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I. Interactive Graphics at the Rensselaer LINAC

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INTERACTIVE GRAPHICS AT THE RENSSELAER LINAC

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Graphic representation of information is not new to science and technology. Point plots or curves representing data in two or more dimensions are a natural language of modern science. The chalkboard or pencil and paper are essential tools for investigators when discussing data. One wonders why interactive graphics is only now beginning to work its way into everyday use in the arts and sciences.

In the reactor physics field it is a case of "sink or swim." The sheer volume of data alone is enough to force an evaluation of data handling techniques, both in the generation of "raw" data from experiment and the subsequent processing and production of useful design parameters. A careful analysis of our particular data handling problems at the Rensselaer LINAC laboratory pointed the way to rapid visual and manual interaction between an investigator and his data.

Basic Philosophy

The ultimate goal of interactive graphic processing is to be able to provide the "lay" scientist (one who has neither the time nor inclination to become an expert in computer languages) with visual control and command over steps in data processing and evaluation. Our approach to providing this facility is divided into two basic steps -- the first of which has been initiated; the second step due to be taken about two years from now.

Step One

The first step consists of establishing a completely self-contained small computer with display hardware. To this end we have acquired a Digital Equipment Corporation Graphic-15 system. This system with the options as we specified provides a live visual display approximately 9" x 11" in size, a "light pen" for entering graphic information directly on the display screen, function pushbuttons to call user subroutines and a keyboard for text or numerical entry of information. (See Appendix for a detailed list of hardware)

Although the system is small, and for this reason its performance will fall short of the ultimate goal, it will be of immediate use to the Rensselaer LINAC program.

Step Two

The second step consists of increasing the computing power and input/output capabilities of the Graphic-15 System by several orders of magnitude in order to meet the projected increased demands of interactive processing. This will be implemented by connecting the Graphic-15 system at Rensselaer by telephone to the AEC Computing Center at the Courant Institute in New York.

The technical approach will be to combine the transmission speed of remote batch operation with the real time capabilities of teletype terminal time-sharing. Figure 1 shows how such a system might be implemented using the Courant facilities. Presently a Honeywell DDP-516 computer handles the information flow between the CDC-6600 and its various remote users.[1,2]

The Courant CDC-6600 offers two types of service to the remote user. One is "batch" mode in which a "job" or deck of cards is entered as a unit into the job input queue. The deck is complete at input time with all commands, programs and data necessary to carry out the calculation. After the job is processed and the required output generated, the job is terminated. Rensselaer LINAC is currently using the remote batch facility with an IBM 1130 computer as a terminal.

Time-sharing is also available. A terminal for time-sharing is a low speed device such as a teletype which allows the operator to converse with a "real time" operating system. Programs are executed, parameters and data are entered, program flow changed -- all at the operator's command from the terminal keyboard. Results are returned to the operator on the terminal typewriter for evaluation. To the time-share terminal operator, his program is on-line constantly interacting, accepting new values from the keyboard, producing requested output -- remaining active until the operator commands job termination.

The proposed remote interactive graphics would be a unique combination of the speed of remote batch and the interactive capabilities of time-sharing. The Graphic-15 system will be connected to the time-sharing system to take advantage of the real time computation. Instead of an operator at a terminal keyboard, however, the Graphic-15 system under program control will handle all the conversational inquiries and responses necessary to operate the CDC-6600 time-share facility. The specific responses and commands given by the Graphic-15 system to the CDC-6600 will be generated in turn by interaction of a different nature between the Graphic-15 and its operator. Figure 2 is a block diagram showing this interaction.

Visual interaction, the natural language of the data evaluator, will be interpreted and converted by the Graphic-15 under program control to the conversational language required by the CDC-6600 time-share system. Results generated by the CDC-6600 will in turn be translated into appropriate graphic responses for the data evaluator. In short, the Graphic-15 system will be a two-way language translator enabling commands, program execution and parameter exchange between the data evaluator with his display screen and light pen and the CDC-6600.

To meet the speed requirements of remote interactive graphics, a 2000 baud dataset will be used, the same type as presently employed in the Rensselaer LINAC Remote Batch Terminal system. The higher speed dataset will allow a "conversation" between the CDC-6600 and the Graphic-15 at a nominal 16,000 characters per minute rather than the normal maximum teletype terminal speed of 10 characters per second.

