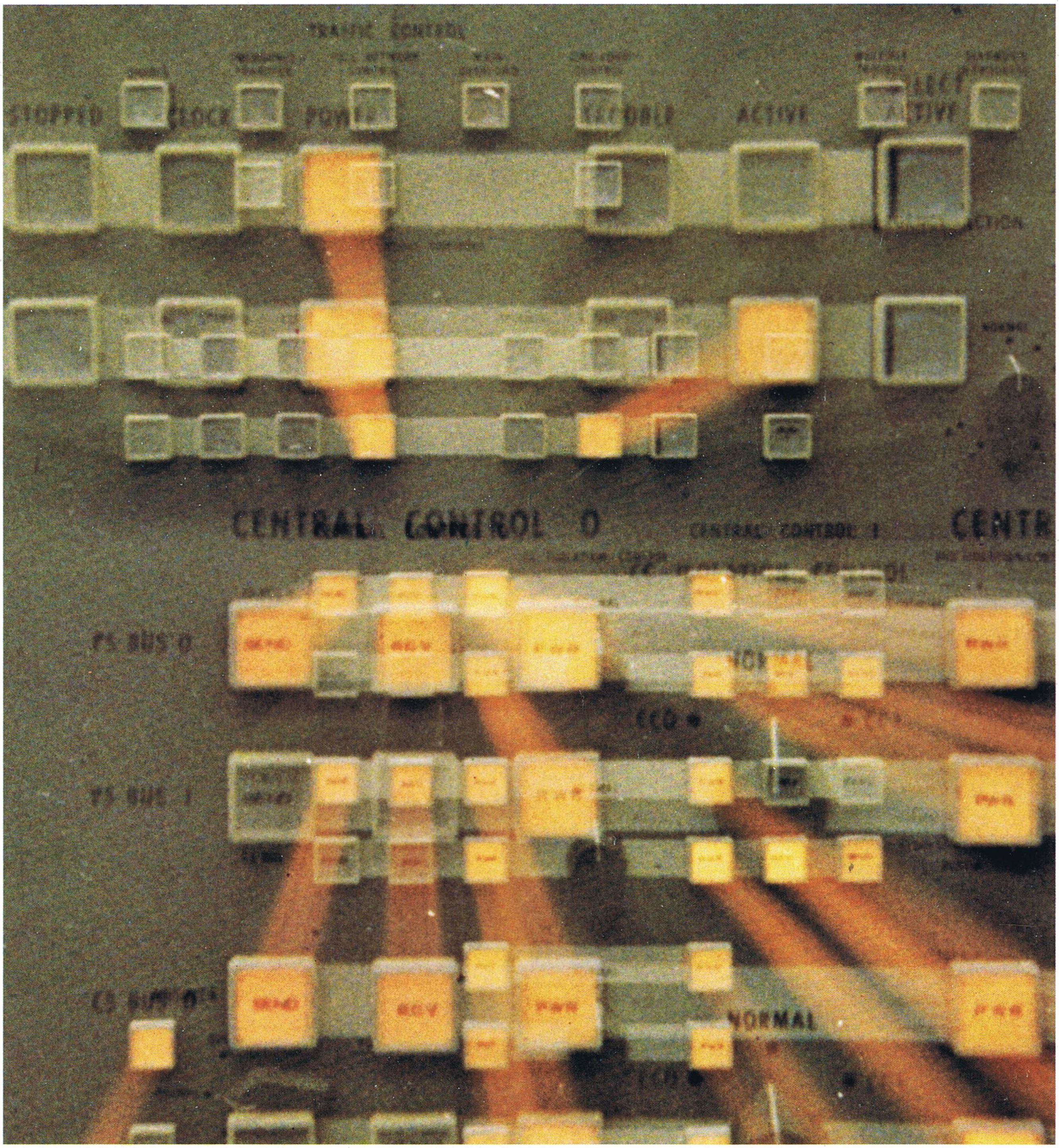
NO. 1 ESS TODAY



INTRODUCTION

The No. 1 Electronic Switching System has had a long and interesting history. This development has been recorded in hundreds of separate documents. While these individual documents accurately reflect the details under consideration at particular moments, it is easy to lose sight of the overall direction of the No. 1 ESS development. Since virtually every major parameter of the No. 1 ESS has undergone significant changes since the first No. 1 ESS office was placed into service in Succasunna, New Jersey, on May 30, 1965, it is especially appropriate to pull together the major points in this development and presents a comprehensive update on No. 1 ESS — in essence to present "NO. 1 ESS TODAY."

This book is not intended to be a detailed document. Rather, its intent is to be broad in its view and to discuss all of the major aspects of No. 1 ESS and how these have changed over the past decade. For the reader interested in more detailed documentation on a given subject, the Documentation section provides a list of all major System documentation on No. 1 ESS.

The various sections of this book were written by the persons in BTL, WE and AT&T with current responsibilities in the given area. We would like to take this opportunity to recognize those who wrote and organized the individual sections:

I. Brief History of No. 1 ESS
T.S. Greenwood,
E.G. Neumiller — BTL
E.R. Kerkeslager — AT&T

II. Call Handling Capacity
E.P. Gould, E.G. Neumiller,
A.A. Stockert — BTL
E.R. Kerkeslager — AT&T

III. Switching Network and Trunks
R.F. Grantges, G. Haugk — BTL
R.L. Pursley — AT&T

IV. Generic Memory Requirements
W.C. Jones — BTL
E.R. Kerkeslager — AT&T

V. Customer Features
G.G. Drew, A.A. Hood, H. Oehring,
E.H. Siegel, A. Zarouni — BTL
E.R. Kerkeslager, R.F. Page, F.L. Sullivan — AT&T

VI. Administrative Features
R.F. Grantges, M.S. Hall,
A. Zarouni — BTL
W.B. Daw, V.E. Kistler,
B.G. Reece — AT&T

VII. Maintenance and Reliability
R.A. Estvander, G.E. Fessler,
R.F. Kranzmann — BTL
V.E. Kistler, A.C. Schwartzenberg — AT&T

VIII. Price
R.K. Eisenhart, E.P. Gould,
J.F. Urich—BTL
C.W. Johnson —AT&T

IX. Growth Capabilities
R.A. Estvander — BTL
J. Gradishar, E.A. Monken — WE
E.R. Kerkeslager, A.C. Schwartzenberg — AT&T

X. EF&I Intervals
J. Gradishar, E.A. Monken — WE
E.R. Kerkeslager — AT&T

XI. Current and Near Future Developments
E.H. Siegel — BTL
C.W. Johnson — AT&T

XII. Summary and Future Directions
E.P. Gould, T.S. Greenwood,
J.D. Johannesen — BTL
P.F. Draudt, E.R. Kerkeslager — AT&T

XIII. Systems in Service
E.G. Neumiller — BTL
E.R. Kerkeslager — AT&T

XIV. Major Documentation and References
P.J. Guenther, E.R. Kerkeslager,
H.C. Murtha — AT&T

Cover Design — W. Panos AT&T

The No. 1 ESS has been a significant development — not only to the Bell System, but to United States and World industry as well. It is the largest development ever undertaken by private industry, with over 2000 man-years of development effort already invested. It was acclaimed in 1968 to be one of the top 10 engineering accomplishments of that year. And finally, it is an outstanding example of the cooperative working of AT&T, Bell Laboratories and Western Electric to produce a system to meet the complexity of present and future switching needs of the Bell System Operating Companies. No. 1 ESS has proved the soundness of the stored program concept and has spawned a whole family of electronic switching systems. ETS, TSPS, No. 2 ESS, AIS, No. 3 ESS, No. 1A ESS and No. 4 ESS rely upon basic development work done for the No. 1 ESS and attest to the continuing soundness of the stored program concept.

The information presented in this book represents current information or current plans. As is necessary for a document of this type, which is not intended to be updated, it should not be used for specific planning or implementation; the detailed letters from AT&T should be used for such purposes. Rather, this book should be used to obtain an overall background on No. 1 ESS — where it has been, where it is now, and where it is going in the future. With such a common background of knowledge about No. 1 ESS, our future directions for the system should more accurately reflect the customers' needs and priorities.

A note on the organization of this book: most sections have been organized generally according to

— what were the capabilities of early systems

— what changes have occurred up to the present

— what are the future plans

The major parameters of the No. 1 ESS have been used as the titles of the sections of this book and each section, while maintaining the general organization noted above, is meant to stand on its own and tell a complete story.

E.R. Kerkeslager
Editor

I - BRIEF HISTORY OF NO. 1 ESS DEVELOPMENT

Although actual design of the No. 1 Electronic Switching System was not begun until the latter half of the 1950's, Bell Laboratories investigations in electronic switching were started much earlier. In fact, Bell Laboratories had an active research program in electronic switching before World War II and has maintained a fundamental development program in this type switching since shortly after the War. Basic concepts of electronic switching were developed in those early days, often before the physical capability to implement them existed. The invention of the transistor by Bell Laboratories in 1948 represented a major step towards making electronic switching a practical reality. As soon as switching transistors became available, development work started on the first Bell System trial of electronic switching — at Morris, Illinois. The Morris trial demonstrated the value of the basic concepts of electronic switching, concepts that were first made available on a standard basis in No. 1 ESS. Some of those basic concepts are:

- Stored program
- Generic program
- Office parameters (PDA)
- Individual Line and Trunk Translations (TDA)
- Simple, universally applicable trunk circuits
- General purpose switches for local/tandem/toll applications
- Single processor-duplicated
- Bus systems
- Automatic trouble detection and diagnosis
- Virtually no wired options
- Seven foot equipment height

These concepts, such as stored program control, appear in discussion, either directly or indirectly, throughout this book; and many of the improvements in No. 1 ESS that will be noted in this book are directly attributable to the soundness of those basic concepts. The following paragraphs describe some of the highlights in the development of No. 1 ESS from 1956 through the beginning of this decade. The selected items mentioned give some indication of the way in which a stored program system like No. 1 ESS can be modified and expanded to provide new capabilities in a relatively short time.

