Final Report
Remote Terminal Subsystem Development Program

by

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The University of Minnesota

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I. Introduction

The purpose of this report is to document the medium-speed remote job-entry subsystem developed by the University Computer Center engineering group under the leadership of Professor R. P. Halverson, UCC Director, 1971-73, and Professor A. Franck, UCC Assistant Director for Engineering. The report was written primarily by John Hoerning who served the development project as a consultant in the areas of data communications technology and data compression. His expertise with the UNIVAC 1004 was a major factor in the success of the program. Professor P. C. Patton, the current UCC Director aided Mr. Hoerning in the editing and preparation of the report and wrote this introduction as well as Section II on the mission of the University Computer Center. Credit is also due Lawrence A. Liddiard, Assistant Director, Systems, who was responsible for the programming effort on the CDC 6600 and the PDP-11.

The RJE subsystem was designed to meet the demand for a greater volume of remotely entered jobs and a greater dispersal of RJE stations throughout the campus. The availability of a number of commercially outdated UNIVAC 1004 terminals at an attractive price provided UCC an opportunity to achieve a cost/performance breakthrough and thus the means to provide a higher degree of remote entry service to users.

Although the opportunity to obtain and refurbish these machines was taken enthusiastically it was not done without due consideration of other alternatives. So rapid is the growth of data communications technology, one should document a development project carefully enough that later users and managers will know why early choices were made; only then can they further evolve the system in a rational cost/effective manner. It should also be noted that although the development project proceeded in an atmosphere of enthusiasm, it was not always one of unanimity. The use of 1004s and even of medium speed terminals at all, for remote job entry had its critics. We hope that this report and the performance of the system will overcome any remaining reservations among UCC staff and the user community.

The first two years of the development program were devoted to the design and development of the CDC 6600 SUPIO communications program, a 6600 I/O channel to PDP-11 link, the PDP-11 programs and, of course, to reviving a number of aging 1004 terminals. Current effort is devoted to maintaining and extending the present system and planning for an augmentation which we are planning to make the subsystem extremely reliable. The present link developed some minor but unfortunately intermittent problems recently after working virtually error free for more than a year. A six week effort to repair this device has encouraged us to continue to development of a previously redesigned version of the link. We hope that this new dual port doubly redundant link plus a standby communications processor and switched data bussing will provide the medium speed remote terminal user the same quality of service that the high-speed terminal user and the central site user enjoy. Since 100% communications front end redundancy by means of a standby processor is difficult to justify in a university research and instructional computing center, we plan to use the standby communications processor to control an electrostatic printer/plotter, a Calcomp ink and pen drum plotter, a paper tape reader/punch, and perhaps a low performance, nine track, high density magnetic tape transport.

It should also be noted here that the PDP-11 is able to accept 2000 baud dial up 1004 and CDC 200 User Terminal units at present but will shortly be expanded to handle Data 100 terminals via 4800 baud dial up lines and the new 1200 baud asychronous Teletype Dataspeed 40 terminal. Long range plans call for all medium speed terminals to utilize 4800 baud dial up lines.

II. The University Computer Center

A. Function

The University Computer Center (UCC) serves as an all university facility for instructional and research computing. UCC is one of the computer centers within University Computer Services; it serves not only individual computer users inside and outside the University but also provides a degree of computing "power" to other centers such as the West Bank Computer Center and the Computer Centers at the Duluth, Morris and Crookston Coordinate Campuses of the University.

B. Structure

The Lauderdale central site facility consists of CDC 6600, ancillary equipment, and the CDC 6400 managed by UCC for MERITSS. The 6600 configuration consists of

6600 Central Processor
10 Peripheral Processors
64K Words Main Core Store
250K Words Extended Core Store
841-7 Disk File
2 - 6603 Disk Files
1 - 3423 Magnetic Tape Controller
4 - 606 Magentic Tape Transports
4 - 607 Magnetic Tape Transports
2 - 3256/501 Printers
1 - 3447/405 Card Reader
1 - 3446/415 Card Punch
1 - 6674 Telpak Modem Controller

During the next twelve months the system will be upgraded by exchanging the 841-7 disk file system and the 6603 systems for a 7054 Disk Controller with five 844 Disk Drives. The magnetic tape transports will all be upgraded to the latest 607 specification and the main memory extended to 96K.

The staff of UCC is organized into three basic areas: 1) System Development, 2) Applications and User Services, and 3) Operations, Maintenance and Engineering Development. These areas each fall under the cognizance of an assistant director. Operations, user services, operating system, and administrative services are each overseen by a service area manager. In addition the statewide timesharing system is operated by UCC and managed by a team of UCC staff members.

The MERITSS management team consists of a full-time manager, system programmer and consultant plus part-time service of six or more UCC staff members. MERITSS terminal users have the potential for accessing the 6400 for remote file entry and limited output return to their terminal. The two machines share a common ECS (extended core store) unit, however, the software development to achieve full use of this feature awaits application requirements.

C. System Performance Requirements

Currently the CDC 6600 handles about 2500 jobs a day for some 7500 users and has the potential to perform 5000 or more such jobs, most of which are small student jobs. Of the current workload about 25% are entered at the central site, about 50% are entered via high speed terminals and some 25% are entered at remote job entry terminals. Over the past few years at least two definite trends appear in the UCC usage statistics: first there is a noticeable increase in the fraction of utilization (on a per job basis) devoted to instructional, rather than research, computing. Since 1968 the 6600 per job usage mix has grown from 40%/60% usage for instruction/research to the current ratio of 50%/50%; second a more recent pattern is developing regarding the ratio of remotely entered jobs. As the number of remote job entry terminals has increased the fraction of jobs entered on medium speed terminals has increased to 25% of the total. As the medium speed remote terminal subsystem grows and becomes more solid, we expect this fraction to increase to 40% of the total.

Computing demand is naturally high at the end of each quarter. In a recent quarter-end month UCC handled nearly 60,000 jobs with an average turnaround time of 35 minutes. Computing service was provided for twenty hours each week day plus twenty hours over the weekend for a total of 120 hours a week.

The intent in the development of the medium speed remote job entry terminal subsystem is to provide a widely available computing capability with a turnaround of 15-30 minutes in off-peak period. Naturally turnaround will tend to suffer somewhat during quarter-end peak periods.

III. Remote Job Entry vs. Central Batch

A. Central Batch

In general a central batch entry system offers the maximum in performance per dollar. In this mode of operation all users either take or send their jobs to the central site. When they reach the central site they are loaded into on-line input equipment for entry into the system. This offers several advantages. Costs are nearly always lower from an equipment standpoint. A far less sophisticated operating system is required. It is easier to monitor input data if it is all queued at a single point.

However, all these advantages in terms of hardware economy and operational simplicity are gained primarily at the expense of the user. He pays a heavy price in terms of the availability of the machine to run his job, travel time to and from the computer site, and substantial delays in turnaround. If the site is fairly distant the average user may be able to utilize only a small percentage of the machine's power. For a given user's job a large powerful machine located distantly may appear to be less powerful than a small, slow machine located conveniently.

In the case of University Computer Center (UCC) of the University of Minnesota (UofM) this computer site is located a substantial distance (about 5 miles) from the main campus. Although there is bus service this is still a major time lag if a user is to input his job directly at the computer site.

B. High Speed Remote Stations

As a result of this problem it is fairly common for large systems to provide a high speed remote station at points convenient to a large number of users. Jobs are input at these sites, where they are batched together and transmitted to the computer center over wideband telephone lines. After being run the results are transmitted back for printing at the high speed station. Although the equipment and lines to accomplish this are expensive and additional personnel and space are generally required, the user can expect a substantial improvement in performance as measured in turnaround time as well as a large increase in personal convenience and time available to perform his work.

On the negative side, besides the expense, there are now several places where his job is queued, one at each high speed station and one at the computer site. This offers several possibilities for a scheduling delay. The high speed batch station is far more convenient since it is now usually within walking distance but may still require a considerable walk.

The other consideration concerning high speed batch stations is the operation level required to maintain efficiency. This class of terminal is usually quite expensive and utilizes a wideband telephone channel. Since the wideband channel is somewhat faster than the normal peripherals a certain imbalance exists. Very tight operations and scheduling are necessary to pass enough work through to justify the cost. This normally requires professional scheduling and operation and precludes a direct user interface. Also, a substantial amount of space is required.

At the UofM two high speed stations have been in operation for some time. One is on the main campus, and the other on the West Bank campus. The size of the UofM campus is such that these are still outside comfortable walking distance for a large number of users. The St. Paul campus is not yet serviced by a high speed station. Neither are the outlying campuses such as Duluth, Crookston, Morris, and Waseca.

The high speed station at Experimental Engineering is a CDC 8090 computer with a 1000 lpm printer and a 1200 cpm reader. This is perhaps the most common type of high speed station. It is connected by a wideband telephone channel which is equivalent to 12 voice grade channels.

The high speed station at West Bank is a CDC 3200 which is a medium speed computer in its own right. This computer is used primarily for direct processing but also funnels data to the CDC 6600 at Lauderdale.

C. Medium Speed Remote Job Entry Terminals

This type of device, known as a remote job entry terminal (RJE) or remote batch terminal (RBT), is the next step in decentralization of computer power. Much cheaper per site than the above types, it normally runs on a regular voice grade line, frequently a dial-up line. From the user's standpoint, these have many advantages over the other alternatives. A network of RBTs insures that one is always nearby. Usage on a single unit is usually light enough to guarantee little or no wait and jobs may run singly, or batched. Most are simple enough to be run by the user and require no staff. Although space is required, it is not extensive and normal office environmental conditions are adequate. To the user running the terminal himself, it is very similar in procedure and turnaround to what one would expect from a small computer, but with the power and flexibility of a large system.

D. Conclusion

For the purpose of distributing large system power to the small user, one who is not a full time computer professional but still needs a substantial amount of computer capability, especially in terms of input/output, the RJE terminal is far more suitable than the other alternatives mentioned. A large system with perhaps 25-30 RJE terminals and several high speed remote stations can do an excellent job of utilizing the economy of scale present in the large computer and still provide the convenience and turnaround advantages inherent in multiple small computers.

This conclusion is consistent with the conclusions of the study "Computers and Information Systems in Higher Education" by P. G. Roll and P. C. Patton, concerning the use of computer systems in higher education within the State of Minnesota. The progress in the terminal area by UCC will be evaluated against that aspect of the plan presented in the above document.

IV. Alternatives

A. Basic Alternative

Although there is a large number of possible alternatives as far as equipment is concerned, these alternatives are severely limited for several reasons. In general each manufacturer's interfaces are different and therefore, equipments from different manufacturers do not readily mix. Even if the equipments are modified to become compatible, the manufacturer will generally not service them.

Therefore, before even considering equipment alternatives we must consider a far more basic alternative. We must either be content to accept whatever equipment a given manufacturer provides or we must be willing to establish a facility which is capable of designing, producing, modifying, and maintaining equipment. Therefore, let us consider these as alternatives One and Two.

Alternative One assumes accepting only the equipment which is supplied and serviced by the mainframe manufacturer. This assumes little or no hardware capability exists at the user level. Prior to this time such capability had long existed at UCC at the software level.

Alternative Two assumes that UCC will extend its hardware capability to a level equivalent to that of its software capability. This assumes establishing the capability of hardware design, production and maintenance.

Let us now discuss the two alternatives in greater detail.

B. Alternative One

On the UofM system, a CDC 6600, our course under Alternative One is rather limited. Most likely it would consist of keeping the CDC 6671, adding an appropriate number of CDC 200 terminals, and tying them to the telephone system through Bell 201A modems. This procedure would provide a workable system; however, certain problems do exist.

First, in order to meet the requirements of the plan presented in "Computers and Information Systems in Higher Education", a rather large number of terminals will be required. The cost of this approach must become a major consideration. Under Alternative One there was little flexibility because of the specific interface requirements of the CDC 6671. The CDC 6671 supports only CDC terminals or those which emulate CDC terminals. On this system this left the CDC 200 as the most likely terminal.