This approach to remote interactive graphics; i.e., making an interactive graphic terminal look to the CDC-6600 like just an extremely fast typist, has the advantage that all existing CDC-6600 time-share software can be used without modification. Modification and development will be necessary however in the Courant DDP-516 software and hardware to allow the use of a high speed dataset in conversational mode. This sort of application of time-sharing is rather unique and would represent a significant contribution to the art of remote processing. Discussions with Courant staff have indicated the technical feasibility of the approach described, adequate manpower at the Courant end might however be a problem in these times of shrinking funds.

Projected Use, Step One

In the experimental cross-section program, the "Step 1" graphics package will be immediately useful for such mundane, but nevertheless important, operations as determining backgrounds, delineating regions to integrate over resonance line shapes or to take resonance integrals, spectrum stripping, etc.

"Raw" data from runs taken under different conditions can now be compared visually before being summed or discarded, eliminating the former tedious and time-plus-paper consuming task of listing and then comparing lists.

The graphics package will also be extremely useful in comparing our newer results with both ENDF evalutions and other experimental results; it is reasonable to expect that this system will lead to evaluation of specific cross sections at this laboratory. This system will be adequate for many analytical calculations in which accuracies of several percent are acceptable; e.g., R-matrix fits can readily be carried out for nuclides where a single channel dominates and the Doppler effect can be ignored; this would apply to mass ~50 nuclides where s-wave scattering dominates.

Within the framework of "Step 1," limited capability exists to perform theoretical calculations. In neutron cross-section theory, the calculational codes are generally too large for use on a PDP-15. The ability to run these codes on the CDC-6600 and have the output transferred via the IBM 1130 to the PDP-15 does exist for the present hardware. The PDP-15 can then display the CDC-6600 output for visual examination. For cross-section calculations which involve parametric studies and comparisons with reference data sets, the graphical display of output will serve to indicate behavior more clearly and point out side effects not normally detected. Other potential uses of the PDP-15 exist in the area of resonance parameter and cross-section manipulations obtained from our experiments. In the identification of cross-section coupling schemes; i.e., single particle, two particle-one hole, one frequently needs properties of summed-weighted resonance parameter, such as strength functions and energy-averaged cross sections. Displays of such data as energy-averaged cross sections versus energy for different width energy-averaging intervals can both be calculated and displayed by the PDP-15, hence identifying the correct coupling schemes for more exotic calculations on the CDC-6600.

We have in the past made considerable use of the sensitivity of spectra to continuous slowing down theory parameters (age, resonance integral, slowing down parameters) and of the sensitivity of these parameters to basic data. However, sensitivity analysis had to be done tediously by "brute force." Interactive graphics provides the potential for more extensive sensitivity analysis and therefore more detailed cross-section evaluation. We expect that continuous slowing down calculations, perhaps with some modification, are sufficiently simple that they can be performed on the PDP-15.

In the integral data testing program, the interactive graphics capability is expected to play a considerable role both in the processing of "raw data" and in the interpretation of the processed data in terms of assessment of basic cross sections. In the processing of raw data effects of uncertainties in the background, detector efficiency and other corrections necessary to arrive at the final spectrum, can be interactively assessed. The process of combining data from different detectors is better carried out and assessed on the interactive graphics. Large bulk storage capabilities of the PDP-15 make it easy to have quick recall of various spectrum data for comparison. This is particularly important for the integral measurements program where a large number of spectra must be measured and correlated. In the interpretation of processed data, the graphics will be useful in comparison of experimental results with theoretical calculations and in theory-experiment normalization. Adjustments of basic cross-section data or other parameters to obtain a good fit between experiment and calculation will be greatly facilitated by interactive graphics. Particularly useful in this respect will be the capability to recall basic cross-section data to determine areas of uncertainty.

Projected Use, Step Two

Step Two gives us the ability to develop more sophisticated graphic programs for general use by our research group.

Automatic search routines are to be carried out to fit cross-section data which correct for multiple scattering, Doppler effects, resonance self-protection, etc. Stochastic calculations may be carried out in real (or almost real) time and compared with experimental averages. Eventually the graphics package will serve as the general Input/Output device for most of the more sophisticated data processing.