Early design of the electronic switching system was reviewed at a conference of AT&T, Bell Laboratories, and Western Electric in November, 1956. At that time, development of system components was well under way for the electronic central office at Morris, Illinois.

In order to proceed with production design, in April, 1958, a new switching systems engineering division was established at Bell Laboratories to provide requirements for the design of an ESS, later called No. 1 ESS. In addition, this division was given concurrent responsibility for systems engineering aspects of the Morris trial.

During 1958, reviews were conducted in the following three general areas, with representation, as required, from AT&T, Bell Laboratories, or Western Electric:

(a) Development of feature requirement lists
(b) Price study comparisons of proposed systems
(c) Determination of the availability and applicability of new art components.

It was agreed that initial features of the system would be limited to essential requirements only, plus a few features requiring little development effort. This was done to reduce development and manufacturing intervals and thus provide for the earliest possible introduction of the No. 1 ESS in the Bell System. By October, 1959, the service date of the first office was set at July, 1965, with plans to improve this to December, 1964, if possible. It was believed that the initial installation should be a replacement of a step-by-step dial office of about 5,000 lines.

In mid-1960, planning was based upon a maximum office size of about 64,000 lines and 16,000 trunk terminals; Western Electric production projections for 1970 were for one million lines. Maximum office sizes and capacities were planned as follows:

- Line Link Networks — 16
- Trunk Link Networks — 16
- Line Terminals — 65,536
- Trunk Terminals — 16,384
- Line Link Switching Capacity — ccs — 236,000
- Trunk Link Switching Capacity — ccs — 236,000

The Morris, Illinois, trial started in November, 1960, with partial (less than 24-hour) service having been provided to a few selected customers earlier in the year.

In 1961, introduction of ESS in the field was proposed in three design phases, as follows:

1. Isolated switching locations with minimum required features
2. Metropolitan switching with expanded features
3. New customer services and data service features.

Ultimately, full toll and tandem capabilities were to be made available. In 1961, Western Electric Company estimated production as follows:

Year	Lines	Year	Lines
1963	5,000	1967	300,000
1964	10,000	1968	350,000
1965	40,000	1969	532,000
1966	150,000	1970	620,000

The Morris, Illinois trial ended early in 1962. At this time, design and production was started on 4-wire No. 1 ESS for Government installations, for which a bid had been submitted by AT&T Long Lines early in the year. The 4-wire installations covered by this sale required substantial Bell Laboratories and Western Electric efforts, causing some delays in 2-wire projects. A universal (generic) program, with feature options, was proposed late in 1962, for application to all 2-wire No. 1 ESS offices. Basic requirements for the Centrex and data communication (DACE) projects were finalized during 1963. The DACE project was later renamed No. 1 ESS ADF (Arranged for Data Features). Those Centrex features which could not be included in the initial installation were scheduled for later installations.

Throughout the early years of manufacturing, many product problems arose which required concerted Western Electric and Bell Laboratories efforts. For instance, material selection in connection with high resistance problems in sealed contacts required considerable attention for over a year. At one time, semiconductor problems required replacing about 14,000 circuit packs already installed in the field. Problems with memory components, ferreed switches, and certain circuit packs also required field replacement in some instances.

By late 1964, proposed cutover dates were established for the early ESS offices, starting with Succasunna, New Jersey, during the first quarter of 1965 and proceeding as rapidly as practicable with offices in Chase, Maryland; Norfolk, Virginia; Philadelphia, Pennsylvania; New York City, New York; and Washington, D.C. At this time four generic programs were proposed:

1. CC
2. SP
3. CC-Centrex
4. SP-Centrex

Beginning with the cutover of Succasunna on May 30, 1965, a substantial number of ESS offices were placed in service progressively as indicated in the following table:

End of Year	Total Installations Placed in Service	Initial Offices	Program
1965	1	Succasunna	Nongeneric
1966	1	Chase	Nongeneric
1967	16	Beverly Hills	CC-1
1968	23	Philadelphia — Locust	CC-CTX-1
		New York — PE6	SP-1
		Peoria-Jefferson	SP-CTX-1
1969	29		
1970	57		
1971	81		

The above figures for total installations placed in service for a given year do not include 41 4-wire offices placed in service by Long Lines in the 1967-1970 period, nor the No. 1 ESS ADF (Arranged for Data Features) office in New York City, placed in service in 1969.

Some of the features provided or trials started during the 1969 to 1971 period were as follows:

Feature	Placed in Service
CCSA	December, 1969
Call Waiting	January, 1970
SLN	April, 1970
Centralized Maintenance Trial	October, 1970
Dial Tone First — Coin Service	October, 1970
4- and 8-Party Ringing	December, 1970
AIOD	April, 1971
32K Call Store	April, 1971
IDDD	August, 1971
AIS Interface	August, 1971

The issue of non-centrex programs was discontinued, starting with issue of the SP-CTX-3 and CC-CTX-2 generic programs released to Western Electric in June, 1969. This was done to reduce the proliferation of ESS generic programs, for easier administration, more reliability, and improved availability of features and options.

This section has mentioned a few selected items from the history of No. 1 ESS. More could have been cited; the following sections will bring many of these into the discussion. What should be noted in general, however, is that the history of No. 1 ESS has been one filled with cooperation and hard work — cooperation among the individual companies of the Bell System to determine what the No. 1 ESS should be and hard work to make the final system be just that.

II - CALL HANDLING CAPACITY

1. INTRODUCTION

The call carrying capacity of a given No. 1 ESS machine is sensitive to the traffic and signaling characteristics of the offered load. A No. 1 ESS operating in a predominately MF signaling environment and equipped with main stations which mainly utilize plain old telephone services (POTS) is capable of exceeding the 100,000 peak busy hour capacity predicted in 1962. A history of the No. 1 ESS capacity is shown in Figure 1. The capacity numbers shown for the SP offices are arrived at by calculating the peak capacity of the CC working in conjunction with its associated SP. Prior to the CTX-5 real time improvements, the CC was the limiting machine in calculating call capacity. Subsequent to the CTX-5 generic there exists the possibility that the SP becomes the limiting machine. Examples of such limiting conditions are: 1) where the offered CCS per line or incoming trunk is low and the desired engineering forces large numbers of line and trunk scanners to be utilized, and 2) in a heavy bylink environment where the real time consumed by faster scanning rates markedly decreases the SP capacity. (Analogous statements apply to a CC only office.) Work is progressing on an SP capacity estimating program (SPCAP) to be used in conjunction with the CC capacity estimation program (ESS1CAP). To calculate the capacity of a given No. 1 ESS office equipped with an SP it is necessary to view the capacity of both the CC and SP. Due to lack of empirical data concerning SP processor capacity the main theme of this section will be weighted towards CC processor capacities with and without an adjunct SP.

In 1962 No. 1 ESS capacity was predicted to be 42,000 to 53,000 for a central control (CC) office and 93,000 to 104,000 calls for an office equipped with a signal processor (SP). The estimated capacity was less than the objective during the period from 1964 until 1968 as development was completed and measurements of actual call carrying capacity became available from tests conducted in cutover offices. The first call capacity measurements were conducted at Beverly Hills during 1966 on the CC-1 generic. These measurements indicated a peak busy hour call (peak BHC) capacity of about 27,000 calls. Soon thereafter, program improvements were made to increase the capacity to 32,000 busy hour calls.

In 1968 the first signal processor generic program was released. The estimated capacity of 59,000 to 73,000 peak BHC was considerably below the 100,000 projected in 1962. To summarize, the 1968 peak busy hour call capacities as stated in the Traffic Facilities practices for CC-1, SP-1, CC-CTX-1, and SP-CTX-1 generic were:

Central Control	30,000 to 36,000
Signal Processor	59,000 to 73,000

2. CAPACITY IMPROVEMENTS

In the past six years, effort has been expended to increase the call-carrying capacity of the No. 1 ESS. Improvements were made through both hardware and software means. Of the several developments that have produced a substantial increase in the traffic handling capacity of No. 1 ESS, the streamlining of the program is the most significant.

The first set of improvements in the software were the so-called "quick fixes" to the CC-1 generic which were released in 1967. More capacity was recovered by software changes in the CC-3 generic released in 1968. These and other software changes were incorporated into the CC-CTX-2 and SP-CTX-3 generics released in 1969.

These improvements were largely the result of streamlining the program and suspending some maintenance checks during high calling periods. The program was streamlined by removing subroutining in high runner legs of the program and expanding the code in line. The in-line code which replaced the use of a generalized subroutine was executed faster since it performed only the required special function. Some routine checks such as false-cross-to-ground (FCG) tests were suspended during high calling periods in order to permit the system to use the time to process calls.

Introduction of the service link network (SLN) in 1970 raised the ESS capacity to 83,000 peak busy hour calls. This represented an increase of approximately 15 percent over the non-SLN capacity. The service link network is an adjunct to the switching network which reduces the number of operations required to hunt and establish paths to ringing circuits and trunk digit receivers. Later program improvements have reduced the difference in capacity between service link and nonservice link equipped offices to about five percent.