Second, the CDC 6671 was in itself a problem due to the requirement for two 6600 Peripheral Processor Units (PPU) to control it. UCC was very short on PPUs and while a cost per PPU could be derived, no additional PPUs could be added to this particular system. Also doubts existed concerning how many lines could be successfully run.

Third, although the Bell modems were quite adequate, they were much more expensive than those offered by a number of independent suppliers.

C. Alternative Two

There are many problems associated with establishing a facility to perform the functions described as Alternative Two. There are also some very significant advantages.

First, by designing an interface between the CDC 6600 and a PDP-11, the overall flexibility of the system could be greatly enhanced. This approach would not only allow expansion to a far greater number of terminals than was previously possible, but would also add the capability of interfacing to many different types of terminals. Since the PDP-11 is a programmable device, interfacing a new type of terminal could be accomplished by making software changes.

Inherent in the advantage just discussed is the ability to consider many different types of terminals in order to find the most cost effective solution. The primary terminal considered under Alternative Two was the Univac 1004. This terminal is readily available on the used market at very reasonable prices. It has excellent peripherals and provides limited off-line programming capability (not available on most RJE terminals). It comes in two different peripheral speed ranges. The only major problems were 1) the model generally available was the small machine, which could not run the Univac terminal program and 2) the available units did not contain the required data line terminal (DLT). Solution to these problems would require developing a DLT at UCC and developing a terminal program to run on the small machine as well as considerable software modification on the CDC 6600.

In addition to the major cost advantage to be gained by allowing wider choice of terminals, the PDP-11 would allow the release of the CDC 6671, as well as the release of a badly needed PPU back to the operating system. This would, in turn, increase the throughput of the CDC 6600 system.

Inherent in Alternative Two was the economy as well as the necessity of establishing a maintenance program for the PDP and the terminals. This program would also make it advantageous to use an independent modem instead of the Bell 201A. Use of independent modems is quite cost effective but usually requires that a user supply his own maintenance program in order to realize maximum savings.

In addition to the advantages in cost and flexibility, a university must always consider the fact that development programs such as represented by Alternative Two offer valuable training as well as part-time employment to a number of students. This includes students in programming, engineering, and other fields. Both graduate and undergraduate students are utilized.

D. Other Alternatives

Although the two basic alternatives exist as described, under each there exists an almost infinite number of sub-alternatives. Each has an option under each of the basic alternatives.

Among the sub-alternatives are a very wide choice in equipments, lines, and basic approaches such as online, high speed stations, medium speed stations and combinations of these.

In general though, the decision is fairly clear cut. It is a major step to establish the capability required by Alternative Two and should not be taken lightly. However, if this capability is established it usually makes sense to expand it as far as is feasible in the interests of economy.

E. Conclusion

The decision was made to proceed with Alternative Two. It was felt that the economics inherent in this approach far more than offset the disadvantages. Later in this report, the two alternatives will again be compared, in retrospect.

V. Project History

By mid 1970 the remote job entry program was already well under way. The high speed batch stations at Experimental Engineering and West Bank were already in and running. Investigations of various types of medium speed batch terminals were being performed. The report "Computers and Information Systems in Higher Education" was nearly complete. A large part of this report was dedicated to analysis and plans regarding remote job entry alternatives.

At about this time St. Thomas College became the first medium speed terminal user on the UM system by using a CDC 160A emulating a CDC 200 terminal. This entered the CDC 6600 through a 6671 communications interface. Shortly thereafter the University purchased a CDC 200 terminal for use on the CDC 6600. At this point, although the total medium speed usage was small, the base for the current communication system was established.

At this time the system was working well but several problems existed. First was the CDC 6671 which was strictly a 16 port character multiplexer. Although this device interfaced a large number of lines its overhead against the system was high. It required 2 PPUs on the 6600 to provide the logical line control it lacked. These PPUs were badly needed for other system functions. To expand the number of PPUs on the system seemed out of the question as the quoted price was $317,000.

One possible solution would have been a complete rewrite of the CDC I/E (Import/Export) 200 program which drives the 6671. This was an inefficient program which could have been improved considerably. However, even with this improvement potential upgrade would still be limited and the 6671 support would still impact the overall efficiency of the system.

In addition to the support drain of the 6671, another problem was apparent. The 6671 was limited to support of only one type of medium speed RBT, the CDC 200. This made any type of terminal mix impossible, as well as communications with other installations which did not use CDC equipment. Clearly, a device with more flexibility, less PPU support, and hopefully less cost, was badly needed.

CDC responded to this need by quoting a CDC 1700 front end processor. This would fulfill the need but cost $200,000. This cost did not include the software which would have been substantial.

Several other alternative front end processors were considered. The one finally selected was the PDP-11, which offered a good balance of the necessary requirements at a low cost. This project was started in late 1970. To use this front end required that substantial software changes be made on the 6600 and on the PDP-11 and also that a "link" be designed and built by UCC to allow the PPU to talk to the PDP-11.

The PDP-11 front end went into production use in mid 1971. It allowed release of the 6671 back to CDC and of one PPU back to the system for other processing. Eventually it will allow the release of a second PPU and will share a PPU with the unit record equipment. Although it is hard to quantify the value of the PPU released back to the system its overall effect is probably far greater than the dollar value of one PPU and one 6671.

Although the implementation of the PDP-11 did result in a substantial cost savings, its most important advantage was that now, for the first time, communications with any other manufacturers equipment was possible. Direct communications between the CDC 6600 and the IBM 360/50 at Administrative Services or the Univac 1106 at Mankato were now feasible.

This facet of the PDP-11 had particular impact in the Medium Speed Batch Terminal (MSBT) area. Although the CDC 200 terminals worked well, they were quite expensive. Expansion into a remote network of the magnitude planned was out of the question using this terminal. What was needed was a MSBT with performance comparable to the CDC 200 but much lower in cost, which would allow expanding the network greatly and make it possible for students to run their own jobs via the terminals.

For some time prior the University had been evaluating the Univac 1004, which was no longer being produced. This machine had been quite successful as a terminal to various Univac computers. Many machines were available on the used market at reasonable prices. All normally needed peripherals were available and several different speeds of card reader and printers were available. In addition these devices were programmable to a limited extent and could do many other functions.

Although the 1004 looked like a good candidate and they were selling on the used market for about 5% of their original value, a number of problems existed.

First, the machines generally available did not have Data Line Terminals (DLT) on them. To buy the DLTs new from Univac would have cost as much as the entire terminal. The alternative was for the University to design and build the DLTs for the used 1004s.

Second, the standard Univac terminal program ran only on machines with expanded memories, which were not readily available on the used market. Purchase of new memories was too costly. The alternative here was to design a new 1004 terminal program which would run on a 1004 with the standard memory.

Third, additional software work on the CDC 6600 would be required to support the 1004 line protocol. This would be done with the work required to interface the PDP-11.

Fourth, as these machines were purchased used and generally in unknown condition, the University would have to set up a facility to refurbish the used 1004s, build and install the DLTs and wire and install the plug-board program.

Fifth, and perhaps most important, since the resulting 1004s would have non-Univac hardware and software in them the University would have to maintain them. Although setting up a maintenance program offered the chances for still further savings, it also promised added responsibilities and problems.

Although this was an impressive list of problems, all these problems had already been taken on in a smaller scale for the PDP-11 project which also had University supplied hardware, software, and maintenance. In addition the CDC 6600 had long used a large amount of University developed and maintained software.

The result of the evaluation was that the potential cost savings of up to 80% on each terminal justified the problems and were the only way the University could develop the type of network required.

The original 1004 was purchased directly from Univac and included a DLT. This was necessary so the terminal program would be done concurrently with the development of the University DLT. Subsequently, a group of ten used 1004s was purchased for refurbishment.

By late 1971, the University DLT was finished as was a terminal program. One of these went to St. Cloud to support the Mankato 1106. At this time the PDP-11 was supporting the CDC 200 terminals but not yet the 1004.

By early 1972, the PDP-11 was also supporting the 1004s. At this time UCC began delivering and maintaining the UCC refurbished 1004s.

By the end of 1972, UCC owned 19 1004 terminals. Of these 17 had been refurbished and were operational while the other two were scrapped for parts. Of the 17 operational terminals, 15 had been delivered and two were awaiting delivery. All terminals can interchangeably communicate with both the CDC 6600 at Lauderdale and the Univac 1106 at Mankato. Four of the terminals have been delivered to colleges outside the Twin Cities. Most are for student and faculty use on the main campus, West Bank campus, and St. Paul campus of the UofM.

In addition to the design and production of equipment the UCC also recorded 88 machine months of maintenance during 1972.

During 1972 a decision was also made to buy and maintain the modems on the terminals. This maintenance was essentially free as the terminals were already UCC maintained. This also allowed additional cost savings. The Astrocom modem built in Minneapolis was chosen for this purpose.

VI. Performance Analysis

A. Terminal Performance

Both the CDC 200 and the U1004 terminals have performed well. In this section an analysis is made of the particular characteristics affecting the performance of each and how deviation of these characteristics affect the overall throughput.

To make this comparison strictly from empirical data would require an endless amount of testing and accuracy would be affected by many factors beyond control such as system load, line conditions, etc. Therefore the approach taken was to make the comparison on an analytical basis to develop the charts and graphs. This was verified by a large number of actual tests to determine how closely actual results approach the theoretical results.

The charts and graphs of theoretical terminal performance were based on a number of conditions. Several of these were: 1) no delay in the central processor response was considered; 2) a character set such as to allow maximum print speed. Since neither of these conditions may be expected to be true continuously, especially during periods of heavy usage, any timed performance in excess of 75% of the theoretical speed should be considered acceptable.

As a result of approximately 50 such tests involving both types of terminals, it appears that both the CDC 200 and the U1004 terminals on our system normally run at 80% of theoretical value. Over a large number of tests both the CDC 200 tests and the U1004 tests averaged 80% of theoretical value. Range encountered was from 71% to 96%. As nearly all tests were run during heavy load conditions this is quite realistic and should represent a fair measure of actual to theoretical performance. The fact that the two ratios are identical serves to verify the charts and graphs developed.

General conditions affecting performance are character length and block length. The U1004 has a shorter character length which gives a shorter transmission time for a block of a given length. On the other hand the CDC 200 uses much larger blocks which greatly reduces line turnaround time on dialup lines. This advantage is negligible on leased lines.

The largest factors affecting terminal performance are the compression schemes. As these schemes are data dependent it is difficult to make a direct comparison. In general the CDC 200 is more consistent through a wide range of data formats. The U1004 may vary from much better than the CDC 200 to much worse than the CDC 200, and do this on almost identical data. This is because the CDC 200 is only sensitive to the number of blanks while the U1004 is also sensitive to location. The overall result is assumed to be equivalent for calculation purposes. To provide any closer analysis would require a tremendous base of completely unbiased data to work from. Since any output format can easily be made to favor one terminal or the other and still appear almost identical, use of a contrived test is impractical except to verify analytical results.

One point of compression that is not data sensitive is the fact that the CDC 200 does not do compression on input. This means the U1004 I generally outperforms the CDC 200 on input although the two are generally equivalent on output. Input normally accounts for about 20% of the total load, with output accounting for about 80%.

The U1004 II is a faster terminal than either the CDC 200 or the U1004 I. This is not important on low speed lines but becomes increasingly important as line speeds increase.

On all charts in this document, actual traces are shown in fine black lines, while overall trends are shown as broad colored lines.

Performance calculations on the CDC 200 are found in chart VI-A1. The performance results are found in chart VI-A2.

Performance calculations on the U1004 I and U1004 II are found in chart VI-A3. Results are found in charts VI-A4 and VI-A5.

Graphs showing comparative results on the input side are found on charts VI-A6 and VI-A7.

Graphs showing comparative results on the output side are found on charts VI-A8 and VI-A9.

B. System Performance

Although system performance in terms of CPU performance is not affected, performance as measured by turnaround is greatly affected.

A user may often submit a job from a remote site and be printing his results in less than a minute.