Having the joint capabilities of a CDC-6600 and PDP-15 Graphic system will add new dimensions to theoretical calculations. Within the neutron cross-section theory program, a strong dependence on parametric analysis is inevitable. Whether one is working with R-matrix theory, coupled-channeled or bound state calculational codes, a standard format is to vary certain input parameters representing physical entities in an attempt to fit experimental data or gain a grasp of parameter sensitivity in cross-section prediction. These computer calculations require the capability of a CDC-6600, but now we are in a position to monitor visually our parametric analysis via displays. For example in coupled-channeled calculations, displays of cross sections or strength functions versus imaginary potential strength along with their known experimental values would enable rapid decisions to be made on proper parameter variations, which would be forwarded to the CDC-6600 for further calculations. Also, many times the volume of cross-section output produced is so large that some interesting side effects may go unnoticed. By rapid graphical scanning of such output sets, these side effects can be efficiently detected and further analyzed. With the large storage facilities available on the CDC-6600, it now also becomes possible to display graphically several data sets or post calculational results simultaneously for relative comparisons.

As the on-line calculational capability increases, interpretation and analysis of fast neutron spectra will be further facilitated. Numerical and analytical spectrum calculations can be performed essentially on-line and compared with the experimental results. Sensitivity analyses can also be performed on-line. The greatly increased size of the data bank made available for quick reference should make evaluation of basic data files (in terms of our integral measurements) easier and more comprehensive. The net result is not only increased efficiency in the turnaround time between the time the experiment is performed and the time meaningful interpretation is obtained in terms of basic data, but also an increase in the breadth of analysis.

Performance to Date

The Graphic-15 system was installed at the Rensselaer LINAC and accepted in December of 1971. Already several user programs have been developed for local data reduction. The installation went smoothly and all benchmarks were satisfied easily. DOS-15, the recently developed D.E.C. disk-oriented operating system is in use and running well.

Appendix

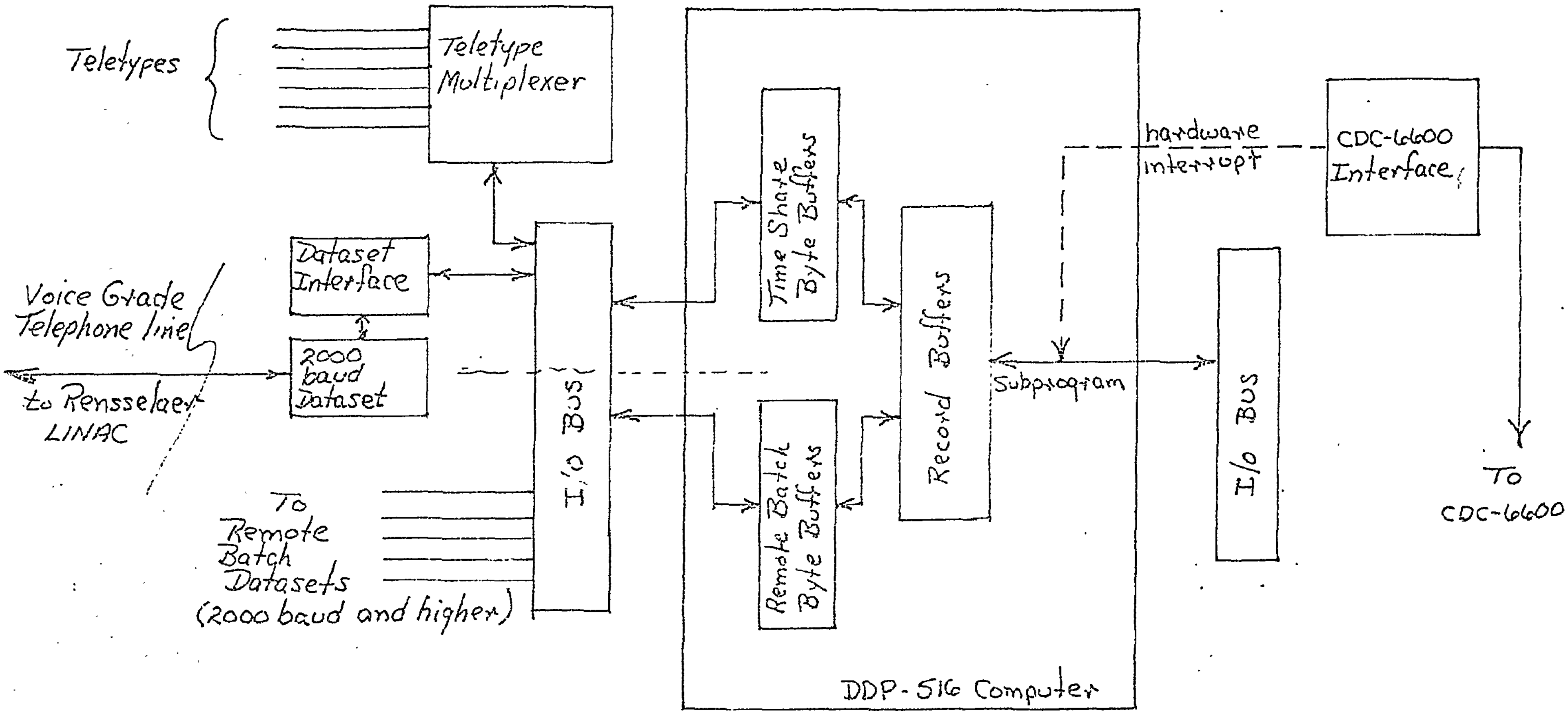
Rensselaer LINAC Interactive Graphic System Equipment List