Improvements in the CTX-5 generic program released in 1971 raised the capacity to 95,000 peak busy hour calls. The improvements were achieved by streamlining the programs used to hunt, busy and idle network paths between lines, trunks, and service circuits, excepting those connected through the SLN. These improvements were applied to both CC and SP, SLN and non-SLN generic programs.

Another set of improvements was released with the CTX-6 generic in 1972. These improvements increased the central control capacity to an average of 110,000 peak busy hour calls for SP offices equipped with SLN. These improvements were achieved by streamlining selected portions of the program concerned with processing received digits, outpulsing, and guard timing of trunks.

With CTX-6, the central control peak busy hour call capacity range (depending on traffic mix) is:

42,000 — 53,000	in a central control office
93,000 — 110,000	in a signal processor office
98,000 — 115,000	in a signal processor office with service link network

Offices which have unique traffic characteristics may have central control capacities above or below the stated ranges. Signal processor capacity in these offices will depend upon both traffic mix and the amount of equipment engineered for the office. For a heavy bylink signaling mix and/or large amounts of equipment, the SP capacity may be lower than CC capacity producing lower office capacity figures than shown in Figure 1.

The latest improvements were released with the CTX-7 generic in 1974. Preliminary measurements show that these improvements raised local office central control capacity by one or two percent over CTX-6, CTX-7 improvements in tandem call processing raised the capacity of an SP tandem office using MF signaling to about 100,000 full switched calls.

Future generic programs (CTX-8 and beyond) will continue to have some small real time improvements that apply to most types of calls. With the advent of the 1A Processor, however, the call handling capacity of No. 1 ESS will receive a significant boost; the new system, called the No. 1A ESS, is projected to have an average capacity of about 240,000 peak busy hour calls. This development will so change the processor — network balance that an expanded switching network will have to be utilized to match the increased processor capacity.

3. CAPACITY RANGES

The call processing capacity of a No. 1 ESS can vary from office to office because the number of program instructions (machine cycles) required to process a call is a function of the complexity of the call and the design of the system. Figure 2 lists the machine cycles used by the central control to process a number of typical call types in the CTX-6 generic. From this one can deduce that offices carrying POTS traffic can process more total calls than one carrying significant amounts of coin or Centrex traffic. An interactive computer program, ESS1CAP, is available to estimate the central control capacity for a given No. 1 ESS office configuration. The program computes capacity from traffic and equipment mix inputs such as percent of incoming, intraoffice, tandem, Centrex and coin calls. The capacity estimating program is a feature of the No. 1 ESS module of the Central Office Equipment Estimation System (COEES).

Figure 3 is a histogram of the estimated CTX-6 central control capacity for 60 existing signal processor offices. The capacity estimating program ESS1CAP was used to calculate capacity from traffic mix data supplied by the Operatiang Companies. The ESS1CAP runs were made for these SP offices assuming that all were non-SLN. ESS1CAP computes and outputs the peak quarter hour capacity. This is converted to peak hour capacity by multiplying by the peak hour to peak quarter hour ratio which typically ranges between 3.70 and 3.95. This histogram indicates that the central control traffic capacity for SP-CTX-6 ranges from 19K to 32K calls per quarter hour. This range is greater than the broad gauge range shown in Figure 1 and emphasizes the necessity of continually monitoring No. 1 ESS call capacity. This is a necessity if the traffic mix is changed drastically. Similar capacity ranges exist for CC type offices. In CC offices, the range is a function of both traffic mix and equipment quantities since the central control must perform the line and trunk scanning in an office not equipped with a signal processor. Insufficient data (small sample size) exists to predict a good range for CC offices; therefore, a mean value is estimated.

The range of signal processor capacities for a given generic is also large. A capacity estimation program for the signal processor (SPCAP) will soon be introduced into the COEES system so that traffic engineers may obtain direct estimates of both CC and SP capacity. In the meantime, a warning message in the ESS1CAP program informs the traffic engineer of those cases when Bell Laboratories should be contacted for an SPCAP run of SP capacity.

4. CENTRAL CONTROL CAPACITY ESTIMATION AND VERIFICATION

The length of time it takes before the processor can respond to a service request determines the processor's exhaust point. As the load in the system builds up, this response time increases. When the response time exceeds the acceptable service objectives for dial tone delay, the system has reached exhaust and cannot satisfactorily serve a higher rate of requests. In the central control, the number of executive control or main program cycles ("E-E cycles") in a quarter hour determines the average delay in serving customers during the quarter hour. In order to meet the dial tone delay criteria, the minimum number of main program cycles per quarter hour has been determined to be 3500 E-E cycles for an SP office and 2400 E-E cycles for a CC office. These minimum cycle rates were established by measuring system response during tests and simulation. The higher cutoff point in the SP office is due to the possibility of greater variability in cycle times especially during overload.

The method used to estimate and verify capacity is to construct a straight line relating the machine offered load and the machine response in E-E cycles to a particular traffic mix. The point at which the line crosses the minimum number of E-E cycles required to meet the dial tone delay criteria determines the maximum load the machine can process. Figure 4 is a curve generated by ESS1CAP for a typical No. 1 ESS signal processor office. The slope of the line is determined by the number of machine instruction cycles used per call as computed by ESS1CAP from the traffic mix supplied and the cycle counts per call as shown in Figure 2. (Cycle counts of each call type are measured in the Bell Laboratories' No. 1 ESS test laboratory and constitute the data base for ESS1CAP.) In Figure 4, the peak quarter hour capacity (27,500) is the point at which the load line intercepts the minimum permitted number of E-E cycles during a quarter hour (3500). Assuming a peak (quarter-hour) / (hour) ratio of 3.85, the peak busy hour call capacity of the central control in this office is 106,000 calls (27,500 x 3.85).

The accuracy of the ESS1CAP generated curve can be verified by a linear projection method using traffic data from the in-service office. Each quarter hour, traffic data is outputted on the TTY giving peg counts of the offered originating and incoming traffic load and the number of central control main program cycles (E-E) during the quarter hour interval. The mean of several peak quarter hour intervals is calculated and this point is plotted on the curve. A mean E-E equal to 15,000 is used for illustrative purposes on Figure 4. A mean no load E-E value is also calculated from traffic data (29,000 E-E at no load is used in Figure 4). A load line through these points is then extended to the exhaust point (3500 E-E). In the example, the intercept is at 31,000 calls per quarter hour. The machine's capacity is rated at 5 percent less than where the load line intercepts the 3500 E-E line to ensure that the resulting E-E visitation rate will exceed the minimum at least 95 percent of the time. The measured capacity in the example is 29,500 calls per quarter hour. Note in this example that the measured capacity exceeds the ESS1CAP estimate. The result obtained in each office is a function of the accuracy of the input data.

The data screening and posting and the calculations involved in estimating processor capacity using the linear projection method can be reduced through the use of the EECAP time shared program. EECAP performs three basic tasks:

a) The creation and maintenance of office descriptive information
b) Storage screening and management of traffic data needed for the calculations.
c) Calculation of capacity estimates.

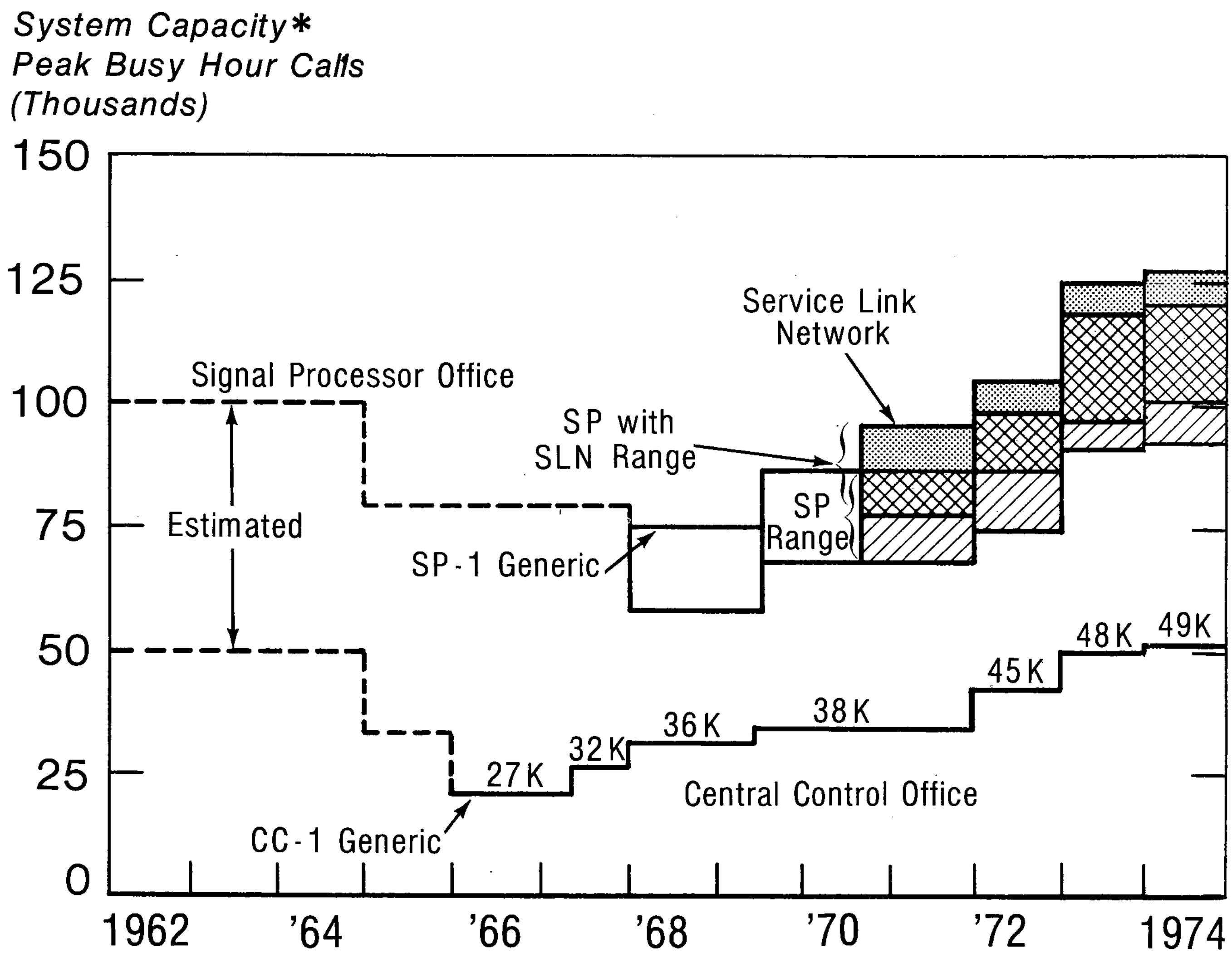
The EECAP program is available to the Operating Companies as a subsystem of PATROL (see Section VI).

