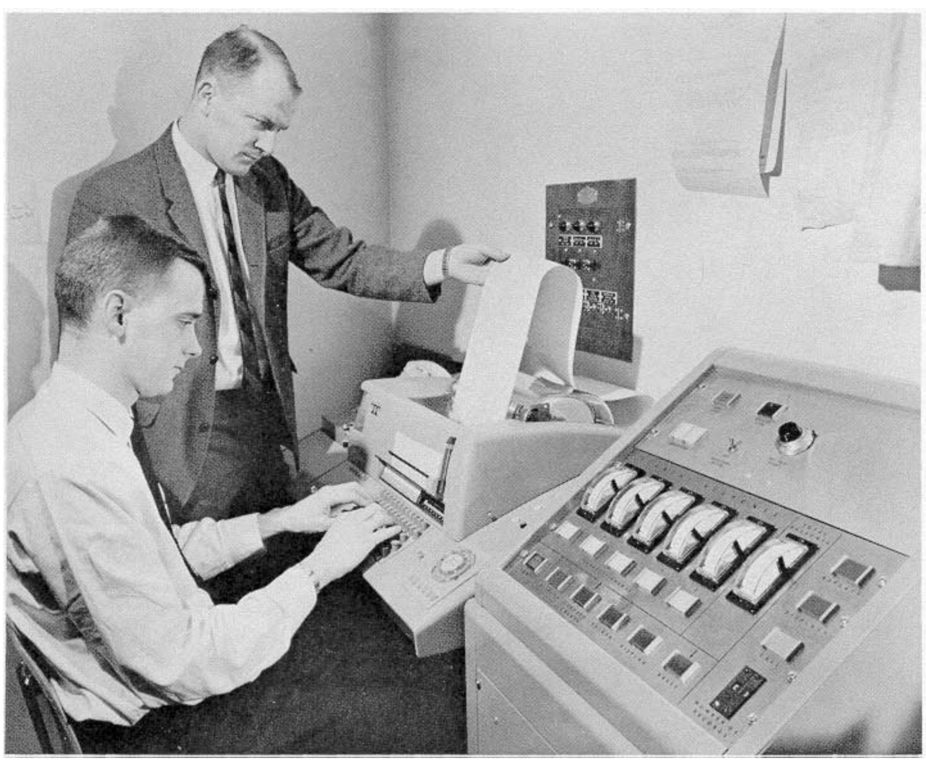


Fig. 16 Teletype for providing students answers to questions used in the Student Response System (GE 235).