C. Performance Enhancement

At this point the primary opportunity for performance improvement exists in the communications link. Further evaluations are continuing in this area. The primary areas being investigated are higher speed dialup modems and low cost high speed "short haul" modems. The tremendous performance improvement available can be readily seen in the charts and graphs.

D. Usage

As the chart on VI-A10 shows, the use of medium speed RBTs has increased from a total of 5% of jobs input in January 1972 to 25% of jobs input in December 1972. This fivefold increase can only be considered as strong user endorsement. This increase did not noticeably affect local batch volume but rather affected the volume of jobs going in through the high speed remotes.

Total hours connect time/month, shown in chart on VI-A11 shows an increase of nearly 5:1 during the year. Nearly all of this increase is in the 1004 terminals which increased from 0 to 750 hrs/mo. while the 200 terminals increased slightly during the year.

The chart on VI-A12 shows progression in number of RBTs during the last 2 years as compared to the estimated requirement. This indicates the requirements may be met by the end of 1975.

E. Reliability

On the CDC 200 reliability has never been a point of concern. This was true because the machine is an old, established product and is maintained by CDC on contract.

On the U1004 a slightly different situation exists. Although the product line is even older than the CDC 200, these machines were purchased used, refurbished by UCC, and maintained by UCC. In addition both the DLT and the terminal program were developed and manufactured by UCC. Also a new, unfamiliar modem (Astrocom) was being used. Furthermore, a large number of terminals were installed in a relatively short period of time. The result of these was that while the great majority of terminals went in smoothly and performed well, several did experience substantial problems. These were rectified and now all terminals are performing well.

Although some problems were encountered in training and holding service personnel, these seem to have been mostly solved and by March of 1973 costs for maintenance by the UCC Engineering Group seem to be well below the forecast for 1973. Monthly maintenance in March averaged just over 6 hours per site. Parts averaged less than $17.00 per site. This is extremely reasonable maintenance and if it can be continued will cause the overall cost/terminal to drop even below the 1973 estimates in this report.

Perhaps the largest single operational factor which shows up as a difference between the CDC 200 and the U1004 is the fact that all the CDC 200s have regular operators and thus, operator error is almost unheard of, while nearly all the U1004s are open shop and may be operated by students, faculty, and anybody else who has the desire. These people have generally had no training and run the terminal from a list of instructions. Although every attempt has been made to keep the operation simple, about 29% of all service calls are false calls and involve operator error rather than equipment problems. This will drop as more people become accustomed to using the terminals.

F. Comparison with Other Alternatives

Comparison of the CDC 200 and the U1004 indicates that they are roughly equivalent in performance. The CDC 200 has an advantage on large records due to its larger block size, while the U1004 has an advantage on short records due to shorter character size and faster peripherals. This is true only on slow turnaround lines. On any leased line or other fast turnaround line the U1004 can be expected to be faster throughout the range.

This speed gained through character size is, however, not without its disadvantages. It limits the U1004 to a 62 character set in normal usage. Although this does not seem much different than the

CDC 200's 64 character set, this difference has been a recurrent problem in the use of the U1004 terminals. One language requires use of all 64 characters and this must be done by setting a switch manually. Other methods of solving the problem are being investigated.

Comparison with a high speed station is not feasible directly, because of differences in usage. If a U1004 II were configured and used as a high speed station, its throughput performance would be about 60% of that of the high speed station at Experimental Engineering.

CDC 200 PERFORMANCE CALCULATIONS

Method:

Analytical calculation to establish performance curves, followed by selective testing to establish our expected deviation from the theoretical curves. The formula derived gives the throughput rate for a given terminal over a given set of lines and modems assuming continuous and error free transmission. The general throughput formula:

$$R = \frac{NR*60000}{TT*CR*NR + TA + 20*TT}$$

gives the throughput rate R in records (cards or lines) per minute, where NR is number of records in the block, TT is transmit time in ms per character, TA is twice the line turnaround time in ms, and CR is the average number of characters per record after compression if any, but excluding synchs, SOM, EOM, and error codes. CR*NR cannot exceed the maximum block size. This formula makes certain approximations but is quite adequate for performance analysis.

Input Calculations:

For the CDC 200 the standard block size is 1000 characters and the character length is 8 bits. No compression is done on input so NR is a constant 12 (960 characters).

Output Calculations:

The same factors apply except compression is now done. NR is now a variable depending on line length and compression achieved.

Tables:

The following tables give the results of both input and output calculations for several different line/modem combinations.

Graphs:

The following graphs illustrate and compare the performance trends of the different terminals.

CDC 200 Performance

Line Char.	Cr	HDX 2000b Dialup				FDX 2400b Leased				FDX 4800b Leased				FDX 9600b Leased			
		Inp	Out	R-In	R-Out	Inp	Out	R-In	R-Out	Inp	Out	R-In	R-Out				
TT		4.0	4.0			3.33	3.33			1.67	1.67						
TA	20	300	300	170	375	17	17	219	375	2	2	330	375	-	-	-	-
NR		12	50			12	50			12	50						
TT		4.0	4.0			3.33	3.33			1.67	1.67						
TA	40	300	300	170	342	17	17	219	375	2	2	330	375				
NR		12	25			12	25			12	25						
TT		4.0	4.0			3.33	3.33			1.67	1.67						
TA	60	300	300	170	227	17	17	219	293	2	2	330	375				
NR		12	16			12	16			12	16						
TT		4.0	4.0			3.33	3.33			1.67	1.67						
TA	80	300	300	170	170	17	17	219	219	2	2	330	375				
NR		12	12			12	12			12	12						
TT		4.0	4.0			3.33	3.33			1.67	1.67						
TA	100	300	300	-	137	17	17	-	176	2	2		375				
NR		-	10			-	10			-	10						
TT		4.0	4.0			3.33	3.33			1.67	1.67						
TA	120	300	300	-	114	17	17	-	146	2	2		293				
NR		-	8			-	8			-	8						

TT: Transmission time in milliseconds/character
TA: Turnaround time x 2 in milliseconds
NR: Number of records per block
CR: Number of characters per record
R-In: Input rate in records (cards) per minute
R-Out: Output rate in records (lines) per minute

UNIVAC 1004 PERFORMANCE CALCULATIONS

Methods:

Method is described in the section for the CDC 200. The same formula is used. Major difference is that the 7 bit transmission code changes the transmission time per character somewhat. Calculation is done for both Mod I and Mod II equipment.

Input Calculation:

For the U1004 as used by UCC, the input block length is constant 280 characters. Therefore this number is used in place of NR*CR. Compression is done on input, so NR is a variable depending on card length and compression achieved.

Output Calculation:

Output block size is a variable up to 337 characters. Compression is used on output, so NR is a variable depending on line length and compression achieved.

Tables:

The following tables give the results of both input and output calculations for several different line/modem combinations.

Graphs:

The following graphs illustrate and compare the performance trends of the different terminals.

U 1004-I Performance

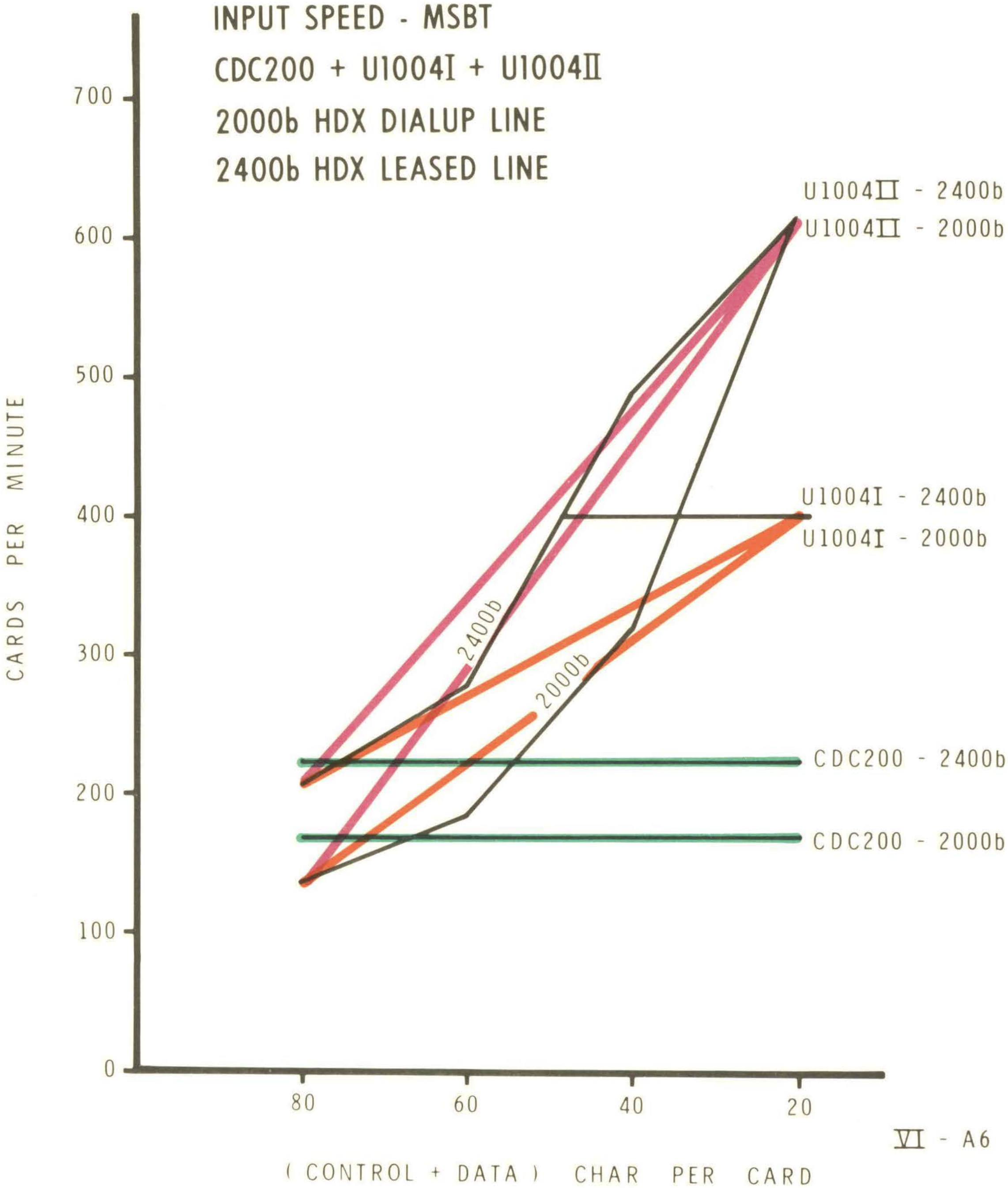
Line Char	CR	HDX 2000b Dialup				F DX 2400b Leased				FDX 4800b Leased				FDX 9600b Leased			
		Inp	Out	R-Inp	R-Out	Inp	Out	R-In	R-Out	Inp	Out	R-In	R-Out	Inp	Out	R-In	R-Out
TT TA NR	20	3.5 300 9	3.5 300 16	400	400	2.92 17 6	2.92 17 16	400	400	1.46 2 3	1.46 2 16	400	400	.73 2 2	.73 2 16	400	400
TT TA NR	40	3.5 300 7	3.5 300 8	311	322	2.92 17 6	2.92 17 8	400	400	1.46 2 3	1.46 2 8	400	400	.73 2 2	.73 2 8	400	400
TT TA NR	60	3.5 300 4	3.5 300 5	178	211	2.92 17 4	2.92 17 5	269	315	1.46 2 3	1.46 2 5	400	400	.73 2 2	.73 2 5	400	400
TT TA NR	80	3.5 300 3	3.5 300 4	133	161	2.92 17 3	2.92 17 4	201	238	1.46 2 3	1.46 2 4	400	400	.73 2 2	.73 2 4	400	400
TT TA NR	100	3.5 300 -	3.5 300 3	-	127	2.92 17 -	2.92 17 3	-	189	1.46 2 -	1.46 2 3	-	384	.73 2 -	.73 2 3	-	400
TT TA NR	120	3.5 300 -	3.5 300 2	-	100	2.92 17 -	2.92 17 2	-	155	1.46 2 -	1.46 2 2	-	315	.73 2 -	.73 2 2	-	400