In the event that there is a significant discrepancy between the estimated and the measured capacity, traffic data from the office should be examined to determine if the traffic mix supplied to ESS1CAP is accurate. The accuracy of the measured capacity will increase as the load increases. It is recommended that EECAP be run monthly or whenever significant increases in offered load are observed.

When engineering a machine based on anticipated traffic characteristics, or projecting capacity for an office to which a sizable addition is planned, it is recommended that ESS1CAP be used as an approximate estimate of the capacity, and the linear projection method described above be used, following cutover, for a refined estimate. Experience has shown that only limited precision can be obtained by any pre-cutover real-time prediction method, such as ESS1CAP. For this reason, it is recommended that ESS offices not be placed into service or abruptly expanded to high-day load levels in excess of 85 percent of the capacity predicted by ESS1CAP. The remaining capacity should be utilized by normal growth of the office. Attempts to cut an office into service with estimated high-day loads in excess of 85 percent of predicted capacity have resulted in machine overloads caused by misestimates of either the traffic mix or the amount of traffic produced by the lines and trunks cut into service.

The method given above is similar to the use of load-service curves to predict capacity. The use of E-E counts instead of dial tone delay is necessary because the load vs. dial tone delay curve is very steep in a processor-limited office.

No. 1 ESS capacity history . . .



* For signal processor offices the graph represents central control capacity as computed by ESSICAP. For generics SP-CTX-5 (1972) and beyond, the signal processor may limit capacity in some offices. In these cases, office capacity will be less than shown.

Figure 1

Central Control Cycles Required to Process a Call SP Office without SLN

(CTX-6)

Call Type	Cycles/Call Type
Incoming SxS	3,550
Outgoing MF	3,650
Incoming MF	4,100
Intraoffice	4,300
Dial 9 Outgoing	4,550
Tandem	4,950
Local Coin	6,250
Outgoing FX	5,700
Outgoing - Attendant Controlled	13,600
Coin Zone	22,700

Figure 2

No. 1 ESS central control capacity . . .

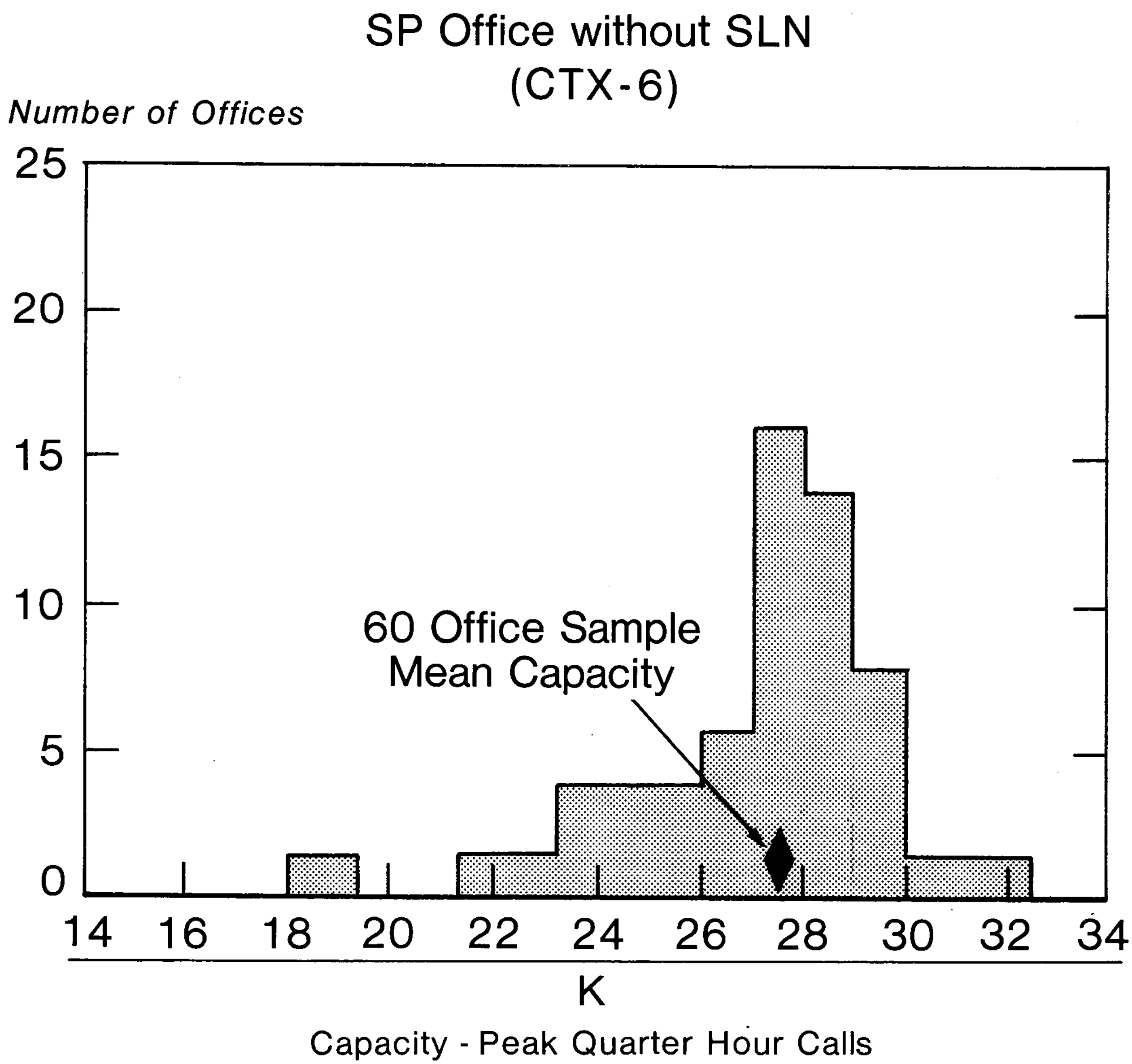


Figure 3

Estimating No. 1 ESS capacity . . .