PDP-15 Computer - 16K words memory
KSR-35 Teletype
Disk memory - 262K word fast access
4 DECtapes
VT-15 Graphic Processor and Console
Light Pen
LK-35 Display Keyboard
6 Function Pushbuttons

REFERENCES:

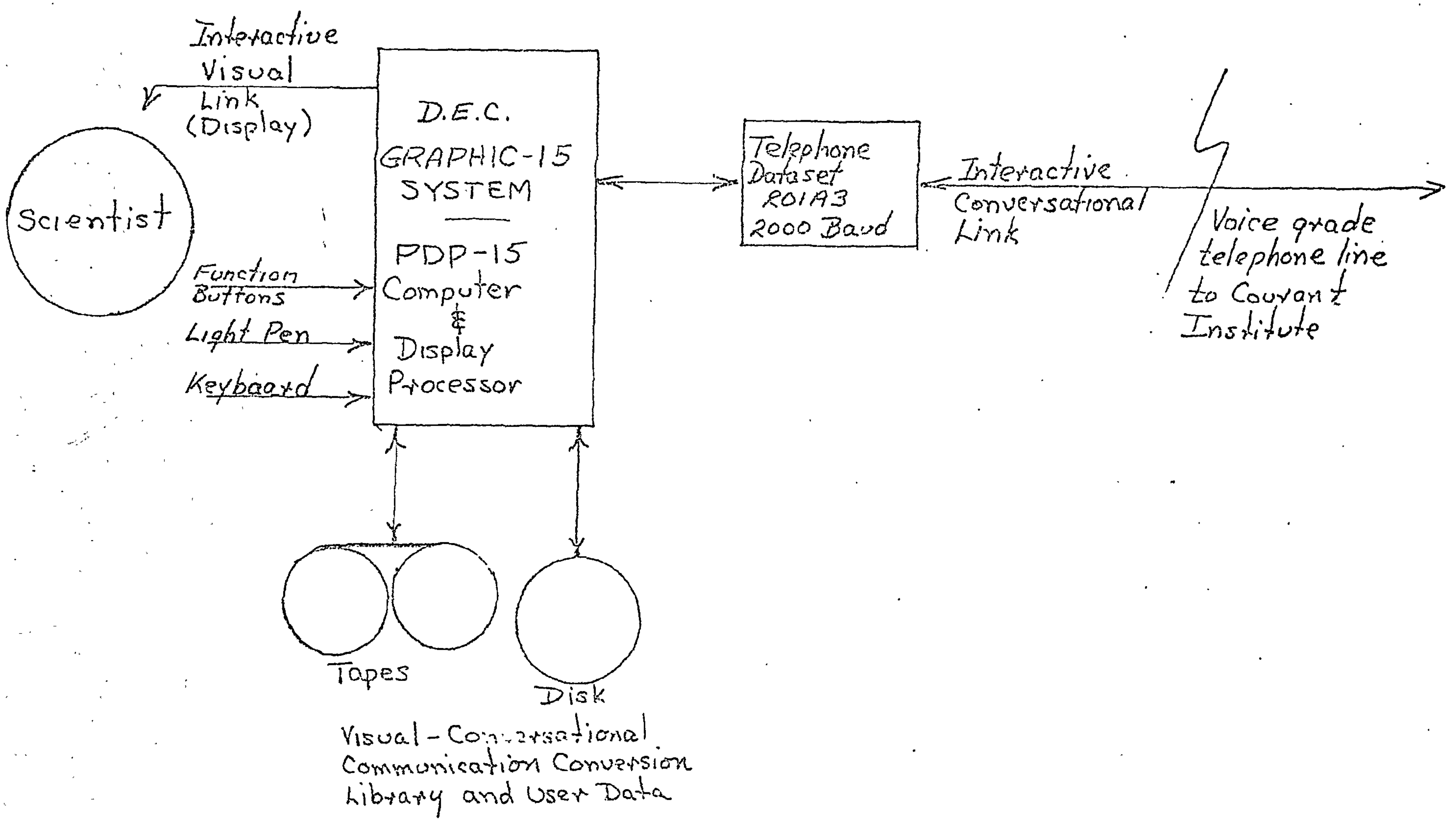
1. "An Interface Between a Control Data 6000 Series Computer and a Honeywell 16-Bit Series Computer," Ronald P. Bianchini, Report No. NYO-1480-119, AEC Computing and Applied Mathematics Center, Courant Institute of Mathematical Sciences, New York University.