TT: Transmission time in milliseconds/character
TA: Turnaround time x 2 in milliseconds
NR: Number of records per block
CR: Number of characters per record
R-In: Input rate in records (cards) per minute
R-Out: Output rate in records (lines) per minute

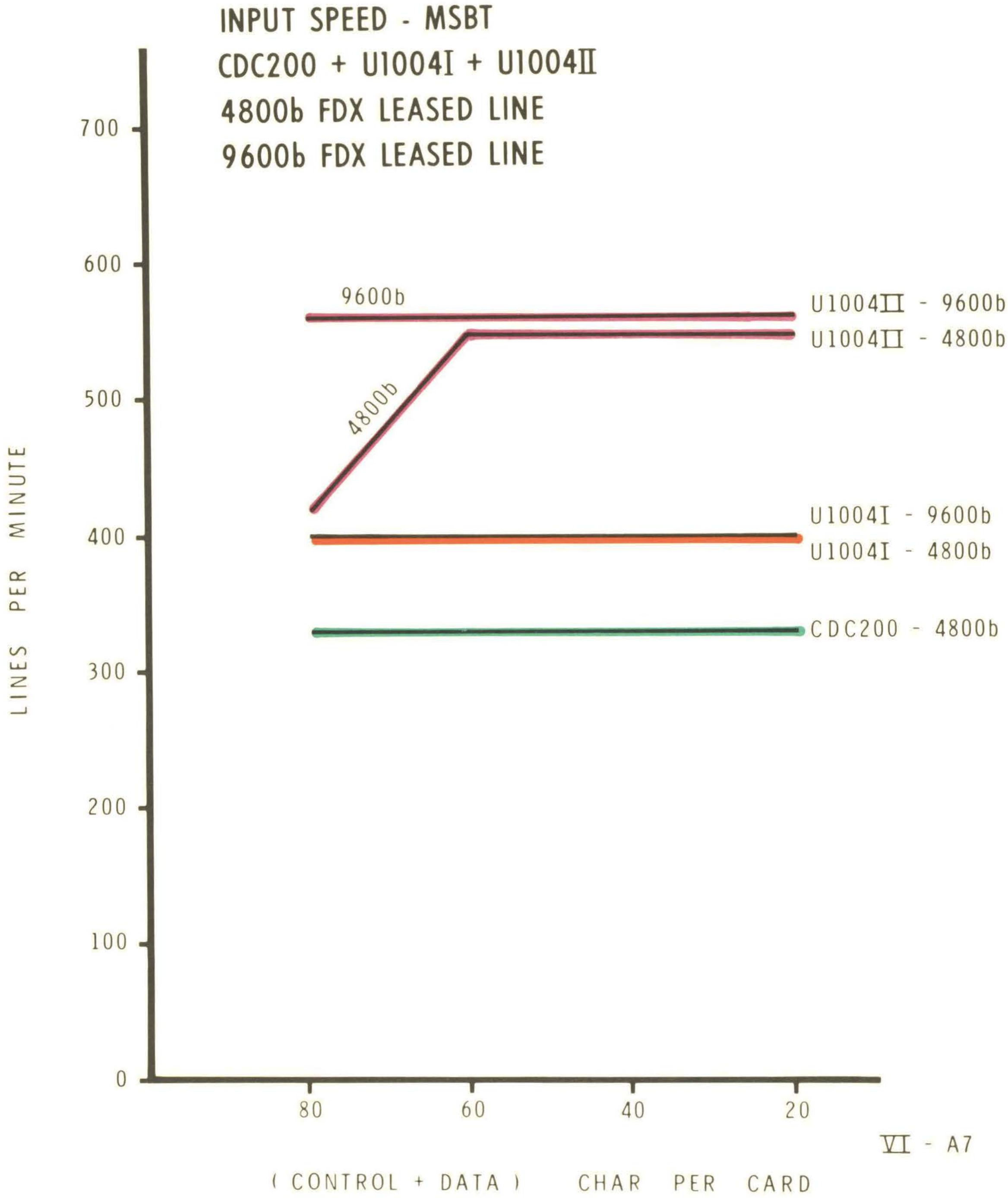
U 1004-II Performance

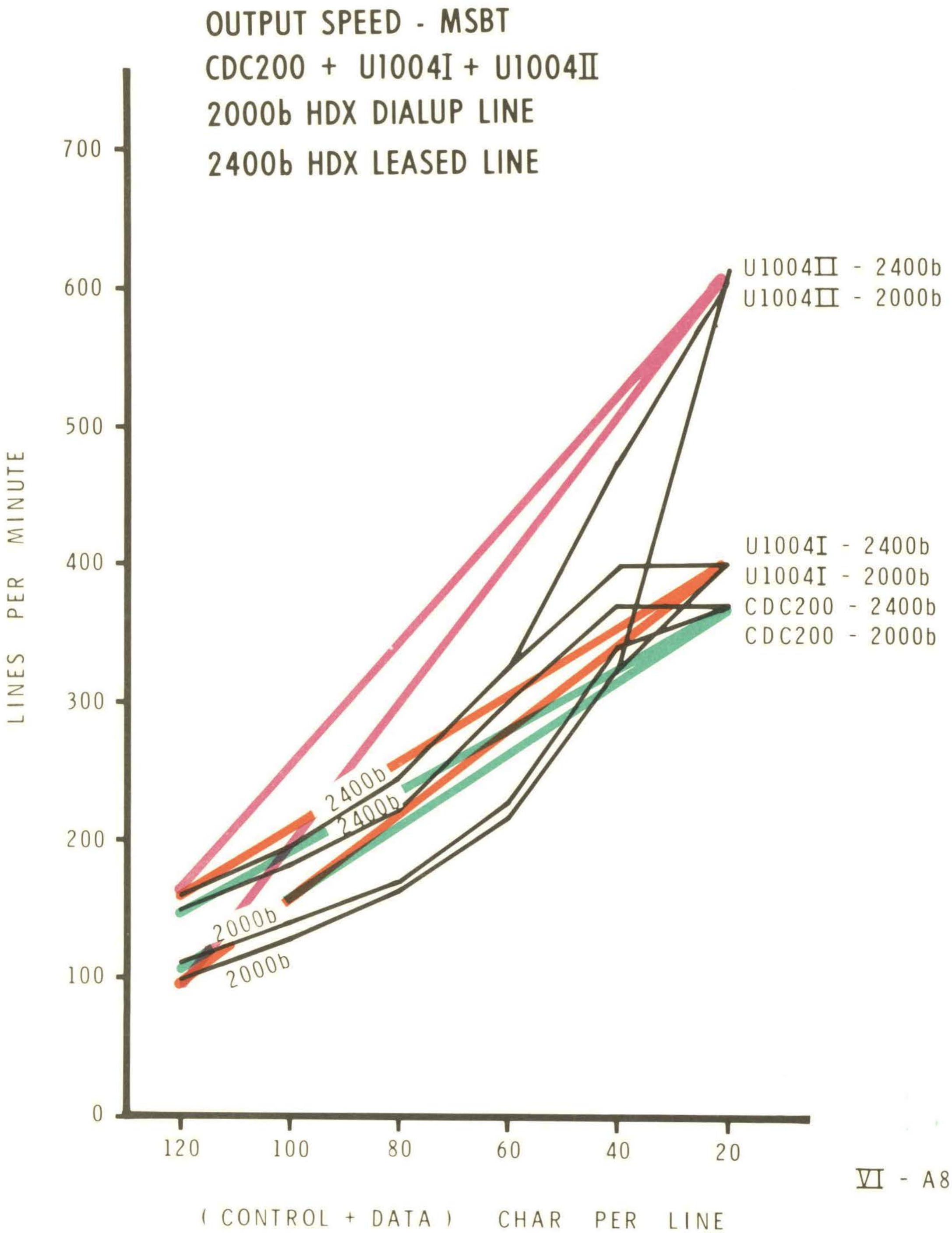
Line Char	CR	HDX 2000b Dialup				F DX 2400b Leased				FDX 4800b Leased				FDX 9600b Leased			
		Inp	Out	R-In	R-Out	Inp	Out	R-In	R-Out	Inp	Out	R-In	R-Out	Inp	Out	R-In	R-Out
TT TA NR	20	3.5 300 14	3.5 300 16	615	600	2.92 17 9	2.92 17 16	605	600	1.46 2 4	1.46 2 16	545	600	.73 2 2	.73 2 16	563	600
TT TA NR	40	3.5 300 7	3.5 300 8	311	322	2.92 17 7	2.92 17 8	470	476	1.46 2 4	1.46 2 8	545	600	.73 2 2	.73 2 8	563	600
TT TA NR	60	3.5 300 4	3.5 300 5	178	211	2.92 17 4	2.92 17 5	269	315	1.46 2 4	1.46 2 5	545	600	.73 2 2	.73 2 5	563	600
TT TA NR	80	3.5 300 3	3.5 300 4	133	161	2.92 17 3	2.92 17 4	201	238	1.46 2 3	1.46 2 4	422	482	.73 2 2	.73 2 4	563	600
TT TA NR	100	3.5 300 –	3.5 300 3	–	127	2.92 17 –	2.92 17 3	–	189	1.46 2 –	1.46 2 3	–	384	.73 2 –	.73 2 3	–	600
TT TA NR	120	3.5 300 –	3.5 300 2	–	100	2.92 17 –	2.92 17 2	–	155	1.46 2 –	1.46 2 2	–	315	.73 2 –	.73 2 2	–	600

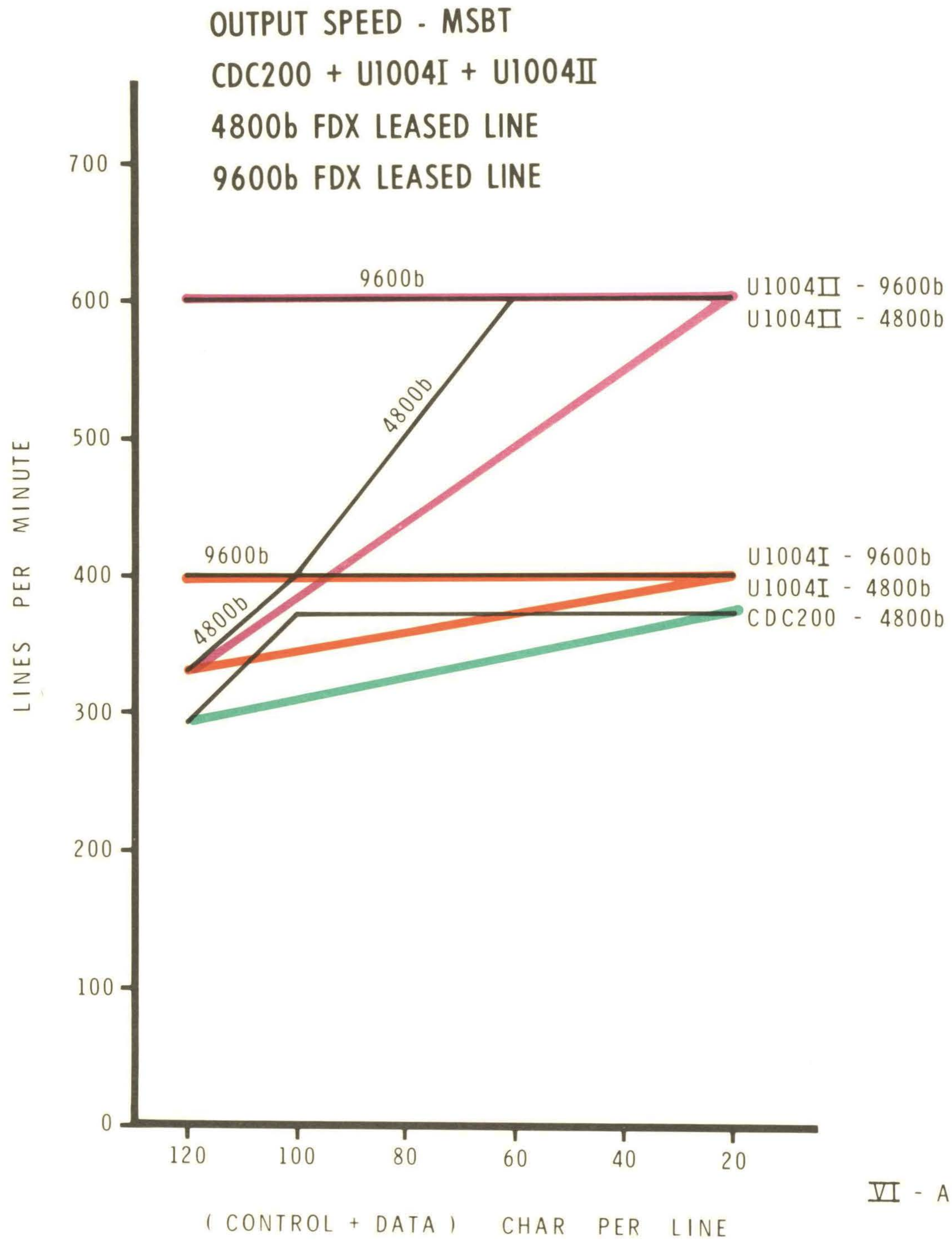
TT: Transmission time in milliseconds/character
TA: Turnaround time x 2 in milliseconds
NR: Number of records per block
CR: Number of characters per record
R-In: Input rate in records (cards) per minute
R-Out: Output rate in records (lines) per minute