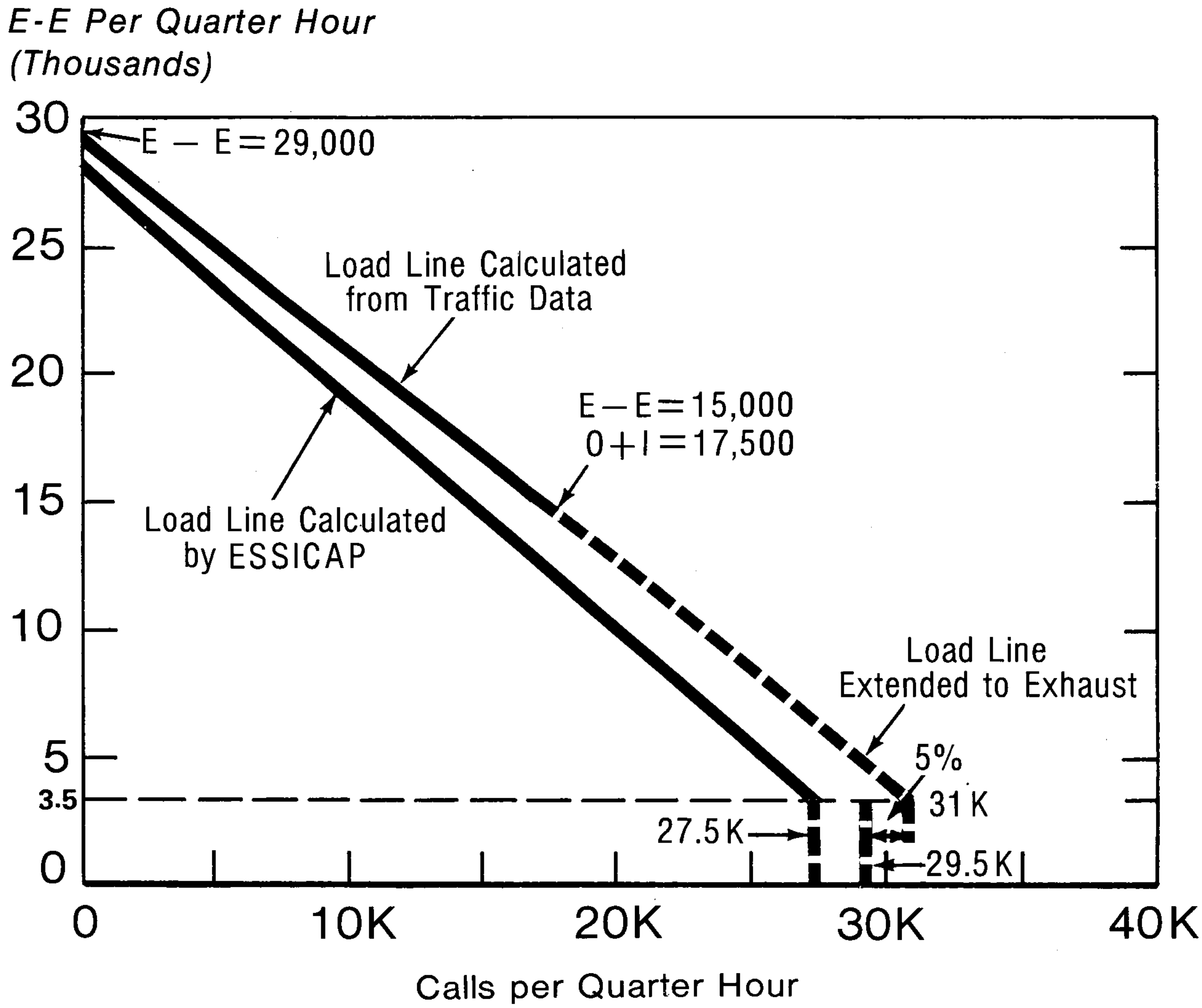


Figure 4

III - SWITCHING NETWORK AND TRUNKS

1. GENERAL DESCRIPTION

The switching network is the major functional unit in most telephone central offices, representing a significant portion of the cost of the office. The switching network serves the function of interconnecting the many lines and trunks served by the office. A second function of the network is to match the traffic between a large number of lightly used lines and a smaller number of heavily used trunks, maintaining a satisfactorily low probability of blocking. The No. 1 ESS switching network also performs link functions — making connections between signal transmitters and trunks, ringing circuits and lines, etc. The reasons for this latter function were to simplify trunk circuits, to eliminate the problems of engineering and administering several different networks, to provide the connecting link function at high efficiency and to provide full freedom to associate trunks with all types of signaling circuits.

These basic functions are performed in an operating environment that slowly changes over the life of the office. Not only can the size of the office change, but the offered traffic per line can change, the proportions of intraoffice, incoming, outgoing and tandem traffic can change, the type of facilities to be interconnected can change and the type of service offerings can change. In order to meet the requirements of an office efficiently at any time and to match the requirements of initial offices that cover a broad range of sizes and traffic characteristics, the network must be capable of very flexible interconnecting patterns. This is accomplished in the No. 1 ESS by the use of a minimum number of basic network building blocks, whose sizes are tailored to acceptable growth or change needs, and which are then interconnected in standardized series-parallel arrangements to form the complete office network.

In order to achieve its initial design goals of practically a "universal" switching system, the No. 1 ESS network became in some ways the most complex yet employed in telephone switching. However, because of its basic building block design, it is quite easy to understand.

Let us begin with an overview, a look at the network as a whole and see how typical calls are handled by sequences of a few basic types of connections. Then we will return to the building block approach, starting at the lowest level — that of the basic crosspoint — and build up the network in all its complexity step by simple step.

Figure I Chart III-1 shows the switching network portion of a No. 1 ESS office. Lines, trunks and service circuits are interconnected by an array of line link networks, junctors and trunk link networks. It is appealing to think of link networks as analogous to line link frames in No. 5 crossbar and trunk link networks as similar to trunk link frames. But the terminology is misleading. It is more accurate to think of a line link network as analogous to a whole No. 5 crossbar office because it includes four stages of switching and is roughly 5 to 15 times as large as a line link frame. The same goes for the trunk link network — trunk link frame analogy.

Perhaps the simplified configuration shown here is still confusing for us to begin with. So let's view the same thing in a still more simplified form by removing one trunk link network and not showing the trunk and service circuits. In Figure 2 the "X" marks indicate that the No. 1 ESS network consists of four stage switching arrays, called either line link networks or trunk link networks, that are tied together by wires called junctors. Some of these junctors have little boxes in them called junctor circuits. (These are used to provide line supervision on intraoffice calls.) It is apparent that to go anywhere in this network a connection has to traverse eight stages of switching.

In fact, there are only four basic types of connections that can be made in the No. 1 ESS as shown in Figure 3 (a purist might claim there are only three). Here we really have stripped the network down to essentials — one line and one trunk link network. The line-to-line connection provides a talking path between two lines. The line-to-trunk and trunk-to-line connections are similar to each other, but the line-to-trunk connection admits of a retrial on blocking (say, from a line to an outgoing trunk — try another trunk if you can't reach the first one) while the trunk-to-line usually does not (say, from an incoming trunk to a specific line). The trunk-to-trunk connection interconnects two trunks, or a trunk and a service circuit, and almost always permits one or more retrials when blocking is encountered. In the next few charts we will see how all the usual types of calls can be built up from sequences of these basic connection types.

On an originating outgoing call, as shown in Figure 4, the originating line is first connected to a customer digit receiver (CDR). This is a line-to-trunk type of connection. When the digits have been dialed, the office selects an outgoing trunk and reserves a talking path from the line to the trunk (a line-to-trunk connection type), to assure its availability after outpulsing. Here is another departure from previous practice. In No. 1 ESS, because we set up sequences of connections, on any one of which blocking can occur, we have to resort to reserving paths ahead so that, in this case for example, we do not discover that after outpulsing to the distant office we cannot provide a talking path because of network blocking.

Path reservation is not difficult, because only logical operations and memory manipulation by the stored program controlled processor are involved, but it is time consuming. In fact, it does get pretty complicated at times, because the control tries to let actual and reserved paths through the network reuse some of the same network links to hold down network load on critical links. Reserved paths are just as "real" to the ESS control as actual paths in use, and both contribute CCS usage.

While the line is held on the CDR after dialing, a transmitter is connected to the outgoing trunk, a trunk-to-trunk connection type. When outpulsing is complete, the reserved line-to-trunk talking path is set up and other connections are abandoned.

As shown in Figure 5, the incoming terminating call is handled by a sequence of (a) trunk-to-trunk, for a receiver, (b) trunk-to-line (talking reserve), (c) line-to-trunk (ringing), and (d) trunk-to-trunk (audible ringing) connections. When ringing is tripped, the reserved talking path is set up and the other connections abandoned. The intraoffice call, shown in Figure 6, requires the sequence (a) line-to-trunk for dialing, (b) line-to-line (talking reserve), (c) line-to-trunk (ringing), and (d) line-to-trunk (audible). The tandem call is handled by a sequence of trunk connections as shown in Figure 7. Again a reserved path is required to insure tha ability to talk after outpulsing.

It should now be clear that the most complex type of telephone calls can be set up by employing sequences and combinations of the four (or three) basic network connection types. In order to do this successfully, however, the network must be capable of very fast response (example, to set up a talking path immediately after ringing is tripped). The crosspoint must be both reliable after many operations (because there are more switch operations per call than in earlier systems) and of low resistance (because there are more in series on each connection). Let us now take the building block approach to understanding how the No. 1 ESS network is constructed.

The most basic unit of the switching network is the sealed reed switch. Operating in clean dry atmosphere under the influence of externally applied magnetic fields, the reed switch will close or release in less than 3 milliseconds with an expected life of well over a million operations and resistance of less than 0.2 ohm when closed. The reed contacts are delicate, however, and cannot be used to make or break current — they must be switched "dry."

The ferreed switch is a 2-wire, magnetically latched, pulse operated device. It consists of two sealed reed switches which are operated and released by controlling the magnetization of adjacent magnetic structures. A four contact version has been manufactured for use in 4-wire AUTOVON switching offices. Because the ESS central processor maintains records of link busy-idle status and connection paths for calls in progress, the network needs no sleeve leads and only the tip and ring paths are switched.

The ferreed crosspoints are packaged in arrays of various sizes; an 8x8 crosspoint array is most commonly used. Basically, the ESS switching network is of the matrix type, similar to crossbar, addressed by horizontal and vertical coordinates. Horizontal and vertical selections are made in switches with the crosspoint at the intersection being closed. The selection operation releases existing connections along the horizontal and vertical selection axes in each switch at the time of operation. The crosspoints remain closed without further power application after being selected. Furthermore, it is not necessary to release each crosspoint when a connection is abandoned. The path will be piecewise taken down at a later time when other paths are set up which use the same crosspoints or ones on the same horizontals and verticals. Connections to customer's lines are broken at the first stage switch, isolating every idle line from the network proper.

Ferreed switches are employed in three different 2-stage switching arrays: two types of line concentrators and an array called an "octal grid." Only one concentrator design is used in any given office. The 4:1 line concentrator design shown in Figure 8 is intended for light to medium traffic offices where the originating plus terminating (O + T) CCS per working line is less than about 4.8. Each first stage switch has 16 line terminal inputs. Each line input has access to the four second stage switches over four A-links which it shares with 15 other lines. Eight lines have access to any given A-link. Two to one concentration is achieved in the first stage as there are 16 inputs and 8 outputs on each switch. A further 2:1 concentration is achieved in the second switching stage which consists of four 8x4 switches. The 4:1 concentrator is an economical design and the link sharing arrangement makes it unnecessary to load balance the first stage switches within the concentrator, beyond maintaining reasonably equal numbers of working lines on each switch by line class or type.