2. "A Remote Entry System for the CDC-6600," E. Franceschini, Y. Feinroth and M. Goldstein, Report No. NYO-1480-148, AEC Computing and Applied Mathematics Center, Courant Institute of Mathematical Sciences, New York University.



Data Flow Paths Through Courant DDP-516

Fig. 1



Information Flow Through Rensselaer Graphic-15 System

FOUR YEARS OF REMOTE BATCH OPERATION FROM THE RENSSELAER LINAC TO THE COURANT INSTITUTE CDC-6600

W. R. Moyer

The Rensselaer LINAC remote batch terminal to the Courant Institute (N.Y.U.) CDC-6600 has been in use for over four years at this writing. It is the purpose of this report to review the terminal system development and to make note of technical accomplishments since its inception.

Background

During the past decade the character of experimental work at the Rensselaer LINAC has changed dramatically. The multichannel analyzer capable of 1024 channels of pulse height or time-of-flight recording has given way to the small on-line computer. Instead of 1024 channels of information being recorded, it is not uncommon today to see several hundred thousand channels being recorded simultaneously. Even though the number of channels recorded per measurement has increased, the great efficiencies effected by the use of automated data acquisition have allowed more measurements per man year -- generating even more experimental data. All these data must be processed in some fashion to extract the desired measurement parameters.

Advances made in our understanding of the physical processes involved in a measurement make even greater demands upon the data processing facility. Not only do we have more data to process, but we have to do more to process each point.

The combined effect of greater experiment complexity, large amounts of data produced and the greater demands of data evaluation is clear. Access to a large, fast computer is absolutely necessary.

Our first on-line data acquisition computer started producing data in 1964. By 1966 we were beginning to feel a real pinch in our data processing capability. The "in-house" IBM 1620 was no longer able to meet the demands of data processing as well as theoretical calculations. We contacted the Courant Institute at N.Y.U. about the use of their control Data CDC-6600. The Courant machine looked very attractive. It had the memory capacity, speed and magnetic tape storage which we needed. We estimated that our entire data processing load for a year (1968) could be handled, using a total of 25 hours if it could be done on the Courant machine. We had the blessings of the AEC and Courant staff to use their facilities. After several months of experience with the Courant machine, it became apparent that the 160 miles which separated us posed an insurmountable hurdle. One obvious problem of using such a distant computer facility is of course the travel time by car or train -- nights' lodging if necessary. Another problem is the turn-around time; i.e., the span of time from problem submission to return of results. Turn-around time in our case was measured in hours, while the typical problem submitted took less than 40 seconds of actual machine time. A Programmer travelling to Courant was lucky if he could get three passes of a problem through the computer in a day.

Other problems with commuting to a distant facility appeared. It is usually true that the person who writes a processing code is the most familiar with its content and idiosyncrasies. To achieve even the three pass per day level, it must be the author or prime user himself who travels to the computer site; for a messenger would likely not know how to correct the errors in program or input data which frequently occur.