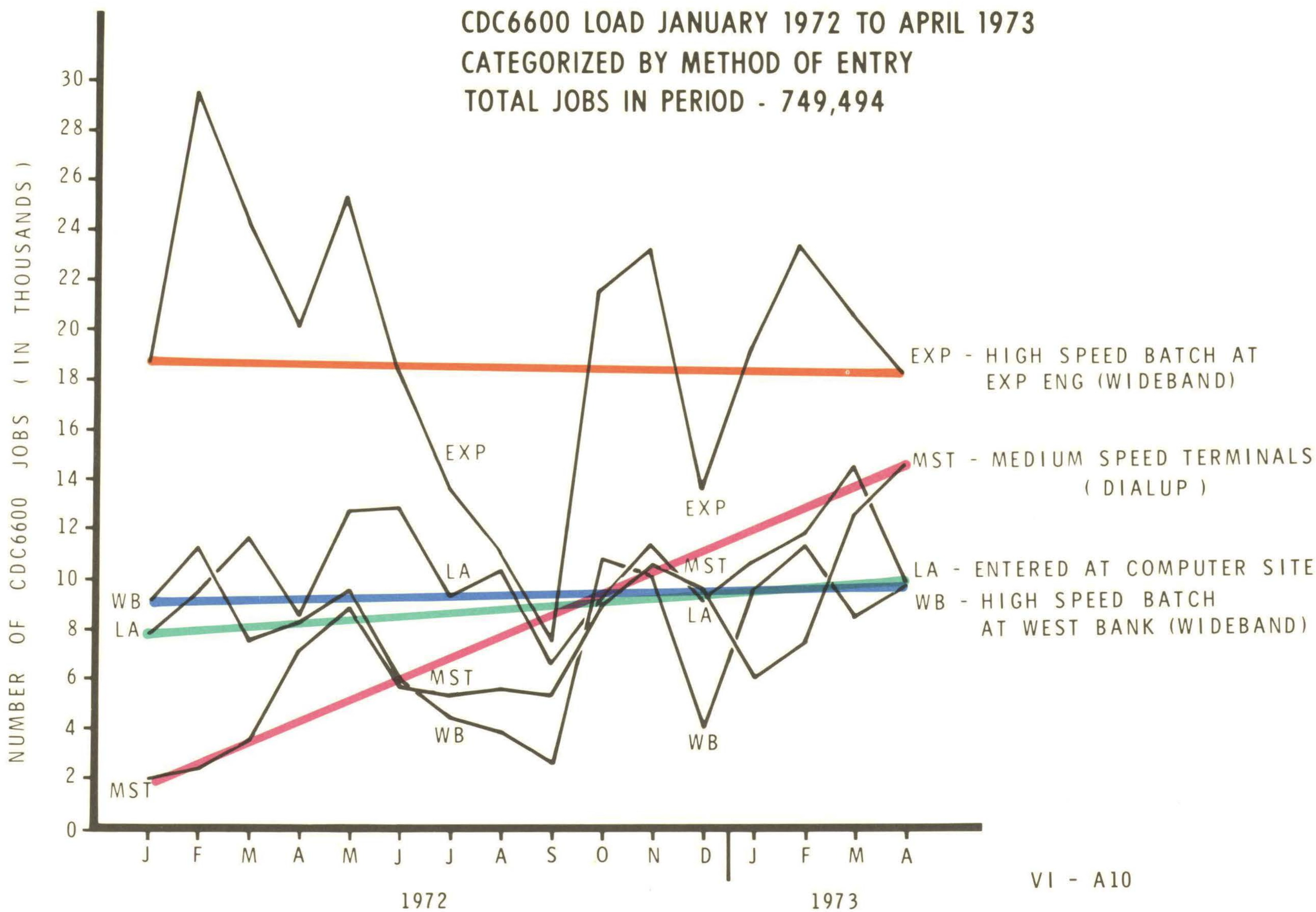

INPUT SPEED - MSBT
CDC200 + U1004I + U1004II
2000b HDX DIALUP LINE
2400b HDX LEASED LINE
CARDS PER MINUTE
700
600
500
400
300
200
100
0
U1004II - 2400b
U1004II - 2000b
U1004I - 2400b
U1004I - 2000b
CDC200 - 2400b
CDC200 - 2000b
2400b
2000b
80
60
40
20
(CONTROL + DATA) CHAR PER CARD

VI - A6

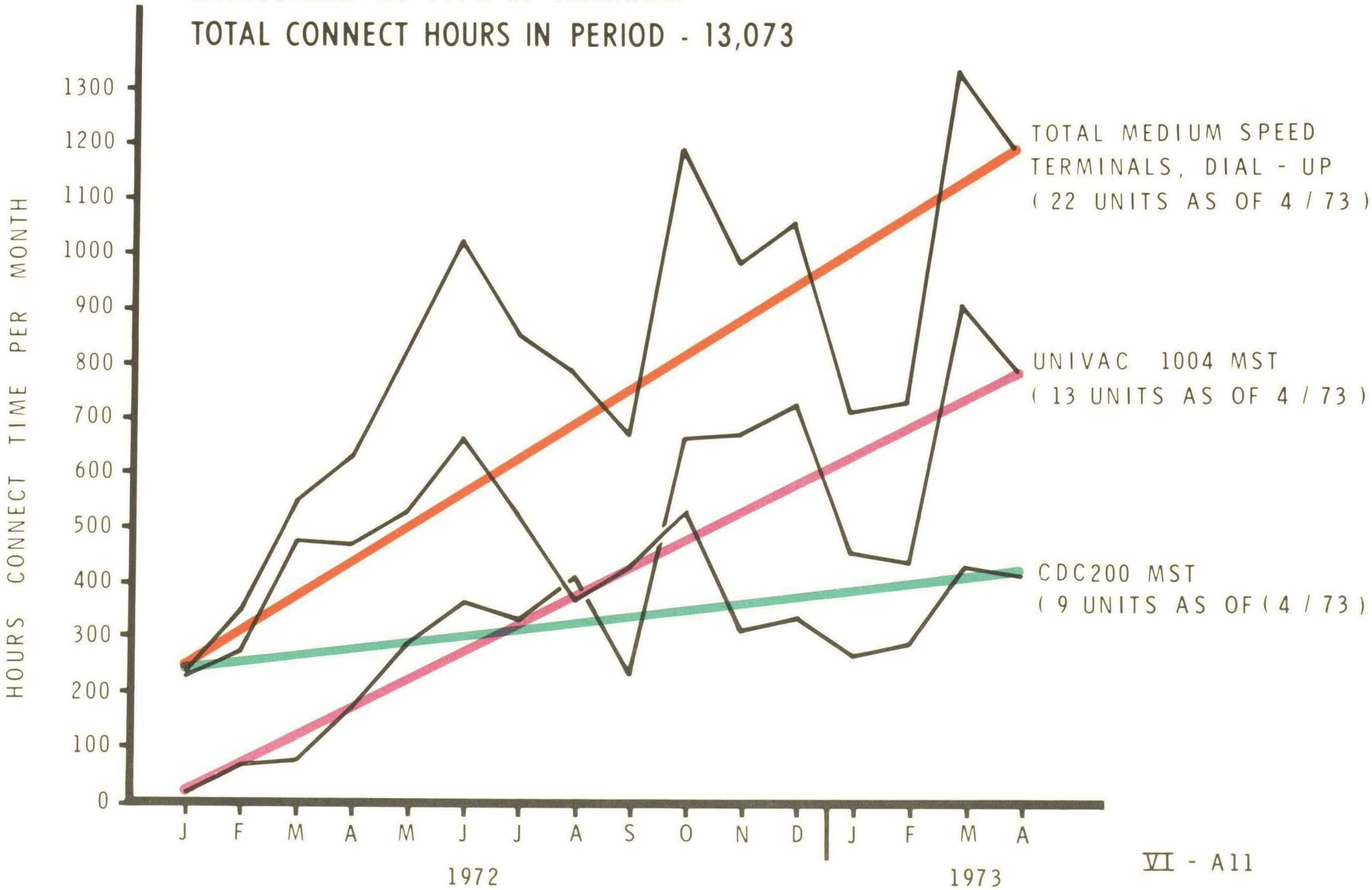

INPUT SPEED - MSBT
CDC200 + U1004I + U1004II
4800b FDX LEASED LINE
9600b FDX LEASED LINE
700
600
500
400
300
200
100
0
LINES PER MINUTE
9600b
4800b
U1004II - 9600b
U1004II - 4800b
U1004I - 9600b
U1004I - 4800b
CDC200 - 4800b
80
60
40
20
(CONTROL + DATA) CHAR PER CARD


OUTPUT SPEED - MSBT
CDC200 + U1004I + U1004II
2000b HDX DIALUP LINE
2400b HDX LEASED LINE
LINES PER MINUTE
700
600
500
400
300
200
100
0
120
100
80
60
40
20
(CONTROL + DATA) CHAR PER LINE
U1004II - 2400b
U1004II - 2000b
U1004I - 2400b
U1004I - 2000b
CDC200 - 2400b
CDC200 - 2000b
2400b
2400b
2000b
2000b