The 2:1 line concentrator design shown in Figure 9 is intended for heavy traffic offices where the O + T CCS exceeds about 4.8 per working line. There is no concentration in the first stage; four lines have access over four A-links to the four second stage switches. Although very unlikely at reasonable loads, blocking can occur in the first switch because a single call can employ two A-links simultaneously — one link actually in use and one reserved.

Line concentrators are grouped 16 together with appropriate control apparatus into units called Line Switch Frames as shown in Figure 10. If 2:1 concentrators are used, a line switch frame (LSF) has 512 input terminals; with 4:1 concentrators, 1,024 terminals are provided. The LSF is a major network building block.

Figure II shows the 2-stage "octal grid," the third type of switch array from which all No. 1 ESS networks are built. The octal grid has 64 inputs and 64 outputs and consists of eight 8x8 ferreed switches fully interconnected to a second stage of eight 8x8 switches.

Octal grids are grouped four together with associated controls into units called junctor switch frames and trunk switch frames as shown in Figure 12. For most switching purposes, junctor switch frames and trunk switch frames are identical. Actually, junctor switch frames have some extra 1x8 switches in stage 1 for "no-test" and other testing function access. These are not shown on the chart.

Figure 13 shows how line switch frames (LSF) and junctor switch frames (JSF) are associated together to form a line link network. Of course we don't literally stack line switch frames one on top of the other, but it amounts to that figuratively when all the interframe wiring has been put in place. Shown this way, the eye can quickly grasp the organization of a vast amount of equipment. The line link network as shown provides 2,048 input terminals with 2:1 concentrators and 4,096 inputs when 4:1 concentrators are used. Every line link network has 1,024 junctor terminations (at the right) arranged in 64 rows of 16 terminals each. A maximum of 16 line link networks (LLNs) currently can be provided in an ESS office providing 32,768 terminals at 2:1 concentration and 65,536 terminals at 4:1. In a line link network there is exactly one path (through four stages of switching) from any given line terminal to any given junctor terminal.

Using the same form of representation, Figure 14 shows how trunk and junctor switch frames are associated together into an aggregate called a trunk link network (TLN). The TLN is not so pretty because the B-link wiring doesn't work out quite so neatly when drawn this way. As shown the TLN interconnects 1,024 trunk terminations at the right with 1,024 junctor terminations at the left. There are four paths through the TLN between any selected pair of trunk and junctor terminals. A maximum of 15 TLNs currently can be provided in a No. 1 ESS office.

Link networks are a lot of switching to buy at one time. Therefore, means have been provided to install them less than fully equipped. Figure 15 shows the original No. 1 ESS plan for partial equipping a line link network by providing less than a full complement of line and junctor switch frames. A similar arrangement has been available for trunk link networks. While these arrangements permitted the amount of equipment installed to be closely tailored to office needs, they were long considered painful because in order to grow a partially equipped network both the B-link and junctor wiring had to be rearranged. In addition, the office call handling capacity was reduced if a partially equipped network existed in the office. In fact, the techniques to grow partial networks "in-service" have only been available for a few years. In January, 1972 partial networks were rated "A&M."

Instead of partial networks, a "fractional" network may be used which consists of four junctor switch frames but less than the full complement of line switch frames as shown in Figure 16. As a fractional network is grown to full size, neither the B-link nor junctor wiring needs to be rearranged.

Other concentration ratios than 2:1 and 4:1 for line link networks are made possible by providing more than four line switch frames per line link network (Figure 17). When this is done, the B-links are multipled at the JSF terminals. When six LSFs per LLN are used, an overall line-to-junctor concentration ratio of 3:1 or 6:1 will be achieved when 2:1 or 4:1 concentrators are used in the line switch frames. At 6:1 line concentration, a 16 line link network ESS office will provide 98,304 line terminations.

Similar multipling arrangements are possible in trunk link networks. At 1:1 concentration a 15 TLN office provides 15,360 trunk terminations. If 6 trunk switch frames per TLN are used instead of 4, a 3:2 (or 1-1/2:1) trunk concentration ratio is achieved and a 15 TLN office would provide 23,040 trunk terminations.

It is important to note that concentration ratios obtained by B-link multipling can be altered by changing the multiple pattern and adding or removing LSFs from the frame line up. Thus, a 6:1 office could be changed to a 4:1 office should CCS per line increase enough to justify the expense. However, a 6:1 office could not be changed to a 3:1 office without removing all the 4:1 line concentrators and replacing them with 2:1 concentrators. Thus, an important decision that must be made carefully for every new No. 1 ESS office is whether to use 2:1 or 4:1 concentrators.

Initially the No. 1 ESS network provided a wide selection of concentration ratio choices for both trunks and lines to permit optimum loading over a wide range of traffic conditions. B-link multipling patterns were available to permit line ratios of 4:1, 5:1, 6:1, 7:1, and 8:1 with regular 4:1 concentrators and 2:1, 2-1/2:1, 3:1, 3-1/2:1, and 4:1 with 2:1 heavy traffic concentrators. Trunk concentration ratios of 1:1, 1-1/4:1, 1-1/2:1, 1-3/4:1, and 2:1 were also provided. However, in the interests of simplicity and economy, in May, 1972, line ratios of 7:1 and 8:1 were rated MD; standard line ratios now consist of 4:1 and 6:1 with 4:1 concentrators, 2:1 and 3:1 with 2:1 concentrators; standard trunk ratios are 1:1 and 1-1/2:1; all other ratios are rated A&M.

We saw earlier that link networks are interconnected by junctors and that each link network terminated 1,024 of them. Interconnecting the tens of thousands of junctors in a large office could be a major problem and changes for growth could be a nightmare. In practice there is little difficulty, however, because, as shown in Figure 18, all junctors are "hard wired" to a junctor grouping frame (JGF) where they are interconnected in subgroups of 16 junctors by plugs and jacks.

Figure 19 shows a representation of the switching network between two lines on different line link networks. At 4:1 concentration some 8,192 line terminations are represented. Two junctor subgroups are shown and we note that the junctors within a subgroup undergo a systematic transposition or "slip" in going from one network to the next. Two different slip arrangements are shown. In actuality, eight different slip patterns are possible. Because different junctor subgroups have different slips, whenever two networks are interconnected by more than one junctor subgroup it makes a difference which subgroups are used. Improper combinations will have less traffic capacity than proper combinations. The problem of deciding in a particular office, which plug to put in which jack on the junctor grouping frame so that all interconnections will have maximum traffic capacity is understood and solved by a computer program, called the Junctor Assignment Program (JAP), available through Western Electric.

Up to now we have assumed that line-to-line calls will bypass the trunk link networks. Actually, there are two other options possible, as shown in Figure 20. In large offices with very low intracalling, the use of intraoffice trunks will be most economical as every such trunk can reach every line in the office. In most offices, a combination of high usage intraoffice junctor subgroups with a common overflow group of intraoffice trunks will handle intraoffice calling most economically. This is an example of alternate routing applied within a central office network.

Trunk and service circuits in No. 1 ESS are of relatively simple design and low cost. This is possible because the central processor accomplishes all the memory functions for which we previously used relays. Figure III-21 shows, for example, a simplified customer dial pulse receiver (CDPR). It uses five magnetic latching relays and requires two scan points to let the central processor know what's going on in the trunk. Even when the associated costs of the scanner and signal distributor points are added to the basic trunk circuit, it's still a pretty inexpensive dial pulse receiver compared, say, to the equivalent in No. 5 Crossbar.

Trunk and service circuits mount in two different ways in No. 1 ESS. Many of the high-runner simple designs come in modules that are simply plugged in to standardized mounting spaces on the so-called universal trunk frame. A nice feature of these trunks is that they can be easily moved from office to office if required and they can be obtained from Western Electric in a relatively short time. Junctor circuits, the supervisory elements required in line-to-line junctors, are also plug-in mounted on the junctor frame. The more complicated trunk and service circuit types are mounted on miscellaneous trunk frames. Work is currently underway on "Cost And Size Reduced Trunks (CAST)," to make the No. 1 ESS trunks both smaller and even more universally pluggable, as well as to hold the line on cost. More details are given in Section VIII-price, and Section X — EF&I Intervals.

Figure 22 gives another representation of the network that points out two things we have overlooked until now — the varieties of cross-connect frames and the service link network (SLN). As the Figure shows, there are five different frames that provide a cross-connect function in the ESS office. We have already described the functions of the Junctor Grouping Frame. The main distributing frame (MDF), trunk distributing frame (TDF) and intermediate distributing frame (IDF) (or Trunk MDF) all tend to look alike, but serve different functions. The TDF distributes trunk and service circuits across the trunk link networks. The IDF interconnects trunk circuits with transmission equipment and, usually, with trunk cable pairs. The function of the MDF is well known. The protector frame provides a place to mount plug-in carbon blocks on the way from the MDF to the cable vault. The carbon blocks break down, or short circuit, at 600 volts and since the ESS line circuits will withstand that voltage, heat coils are not required.

The MDF, TDF, and IDF are modular single-sided frames and employ a type of quick-connect terminal block. This means that Plant effort in running cross-connects is minimized. On the other hand, there can be congestion problems because there is not much horizontal trough space provided. Plant-traffic teamwork can solve the congestion problem and still achieve good line load balance. The COSMIC-COSMOS System is now recommended in place of the ESS modular MDF for subscriber and tie line terminations. For the TDF and IDF, the new low profile conventional distributing frame (LPCDF) is recommended.

The service link network is an array of 2-stage switching frames. On one side terminate every line-to-line junctor circuit and incoming trunk. On the other side terminate ringing, audible ringing and incoming receivers. Figure 23 shows how the SLN is used on an incoming terminating call.