A final, and possibly most serious flaw in travelling some distance to a computer center is the separation between the point of problem submission and the researcher's primary data, records and familiar references. Frequently a computer result will raise a question which can only be answered by reference to notes "back at the lab." This situation usually results in a colossal waste of time.

Discussion with the Courant staff led to our interest in the possibilities of a remote terminal system capable of operating in batch mode into the CDC-6600.

Remote Batch

The difference between a "remote batch" terminal and a "time sharing" terminal should be made clear at this point. Time sharing is usually carried out with operator-machine interaction via a teletype terminal or equivalent. Interaction is usually conversational with the operator supplying abbreviated commands and input data while receiving output information in real time.

A remote batch terminal as far as the operator is concerned is functionally identical to the main system card reader and line printer. Jobs are loaded complete with system command instructions, programs, data, etc. as an integral input file. After the entire job is processed, output is available in the form requested by input commands. No attempt is made to interact in "real time." The remote batch form of operation was decided upon.

Communication Link

Establishing the form and mode of communication required the close cooperation of both ends of the proposed link. Based upon speed requirement and initial cost among other factors, a single voice grade private line leased through G.S.A. was to be used from Manhattan Island to Albany, New York. The system was to be "dial-up" so that we could telephone other datasets if we should desire, and so that the dataset at Courant could be dialed by other users. The maximum speed dataset supplied by the Telephone Company for this type of line is the 201A series datasets clocking synchronously at 2000 baud (bits/second). Courant selected a 201A3 dataset with internal clocking. Any equipment which we would select would have to be compatible with this dataset.

Hardware

A market survey was initiated to see what equipment could be used as a remote batch terminal. Among factors used as a selection guide, the following were prime:

(a) The system should be compatible with the Western Electric 201A3 type datasets.
(b) The entire system should be commercially available so that the system could be easily duplicated by other users.
(c) The terminal should be as versatile as possible to take advantage of communications software developments at Courant.

Two possible approaches were seen. One was that of a hardwired or fixed program terminal; the other a general purpose computer with communications capability. Each approach has its strengths and weaknesses.

I. Hardwired Terminal

con:

-- handles limited character set
-- fixed record length usually one line or card
-- speed limit about one line or card per second on half duplex

pro:

-- turn-key operation
-- about half the cost of computer approach
-- when not being used as a terminal, it can list or duplicate decks
-- Courant was initiating a program to communicate with a Univac DCT-2000, a hardwired terminal

II. Computer with Communications Capability

con:

-- greater cost than hardwired terminal
-- extensive communications software development required

pro:

-- character set unlimited
-- binary transmission possible
-- record length not fixed
-- with software, the computer can be made to imitate any hardwired terminal
-- when not being used as a terminal, it can run local jobs in FORTRAN IV for data formating, etc.
-- larger choice of peripherals

The decision was to opt for the more versatile computer system -- the logical candidate being at that time an IBM 1130 with a synchronous communications adapter, a card reader/punch, line printer, disk and calcomp type plotter. The particular configuration chosen is given in Appendix A. Software development for the terminal was carried out at the RPI LINAC site with the close cooperation of Courant staff. IBM offered software development assistance, but was of little help due to the unusual nature of the application.

History

The system was operable as a computer as soon as it was delivered. Immediately users began to make use of the data formating (such as paper tape to card conversion) and graphic output capabilities of the IBM 1130. Software development was begun to make the IBM 1130 emulate a Univac DCT-2000 hardwired terminal. The first successful transmission from the IBM 1130 card reader, through the telephone line, through the interface system at Courant*, directly into the CDC-6600 job input queue took place in the fall of 1967. Two-way communication was established in December 1967. Two other

*"An Interface Between a Control Data 6000 Series Computer and a Honeywell 16-Bit Series Computer." AEC Computing and Applied Mathematics Center, Courant Institute of Mathematical Sciences, New York University, NYO-1480-119 October 1969.

AEC contractors with similar IBM 1130 configurations were supplied with the software developed at Rensselaer. No problems were encountered and they were able to communicate with Courant immediately. In return, one contractor (Brandeis) modified the software package to transmit binary records, taking advantage of software improvements effected at Courant. Brandeis transmitted the modified package to us by telephone via the Courant CDC-6600.