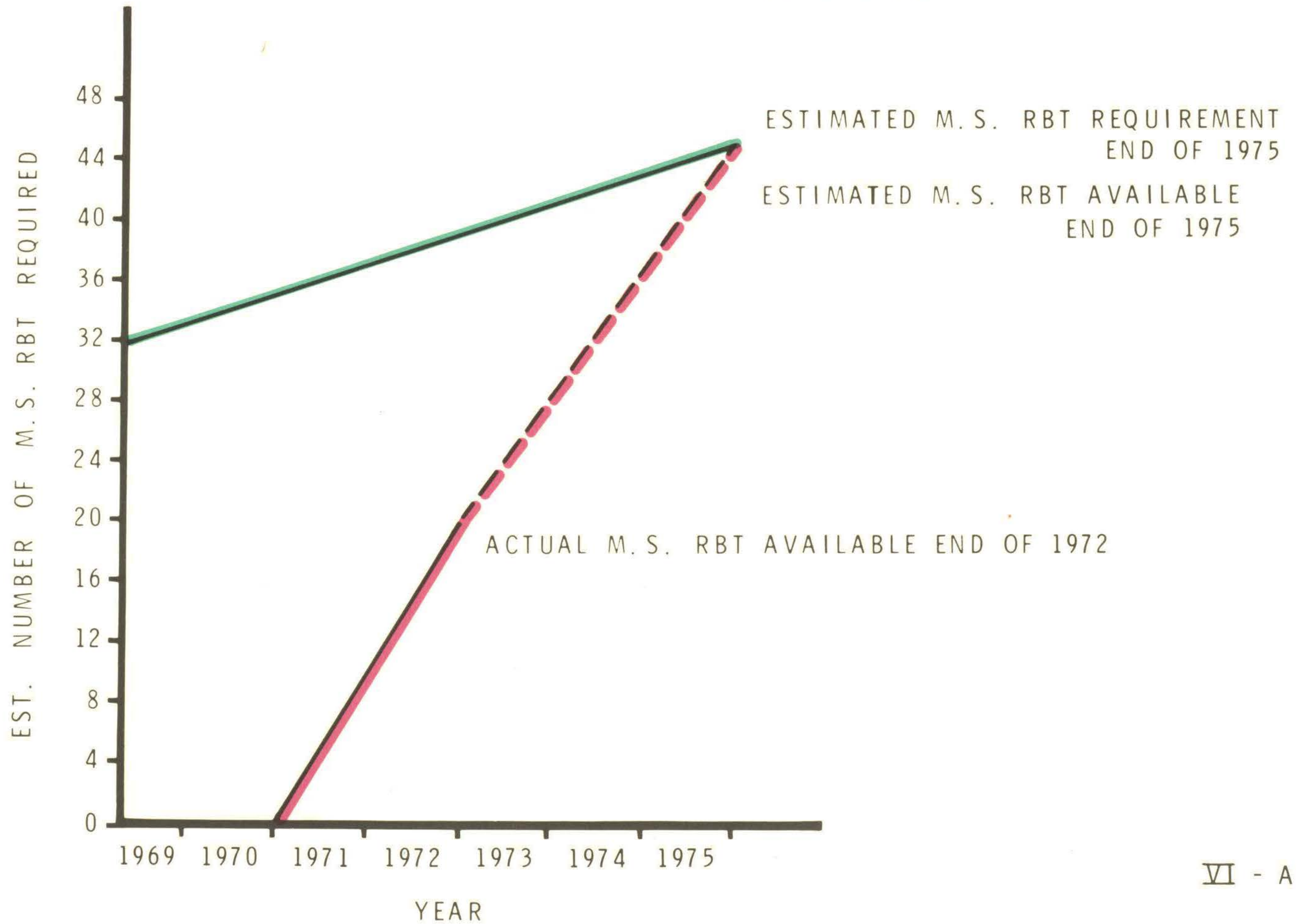

OUTPUT SPEED - MSBT
CDC200 + U1004I + U1004II
4800b FDX LEASED LINE
9600b FDX LEASED LINE
700
600
500
400
300
200
100
0
LINES PER MINUTE
9600b
4800b
9600b
4800b
U1004II - 9600b
U1004II - 4800b
U1004I - 9600b
U1004I - 4800b
CDC200 - 4800b
120
100
80
60
40
20
(CONTROL + DATA) CHAR PER LINE


CDC6600 LOAD JANUARY 1972 TO APRIL 1973
CATEGORIZED BY METHOD OF ENTRY
TOTAL JOBS IN PERIOD - 749,494
NUMBER OF CDC6600 JOBS (IN THOUSANDS)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
J F M A M J J A S O N D J F M A
1972
1973
EXP
MST
LA
WB
EXP - HIGH SPEED BATCH AT EXP ENG (WIDEBAND)
MST - MEDIUM SPEED TERMINALS (DIALUP)
LA - ENTERED AT COMPUTER SITE
WB - HIGH SPEED BATCH AT WEST BANK (WIDEBAND)

MEDIUM SPEED BATCH TERMINAL LOAD JANUARY 1972 TO APRIL 1973
CATEGORIZED BY TYPE OF TERMINAL
TOTAL CONNECT HOURS IN PERIOD - 13,073



ACTUAL AND PROJECTED AVAILABILITY OF MEDIUM SPEED REMOTE BATCH TERMINALS VS. ESTIMATED REQUIREMENTS



VII. Financial Aspects

A. Cost of Project to Date

The total cost of the project through December 31, 1973 excluding the 200 terminals, has been $77,441 in development costs, $122,754 in production costs, and $22,000 in maintenance costs, for a total of $222,195. This figure makes no allowance for savings due to equipment replaced. That will be done in a comparison section.

B. Comparison of Alternatives

For comparison purposes all data must be reduced to a common base. This base is monthly cost including maintenance. All numbers will be reduced to these terms.

For purchased and manufactured equipment the procedure will be: 1) New equipment will have costs amortized over a 60 month period, 2) Factory refurbished equipment will be amortized over a 48 month period, and 3) UCC refurbished and produced equipment will be amortized over a 36 month period.

Development costs will be amortized on a monthly basis and this charge spread over all delivered products to which it applies.

Maintenance costs will be calculated on a machine/month basis and will be calculated on the basis of a calendar year.

The chart on VII-A1 shows comparative costs between the 1004 and the 200.

The chart on VII-A2 shows comparative costs between alternative 1 and alternative 2 for the entire system.

The chart on VII-A3 shows comparative costs between HSBT and each alternative MSBT.

The chart on VII-A4 shows cost calculation for the 200 terminal, the CDC 6671, and the Bell 201A modem.

The chart on VII-A5 shows cost calculation for the refurbished 1004 terminals with UCC produced DLTs.

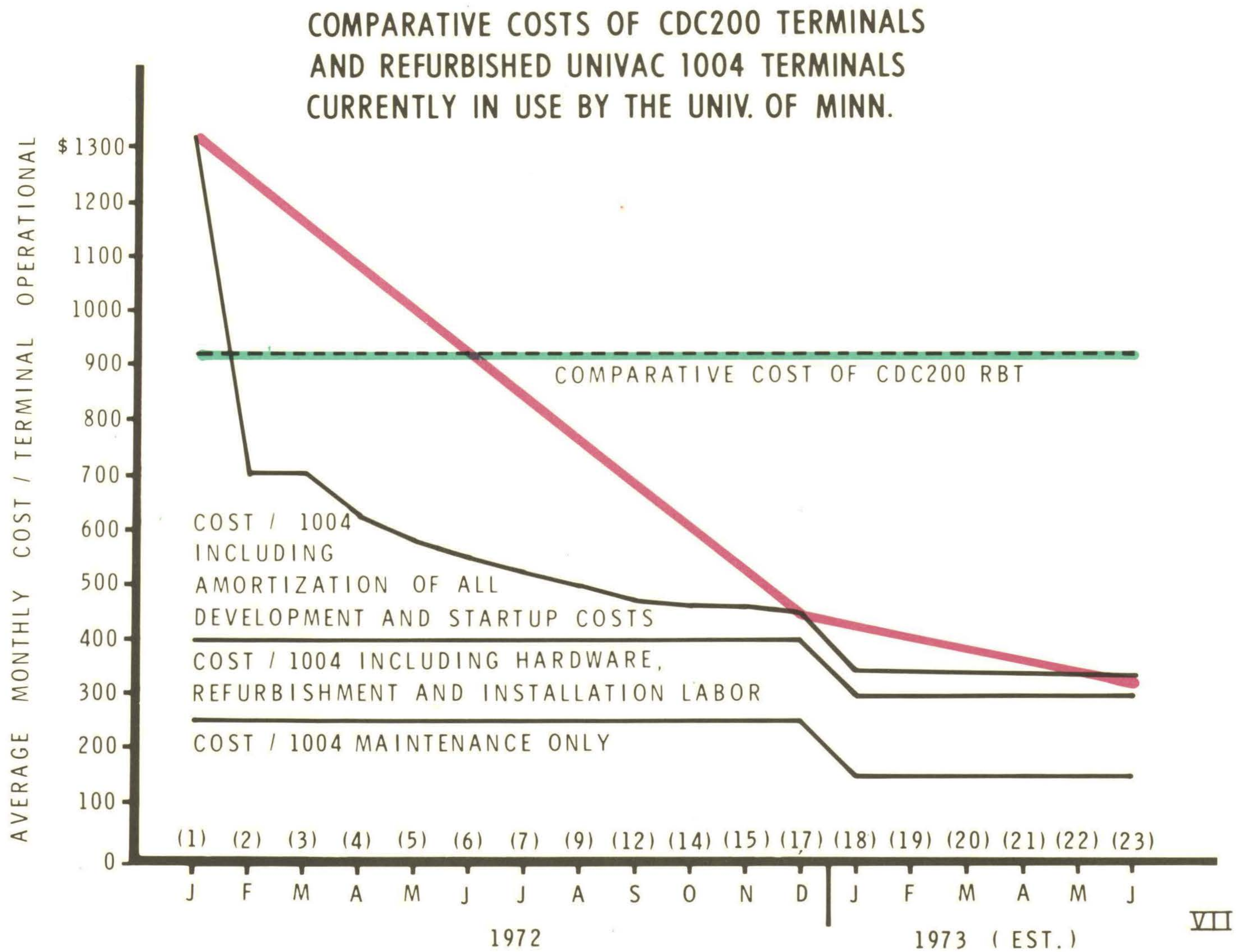
The chart on VII-A6 shows cost calculations for the PDP-11 front end.

The chart on VII-A7 shows cost calculations for the Astrocom modems.

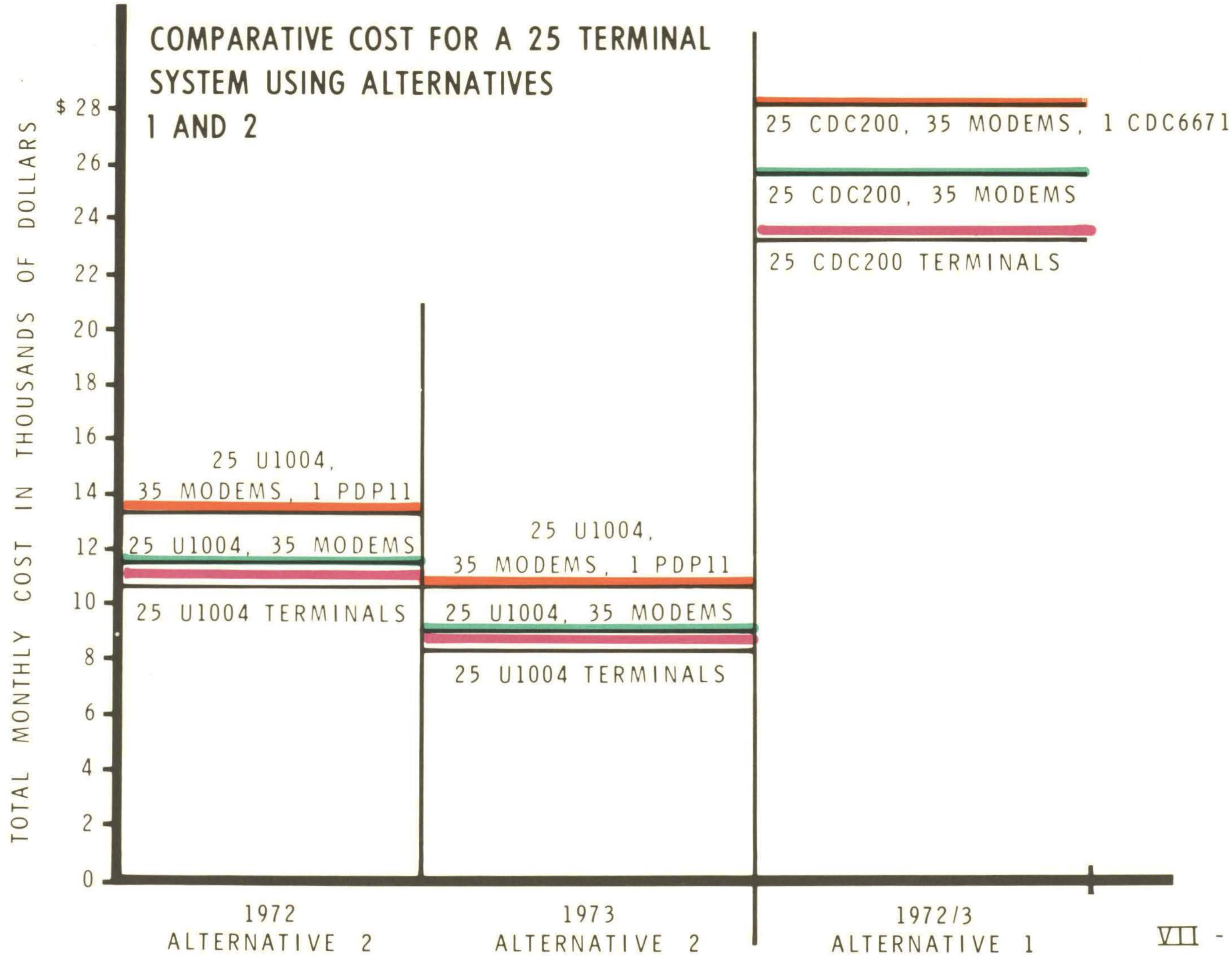
The chart on VII-A8 shows calculations for the comparison of cost effectiveness for the entire system.