First the call is switched through the 2-stage SLN to a receiver. This saves connecting to a receiver on the TLN through an 8-stage trunk-to-trunk path. If the trunk is blocked in the SLN, or no accessible SLN receiver is available, the call can be switched trunk-to-trunk on an overflow basis. After inpulsing, a trunk-to-trunk path is set up for talking. The SLN is used to ring over the talking path and send audible ring back over the trunk. This saves a line-to-trunk connection for ringing and a trunk-to-trunk path for audible needed in the non-SLN office and requires no juggling of reserved paths. Finally, on ringing trip, the incoming trunk is cut through at the SLN to the called line.

The SLN was introduced into No. 1 ESS in the late 1960's in an effort to save central processor "real time" and thereby substantially increase the call capacity of the office. This goal was achieved, but the SLN also substantially complicated office wiring and administration and was quite expensive. Recent program improvements have reduced the call capacity gain of the SLN office to approximately five percent over the non-SLN office, thus making the cost-effectiveness of the SLN quite marginal. In December, 1972, AT&T recommended that the SLN be rated A&M.

2. NETWORK CAPACITY

It is clear that over the years since its introduction there have been relatively few changes in the design of the No. 1 ESS network. Most of those that have occurred have been in the direction of increasing simplicity and better matching it to its principal role as a network for a large metropolitan switching machine. The initial design was intended to serve offices of any type from about 4,000 lines up. Several features, such as the partial equipping of link networks, were particularly intended to maximize economy in smaller offices.

Another reason for the stability of the design is that the initial design contemplated call handling capacities of about 100,000 busy hour calls — a capacity that has only recently been obtained. Thus, no offices so far have been able to exceed the capacity limits of the switching network.

Initial termination capacity limits for lines ranged from 32,768 at 2:1 concentration, to 65,536 at 4:1 concentration, to 131,072 at 8:1 concentration. These limits correspond to 16 fully equipped line link networks at the various concentration ratios. Today, the maximum termination capacity is set by 16 fully equipped 6:1 line link networks (98,304). Trunk and service circuit termination capacity initially ranged from 16,384 at 1:1 concentration to 32,768 at 2:1 concentration. These limits correspond to 16 fully equipped trunk link networks. With the advent of the service link network, the maximum number of trunk link networks decreased to 15 (the SLN took the place of the sixteenth TLN). TLN termination capacity today, therefore, ranges up to 23,040 (15 TLNs at the 6:4 maximum TLN concentration ratio).

Figure 24 shows the No. 1 ESS network traffic capacity as measured by CCS. The capacity varies as a function of the percentage of the originating CCS which is intraoffice (IAO) and as a function of the percentage of the incoming CCS which is tandem (TDM). The chart assumes 4:1 line concentration and 1:1 trunk concentration. The network's capacity is greater for offices with few intraoffice or tandem calls — most calls are outgoing or incoming terminating. If the traffic is mostly intraoffice with little tandem, or mostly tandem with little intraoffice, only one-half of the network is being utilized (the LLN or TLN sides respectively) and the maximum network capacity is significantly reduced. If there is a lot of intraoffice and tandem traffic then both sides of the network are being used and the capacity is increased. Most existing local offices have less than 50 percent intraoffice traffic and less than 25 percent tandem and fall within the shaded region where the network's capacity is greatest.

3. FUTURE DEVELOPMENT

Network design changes contemplated for the future are in the direction of equipment modernization and increased capacity. The development of new network frames using the miniaturized remreed switch is discussed elsewhere in this text (Section VIII — Price) so the remarks in this section will be confined to measures designed to increase maximum network capacity.

With the advent of the 1A Processor, No. 1 ESS call carrying capacity will substantially increase and will exceed the capacity of the switching network as presently designed. To correct this anticipated imbalance, a trunk link network double the present size (2,048 terminations at 1:1 concentration) has been designed. The new design, known as the 2048 TLN, will make its first appearance in mid-1974 in a trunk-only toll/tandem office and will give such an office a maximum capacity of 30,720 trunk terminations (15 x 2048) and in excess of 250,000 switched CCS. At a later time it is anticipated that the maximum number of line link networks possible in an office equipped with 2048 TLNs will be increased from 16 to 28. This change is expected to nearly double the present line termination and CCS capacity of the switching network.

The 2048 TLN can be viewed as two of the present 1024 terminal TLNs with revised B-link wiring interconnecting both networks. Alternatively, one may visualize the TLN design as shown in Figure 25 with 32 octal grids in each stack. The 2048 TLN will contain 1024 8x8 switches or some 65,536 crosspoints. It is planned that procedures will be provided so that existing 1024 TLNs (at 1:1 concentration) can be rewired in pairs to form 2048 TLNs.

4. MECHANIZED ENGINEERING

No report on the No. 1 ESS network would be complete if it failed to mention the area of mechanized aids to engineers in the field — an area pioneered by No. 1 ESS. Back in the middle 1960's, Bell Laboratories and AT&T began exploratory work in the area of mechanized aids to traffic engineering. Initially there were two reasons for this effort: a desire to provide better tools for engineers in the field and an engineering problem in large No. 1 ESS networks. The network engineering practice issued in 1964 would not work in large offices. The only solution available seemed much too complex to manage by hand as it involved the use of many tables and long repetitive calculations. About this time, remote access time-shared computers were coming on the scene and these seemed to provide an ideal solution to the problem.

In 1968, after tests were performed in several Operating Companies, AT&T Traffic made available the first centrally developed and maintained mechanized switching engineering aid employing interactive time-shared computing techniques and featuring a "natural dialog" language. This was the No. 1 ESS Mechanized Engineering Aids and Record System (MEARS) program intended primarily for engineering the No. 1 ESS switching network.

The success of the MEARS program and the availability of "natural dialog" software developed for MEARS helped to make possible the more ambitious Central Office Equipment Estimation System developed by Business Information Systems (BIS) personnel. COEES engineers plan complete central offices with many of the interactive features of MEARS. In late 1972 COEES made available to the companies the initial modules of No. 1 ESS COEES. Additional modules are scheduled for implementation in the near future. Since No. 1 ESS COEES contains the basic network logic of the MEARS program, the stand-alone version of MEARS was discontinued at the end of 1973. At that time it was the longest continuously operational, time-shared program system in the Bell System — not counting those continuously operational, time-shared programs in Succasunna, Pennsylvania 6, etc.

The COEES "MEARS" function now provides a flexible tool that assists the calculation and decision-making process of Operating Company traffic engineers, in the planning of No. 1 ESS equipment. As a mechanized aid to the engineer, MEARS does exactly those computations relevant to the engineering problem at hand, reflecting the most current engineering techniques.

MEARS applies interactive time-sharing computing techniques to the more mechanical parts of the traffic order preparation and central office traffic planning processes. It provides an aid to traffic engineering knowledge and judgment — not a substitute for them. It eliminates the mathematical drudgery and opportunity for numerical mistakes, while providing the latest pricing and engineering information. More importantly, MEARS assists the skilled and thoughtful engineer to do the best job. No longer burdened by massive calculations, the engineer can look at more possibilities than were ever before feasible. More facts can be examined before the decision is made. MEARS also helps the less skilled engineer do a better job. With built-in definitions, lessons and other aids, the system can help the user "learn by doing."