Performance

The effect of direct access to the innards of the Courant CDC-6600 was dramatic. Within months after the link was operational all major computing at the Rensselaer LINAC was being done on the CDC-6600 via the IBM 1130 terminal. Although there have been many performance improvements at both ends of the telephone line, the basic philosophy of the terminal operation has remained unchanged. Current performance specifications are given in Appendix B.

Jobs entered into the terminal go directly into the CDC-6600 operating system queue and are handled just as if they had been entered on-site. The person who submits the job can interrogate the status of his job at any time through simple keyboard commands. Output can be received at the terminal in the form of listings or punched cards. Output may also be directed to any peripheral device at Courant under the control of the operating system. Through the operating system the terminal user can request his tapes to be mounted, his job proceeding from the point of request after the CDC-6600 operator has mounted the requested reels. Virtually any user program which can be run at the CDC-6600 site can be run from the remote terminal with much less turn-around time and greater coupling between the user and the 6600 operating system.

Aside from the great benefit of having access to -- but not having to staff or maintain -- a CDC-6600, a number of incidental side benefits to the terminal user are worth noting. Software development is expensive and LINAC data is irreplaceable. Our usual operating procedure is to store primary data and programs on cards or tape at the terminal site. These data are transmitted once to Courant and stored on tape for processing as needed. Thus important information exists in two physically separate locations eliminating the chance of information loss due to physical catastrophe.

A remote terminal user can communicate with other remote installations via the CDC-6600 independent of the type or speed of terminal at each remote site -- a great opportunity for software sharing.

The remote terminal on a "dial-up" telephone line is not limited to communicating with only one computer center. This is especially true of the more adaptable computer system terminal compared with the hardwired terminal. Two experiences show the possibilities. The first occurred when the Courant CDC-6600 was scheduled for an extensive maintenance period. Within a week the Courant staff had interfaced another CDC-6600 somewhere else in Manhattan to the telephone system. By dialing another number it was "business as usual" for us.

As an experiment in versatility of our IBM 1130 terminal, we made arrangements with EDP Resources, Inc., a commerical computer service outfit, to phone into their IBM 360/95 in Canada. In the time it took to place the call, a remote job entry program was loaded into our IBM 1130 and a test problem run on the Canadian machine.

Reliability

When considering the reliability of remote batch operation, usually the big unknown is the communications link over which one has little control. In the past twelve months we have lost less than five hours of access time due to telephone problems. Line problems have been easily detectable and have usually been corrected within two hours of notification to the Telephone Company repair service.

Sporadic errors due to impulse noise or short duration bursts are detected by communications software and record re-transmission is initiated. The error rate is low -- less than one error per day. There has been no evidence of any errors which have not been detected and corrected by the communications software.

Summary

Remote batch operation from the Rensselaer LINAC to the Courant Institute CDC-6600 has been very successful. Probably the greatest tribute to the capability of remote batch processing is the fact that the Courant Institute staff itself uses a remote terminal for in-house processing and operating system development. Any conceivable user program which can be run "on-site" can be run on a remote batch terminal.

Appendix A

Rensselaer LINAC Remote Batch Terminal

IBM 1130 Computer consisting of the following components:

1131	Model 2B Central Processor	8K core
1132	printer 120 column	
1134	paper tape reader, 50 characters/second	
1142	Model 7 card read punch	
1627	Model I plotter	
7690	synchronous communication adapter	

Appendix B

Rensselaer LINAC Remote Batch Terminal to Courant CDC-6600

Performance Summary

Dataset type:	201A4 (2000 baud, half duplex)
Carrier:	dial up - voice grade leased telephone line (G.S.A.)
Distance:	about 160 miles
Mode:	binary synchronous communication
Speed - xmit:	about 16,000 card columns/minute A typical FORTRAN program transmits at the card reader limit of 400 cards/minute Full 80 column data cards run at the worst case speed of about 200 cards/ minute
Speed - receive:	about 1 line per second Speed limitation is due to the terminal 1132 printer A typical FORTRAN listing could be received at 400-500 lines/minute given the appropriate printer. The cost of a faster printer could not be justified in 1967 when the system was experimental. Lack of funds preclude it now
Speed - punch:	about 2 cards/second limited by the terminal 1442 punch mechanism
Data modes:	any -- since transmission mode is binary. Records assembled in the IBM 1130 terminal prior to transmission are in CDC-6600 60 bit internal format
Error rate:	Detectable errors due to telephone link -- less than one character/day