The chart on VII-A9 shows calculation of cost for a high speed batch station.

The chart on VII-A10 shows calculations of comparison cost effectiveness of high speed station vs. each alternative of medium speed station.

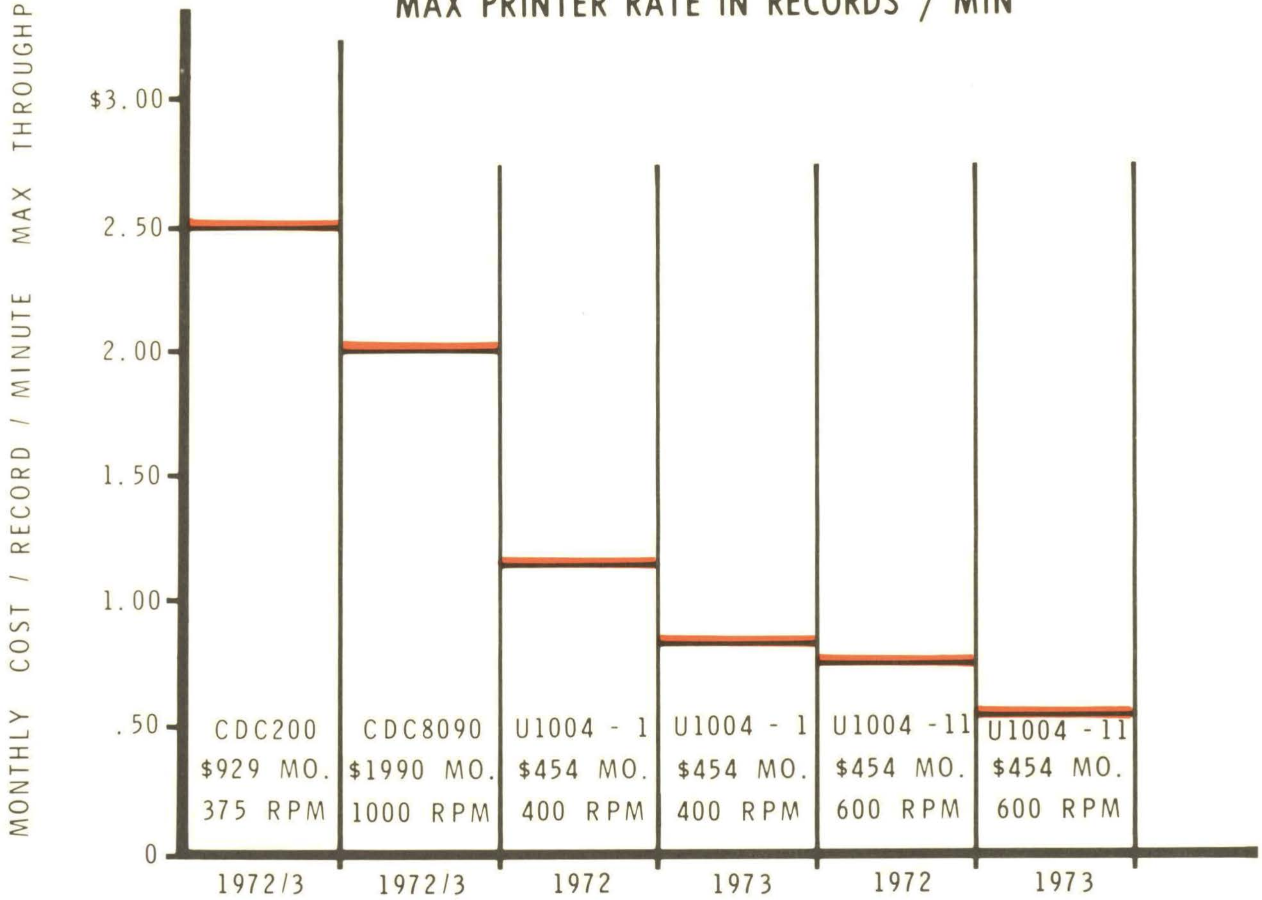

COMPARATIVE COSTS OF CDC200 TERMINALS
AND REFURBISHED UNIVAC 1004 TERMINALS
CURRENTLY IN USE BY THE UNIV. OF MINN.
AVERAGE MONTHLY COST / TERMINAL OPERATIONAL
$1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
COMPARATIVE COST OF CDC200 RBT
COST / 1004
INCLUDING
AMORTIZATION OF ALL
DEVELOPMENT AND STARTUP COSTS
COST / 1004 INCLUDING HARDWARE,
REFURBISHMENT AND INSTALLATION LABOR
COST / 1004 MAINTENANCE ONLY
(1) (2) (3) (4) (5) (6) (7) (9) (12) (14) (15) (17) (18) (19) (20) (21) (22) (23)
J F M A M J J A S O N D J F M A M J
1972
1973 (EST.)

VII - A1


COMPARATIVE COST FOR A 25 TERMINAL SYSTEM USING ALTERNATIVES 1 AND 2
TOTAL MONTHLY COST IN THOUSANDS OF DOLLARS
$ 28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
25 U1004, 35 MODEMS, 1 PDP11
25 U1004, 35 MODEMS
25 U1004 TERMINALS
25 U1004, 35 MODEMS, 1 PDP11
25 U1004, 35 MODEMS
25 U1004 TERMINALS
25 CDC200, 35 MODEMS, 1 CDC6671
25 CDC200, 35 MODEMS
25 CDC200 TERMINALS
1972 ALTERNATIVE 2
1973 ALTERNATIVE 2
1972/3 ALTERNATIVE 1

COMPARISON OF COST / THROUGHPUT MAXIMUM FOR HIGH SPEED STATION VS MEDIUM SPEED TERMINALS

$$\text{COST} = \frac{\text{MONTHLY COST}}{\text{MAX PRINTER RATE IN RECORDS / MIN}}$$



Calculation of Cost/CDC 200, CDC 6671, Bell 201A Modems

Sample: 3 terminals used by UofM. One is leased from CDC. One was purchased new. One was purchased used. All are under CDC contract maintenance. Leased terminal is taken at true lease price with maintenance. Terminal purchased new is amortized over 60 mo. period plus cost of contract maintenance. Terminal purchased used but factory refurbished is amortized over 48 mo. plus cost of contract maintenance.

Calculation:

Terminal 1	- 46,000 over 60 mo.	=	$ 767	mo.
Terminal 2	- 21,126 over 48 mo.	=	440	mo.
Terminal 3	- Lease w/o maint.	=	750	mo.
Maintenance	- 3 term. @ 277 mo. each	=	831	mo.
			$ 2788	mo.
Average cost/200 term		=	$ 929	mo. incl. main.

Cost of CDC 6671	$ 1253	mo. incl. main.
Cost of two PPU to Support 6671	1122	mo. incl. main.
	$ 2375	mo. incl. main.
Cost of Bell 201A Modems	$ 72	mo. incl. main.

Calculation of Cost/Refurbished Univac 1004

Sample: Group of the first 17 such terminals refurbished and prepared for delivery. Fifteen of these had actually been delivered by the end of 1972, and the other two were in a stage of semi-completion being readied for delivery. As all equipment was purchased and essentially all labor complete on these two they were included in the sample.

In addition, to the group of 17 machines refurbished by UCC, one additional 1004 was purchased directly from Univac. This was a used machine which had been factory refurbished and included a Univac DLT. Although this machine was substantially more expensive than the others it was necessary to allow the development effort to proceed in a parallel fashion and to avoid greatly extending the schedule. In light of this and due to the fact that it is likely that one 1004 will always remain for use by the UCC 1004 group, this machine is considered to be a development expense, while the other 17 are considered to be production expenses.

All parts and equipment costs are taken from the paid invoices. Such costs are actual dollar expenses incurred by UCC. They are then allocated either to development, production, or maintenance. No material handling charge is added.

All labor charges are taken from accounting records at actual salaries of those people working on the project. In this way normal fringes such as vacation, holiday, and sick leave are included in the labor cost. However, no overhead burden is considered beyond this. All labor accrued to the project has been estimated in terms of people and time by the responsible individuals. Salary levels have then been applied to form a labor cost base. This labor cost was then allocated into the phases of development, production and maintenance.

All test equipment, training and miscellaneous charges have been considered to be developmental in nature and are charged as such.

Development and startup costs have been accumulated against the entire 1004 project. These costs include development of the UCC data line terminal (DLT) for the 1004, development of the 1004 terminal

Program, and specification of the multiple interface line protocal acceptable to both the CDC 6600 and the Univac 1108. This cost includes the initial development 1004. Development costs are amortized over a 48 month period and are distributed to all machines actually in the field during a given month and added to the cost of each terminal.

Production costs have been accumulated as the cost of the 17 used 1004s purchased plus the necessary parts for refurbishment plus the parts to build 17 UCC DLTs for them, plus refurbishment and installation labor. This total cost/machine is then amortized over a 36 month period to arrive at a monthly cost.

Maintenance costs have been primarily labor as many spare parts were supplied with the purchase of used machines. Maintenance costs are accumulated on a machine/month basis only on machines delivered into the field. The cost of maintenance per machine/month is considered to be constant for a calendar year and will be adjusted each year. The cost per machine/month for 1972 has been calculated at $250. This is somewhat high but includes substantial learning, training, and development of maintenance procedures and devices. All of these were treated as 1972 expense items. Estimated cost per machine/month for 1973 is $150.

Calculation:

Development Costs		
Equipment and Parts	$21,090	
Misc.	3,446	
Labor	23,009	
	47,545	
Amortized over 48 mo.		990/mo.
Production Costs (17 terminals)		
Equipment and Parts (1004)	$47,272	
Parts (DLT)	8,352	
Labor	34,000	
	89,624	
Cost per Unit		$5,272/unit
		$ 146/mo.

Maintenance Costs (1972)

Labor and Misc. Parts		
88 Machine Months	$22,000	
Cost Per Machine/Month		$ 250/mo.

Average Cost/Unit/Mo. - Jan 1972 (1 Unit)

Maintenance	$ 250
Production	146
Development (990/1)	990
	$ 1,386 mo.

Average Cost/Unit/Mo. - Dec. 1972 (17 Units)

Maintenance	$ 250
Production	146
Development (990/17)	58
	$ 454 mo.

Average Cost/Unit/Mo. (Est) - June 1973 (23 Units)

Maintenance	$ 150
Production	146
Development (990/23)	43
	$ 339 mo.

Calculation of Cost/PDP-11 front end

Sample: One unit purchased new by UofM. Includes initial purchase and subsequent upgrade to 8 ports. Includes ports and labor to develop 6600/PDP-11 interface and all software on 6600 and PDP-11 to support terminals.

Calculation

Initial PDP-11	$23,535	
Upgrade of PDP-11 to 8 ports	3,800	
Labor on interface	8,596	
Parts for interface	5,795	
Software labor on PDP-11	8,250	
Software labor on 6600	13,050	
	$63,026	
Cost of PDP-11 amortized over 60 mo.	1,050	
Estimated monthly maintenance	150	
Cost of one PPU to support PDP-11	561	
	$ 1,761	mo. incl. maint.

Calculation of Cost/Astrocom modems

Sample: 13 Astrocom modems purchased and maintained by UCC. Maintenance cost of these items is considered to be 0 as it is already included in maintenance costs for the 1004 terminals and the PDP-11.

Calculation:

Purchase price	$1050	
Amortized over 60 mo.	18	
Maintenance (see above)	0	
Data Access (not required for Bell 201A)	2	
	$ 20	mo.

Comparison of Cost Effectiveness

Sample: Since the RBT system was already in existence prior to this effort, we currently have a system which is approximately two thirds 1004 terminals and one third CDC 200 terminals. Comparison is further complicated by the fact that most of the CDC 200 terminals on the system are owned by outside users, and by the fact that some of the 1004 terminals produced by UCC are at present only going into the Univac 1106 at Mankato. Therefore in order to compare the alternative approaches for cost effectiveness we will compare the cost of implementing the entire subsystem as it exists by alternative 1 and also by alternative 2. The slightly simplified assumption will be that the subsystem consists of one communications front end, 10 ports and 10 modems on the front end, and 25 terminals with 1 modem each.

Alternative 1: This alternative is not to implement a hardware design, production, and maintenance facility within UCC. This would require staying with standard products for which contract maintenance is readily available. In this case that would be the CDC 6671, CDC 200 terminals, and Bell 201 A modems.

Calculation of Cost: alternative 1

Cost of 6671 and 2-PPU	$ 2375	mo.
Cost of 25 terminals (200)	23335	
Cost of 35 modems (Bell 201A)	2520	
Total monthly cost including maintenance	$28120	mo.

Alternative 2: This alternative is to establish a hardware design, production, and maintenance facility within UCC. This allows the purchase and refurbishment of used equipment, design of special products to allow best use of it, and maintenance of the entire subsystem. Specifically, this allows the approach taken concerning the PDP-11 front end, the 1004 terminals, and the Astrocom modems.

Calculation of Cost: alternative 2

Cost of PDP-11 and 1-PPU	$ 1761 mo.
Cost of 25 terminals (1004)	10825
Cost of 35 modems (Astrocom)	700
Total monthly cost including main.	$13286 mo.
Total estimated monthly cost after 1972.	$10686 mo.

Conclusion: Even should the entire system have been implemented during 1972, alternative two would effect a net monthly savings of $14776. or 52.5% over alternative one. Assuming the 1973 maintenance estimates are correct, the savings will increase to $17276. or 61.4% during 1973. Substantially larger savings are possible should the 1004 terminals outlive their amortization schedule of 36 months.

Calculation of Cost/CDC 8090 HSBT

Sample: One unit owned by UofM. As this unit was received in an equipment trade no cost figures are available from invoice. Instead cost figures were taken from CDC price catalog for the last year in which this system was listed.

Calculation:

Monthly rental incl. maintenance	$ 4,250
Purchase price	163,000
Monthly maintenance	830

Sample: Although the above prices represent the CDC 8090 HSBT currently owned by UCC, that price is now obsolete as new units are no longer available. Used CDC 8090 HSBTs are now priced from the manufacturer at substantially less and are available with contract maintenance. Therefore this price will be used in all comparisons.

Calculation:

Purchase price	$ 65,000
Amortized over 48 mo.	1,354
Maintenance	636
Total monthly cost incl. maint.	$ 1,990

Comparison of Cost Effectiveness

In general it is difficult to compare a high speed station such as the CDC 8090 with a medium speed station such as the CDC 200 or U1004. There are several reasons for this. First, the HSBT is usually connected by a wideband telephone line which allows the peripherals to run at top speed. Second, the HSBT is usually scheduled and run by professional operators who can batch and schedule the work so as to keep the work flow constant.

However, these factors are basically differences in use and do not represent restrictions on the equipment. Most MSBTs can be connected to lines fast enough to allow full speed operation. Obviously, operational procedures may be changed if desired.

In view of these factors the only reasonable basis of comparison is to compare the maximum throughput of each type of terminal, assuming the lines and operational procedures are adequate for full speed operation. This rate is then adjusted by monthly cost to provide a measure of cost effectiveness.

The CDC 8090 has a 1000 LPM printer. Dividing this rate into the monthly cost of $1990 yields a cost effectiveness number of $1.99.

The CDC 200 has a 375 LPM printer. The cost effectiveness is therefore $929/375 = $2.48.

The U1004 has either 400 or 600 RPM peripherals, depending on model. We have not distinguished between the models as to cost. Therefore, this yields four cost effectiveness numbers.

CE modI, 1972	=	454/400	=	$1.14
CE modII, 1972	=	454/600	=	.76
CE modI, 1973 est.	=	329/600	=	.82
CE modII, 1973 est.	=	329/600	=	.55

VIII. User Acceptance

A. Within UCC

User acceptance by the staff of UCC has been only fair. There are several reasons for this. First, literally all staff members work either at Experimental Engineering, where the high speed station is, or at Lauderdale, where the central processor is located. Because of this, staff members have none of the access problems of the outside user. Also no medium speed terminals are available or needed at these locations. In addition a large amount of staff work is such that it must be run "hands on" during times when the system is not available to service users. The result of these factors is that very little work by UCC staff has been run on the medium speed terminals which are designed more for the service user.

B. Service users

Service users, as defined here, includes all users not on UCC staff. This includes faculty, students, research programs, other colleges, and in some cases outside commercial or non-profit organizations. In general anyone who receives a charge number and is not UCC staff is considered a service user.

These users are widely scattered. They are at Main Campus, West Bank Campus, St. Paul Campus, local colleges, distant colleges, and commercial districts around the Twin Cities, to name just a few.

The typical MSBT user has either a CDC 200 or U1004 terminal located in or near his building. He walks to the terminal, places his input deck in the reader, dials up the computer, and operates the terminal himself. He may wait for his output or return later for it. He may have to wait a few minutes for the terminal if it happens to be busy, but usage is generally moderate enough so that he can get on quickly. In this manner he develops a greater understanding of how the system works than if he submits a deck to a scheduler who then takes care of everything. He also develops a much higher degree of personal identification with the system he is using.

In reference back to chart VI-A1, it is apparent that in the year 1972, MSBT usage increased fivefold. By the end of April 1973, this increase was sevenfold. This amounts to 26% of all CDC 6600 jobs on over 14,000 jobs per month. There is still much capacity left as many of the newer terminals are as yet being run only several hours a day.

It is interesting to note that of the increase in CDC 6600 usage in the 16 month period, nearly all the additional work is being entered from medium speed terminals. The high speed stations remained constant in usage and the locally entered work increased only slightly. Apparently a substantial number of users feel that the MSBT answers their needs better than the other forms of entry.

Perhaps most indicative of user reaction to the MSBT was the fact that of the four most used MSBTs, three are located within a city block of a high speed station, and the fourth was located adjacent to the 6600 itself. This can only be considered a high level of acceptance of the MSBT concept by the service user.

IX. System Longevity

A. Maintenance of System

Because of the large number of U1004s manufactured and their age, there is a ready source not only of more systems if required, but also of parts to maintain the current systems. These parts are generally free or at little cost.

The basic concept of UCC maintaining its own equipment has proven to be quite profitable. Current cost appears to be between one third and one half the cost of contracting this maintenance out. As personnel gain experience and the system expands the ratio should continue to improve.

Currently the UCC Engineering Group is maintaining all the local U1004s, the PDP-11, the 6600 link, and the Astrocom modems. This provides an adequate base for a maintenance operation. In addition this group handles 1004 refurbishment, DLT production, and 1004 program board wiring. An obvious possibility is for this group to expand into maintenance of other equipment. In general the more maintenance done by UCC, the more cost effective it will be. However, this maintenance must be carefully chosen to fit into the current capabilities of the group and not require extensive training in proportion to expected revenue.

B. Expansion of System

The supply of U1004s makes expansion of this system quite feasible. The more terminals produced, the lower the cost will be per terminal month. It is also feasible to expand to multiple front end computers to control more terminals. Depending on usage, a system the size of the CDC 6600 may conceivably support up to 100 batch terminals.

C. Future Development

Although the system is currently running well, a number of possible future enhancements exist. Most of these are being evaluated for future use if conditions warrant. We shall consider these possibilities starting at the central processor side.

It is possible to move some of the work currently being performed by the 6600 CPU or PPUs outward into the front end computer, thus increasing the central processor power available. This is consistent with the principle of moving routine work into less powerful and cheaper equipment.

Another possibility is to use the front end computer for additional communications uses. These could include other terminals, asynchronous terminals and even high speed terminals.

It is also possible to use the front end computer for non-communications applications. The most obvious of these is to attach new peripherals which may not be easily attached to the central processor.

Concerning lines, although all lines so far have been dial up voice grade, use of leased lines for higher speeds may be desirable. Even wideband lines may be incorporated.

Modems offer one of the largest possibilities for total system improvement. Even on the current dial up lines it is possible to more than double the throughput by appropriate modem choice. Leased lines offer still higher performance when coupled with high performance modems. Speeds to five times the current speeds are not difficult to attain. Where distances are limited, short haul modems offer still higher performance at nominal cost. Herein seems to lie the most cost effective means of performance increase.

However, changes in modem and line combinations are not without their problems. Changes from dial up to leased lines make substantial differences in the amount of hardware required in the front end processor. High performance modems may each cost far more than our refurbished U1004 terminals. Changes in the modem/line configuration must be carefully evaluated as related to the overall system performance and cost.

The last area to be considered for possible future development is the U1004 terminals themselves. To date all are used only for terminal use and card listing. All have only a card reader and printer as peripherals. The U1004 is actually a good stand alone computer which was designed to do a variety of data processing jobs. In addition to this many additional peripherals are readily available, including extra card reader, card punch, paper tape reader, paper tape punch, and magnetic tapes. Many such peripherals are owned by UCC but have not been refurbished. It is quite likely that the U1004s could be applied to new applications in some cases, both in a communications environment or as a stand alone system.

The primary resistance to such usage of the U1004s is due to two reasons; 1) possibility of interference with the prime objectives of these terminals, and 2) the greater degree of difficulty in programming the U1004 as compared to other programmable devices.

X. Summary and Conclusions

This document has described the development and current status of the Remote Terminal Subsystem. It has dwelled on what decisions were made, why, and the results of those decisions. Considerable analysis has been presented regarding usage, performance, and cost. It is now appropriate to draw some conclusions.

The need for a Remote Terminal Subsystem and for widely distributed MSBTs has certainly been shown. If general industry trends have not shown this, then the overwhelming response by the users at the UofM has shown this to be true. The impact of more localized distribution of computer power can be easily seen in the charts in section VI.

The decision for UCC to take an active role in hardware design, production and maintenance has often been questioned. This transition has not been without problems. However, to dwell on the problems at this point is to stare at the tree while ignoring the forest. The overall system is now running quite smoothly and provides a level of user service not offered by the other alternatives.

The current level of user service has been reached at a cost level about 35% of that required by conventional approaches. Indeed, it is doubtful whether or not this level could have been reached at all by merely using the vendor supplied equipment. The charts in section VII readily point out that a monthly cost saving of $17,434.00 is being realized as a result of this approach. This savings is expected to increase with time and the number of terminals in use.

In addition to cost savings the University also has gained substantially in other regards. UCC now has far more flexibility to implement new requirements. Faster response to user problems is possible. Students associated with the development program gained valuable experience and student users are being exposed to methods of computer operations more nearby resembling what they will encounter in private industry.

Specific equipment choices have all performed well. Problem areas have been defined and corrected. The performance levels have been up to or above accepted industry standards.

In conclusion, the authors of this report strongly feel that the program has been a major success. It has provided a high level of user service at minimal cost while increasing flexibility.