No. 1 ESS Switching Network

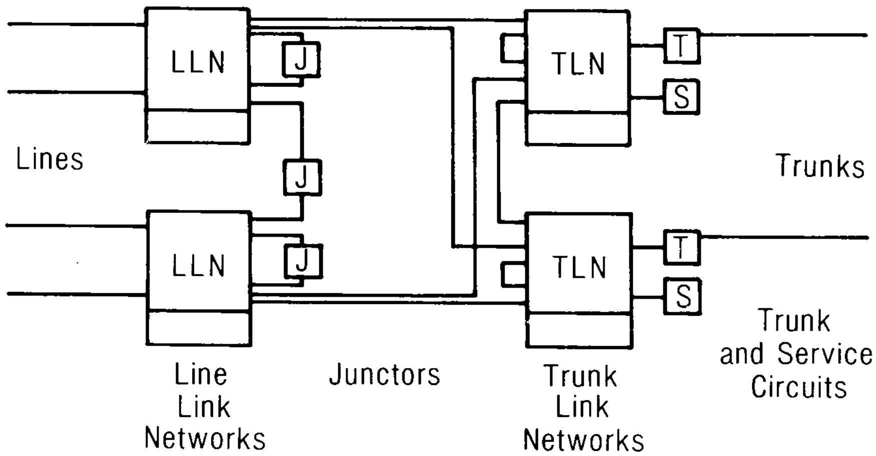


Figure 1

Four Stage Line and Trunk Link Networks Interconnected by Junctor Groups

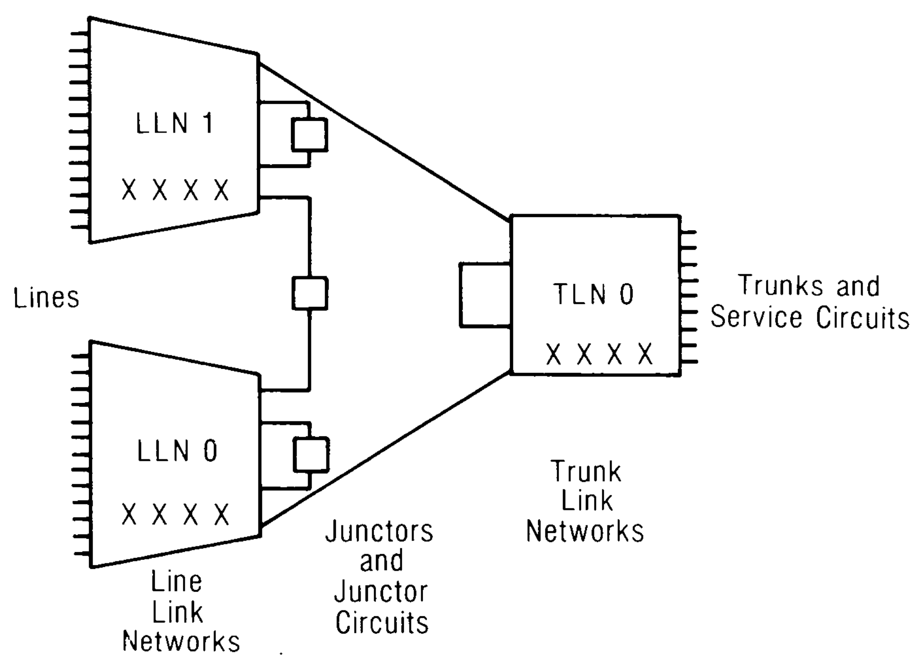


Figure 2

Basic Connection Types

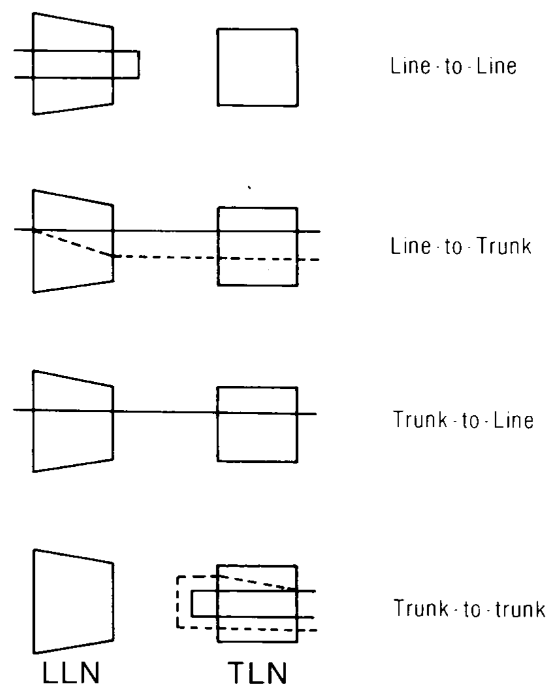


Figure 3

Originating Outgoing Call

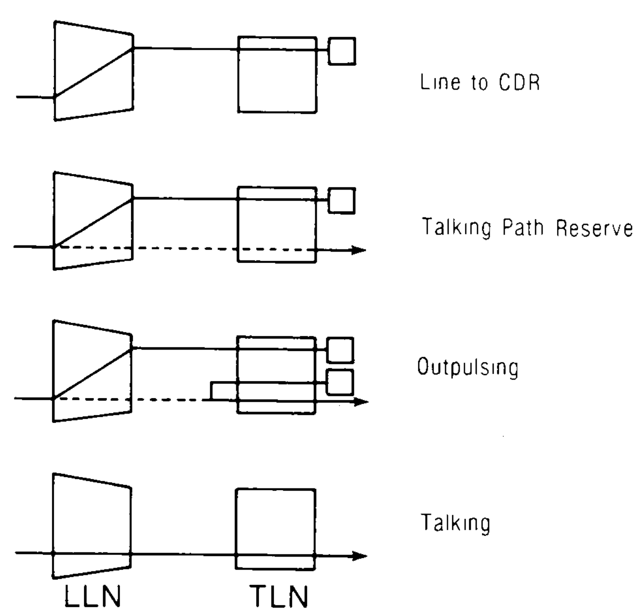


Figure 4

Incoming Terminating Call

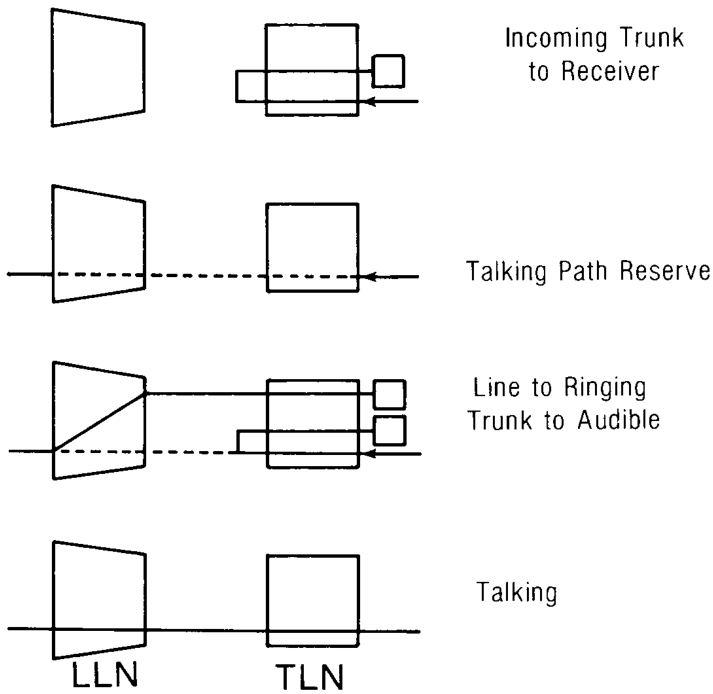


Figure 5

Intraoffice Call

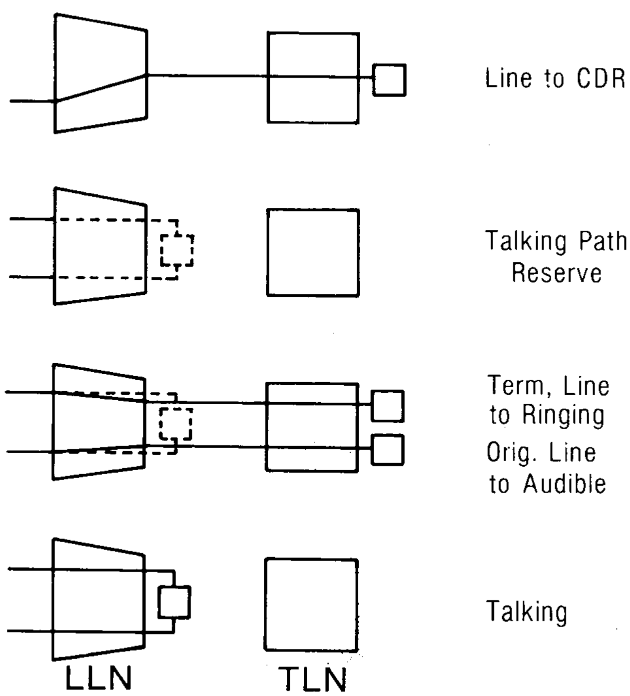


Figure 6

Incoming Through Call

Tandem

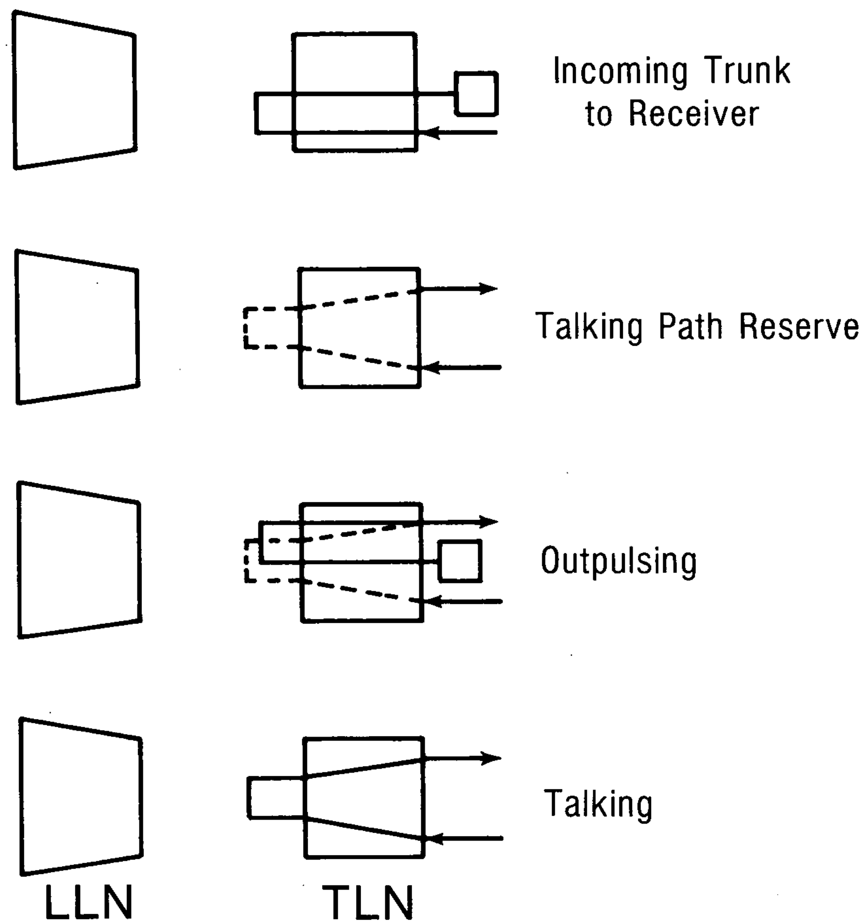


Figure 7

4 to 1 Line Concentrator

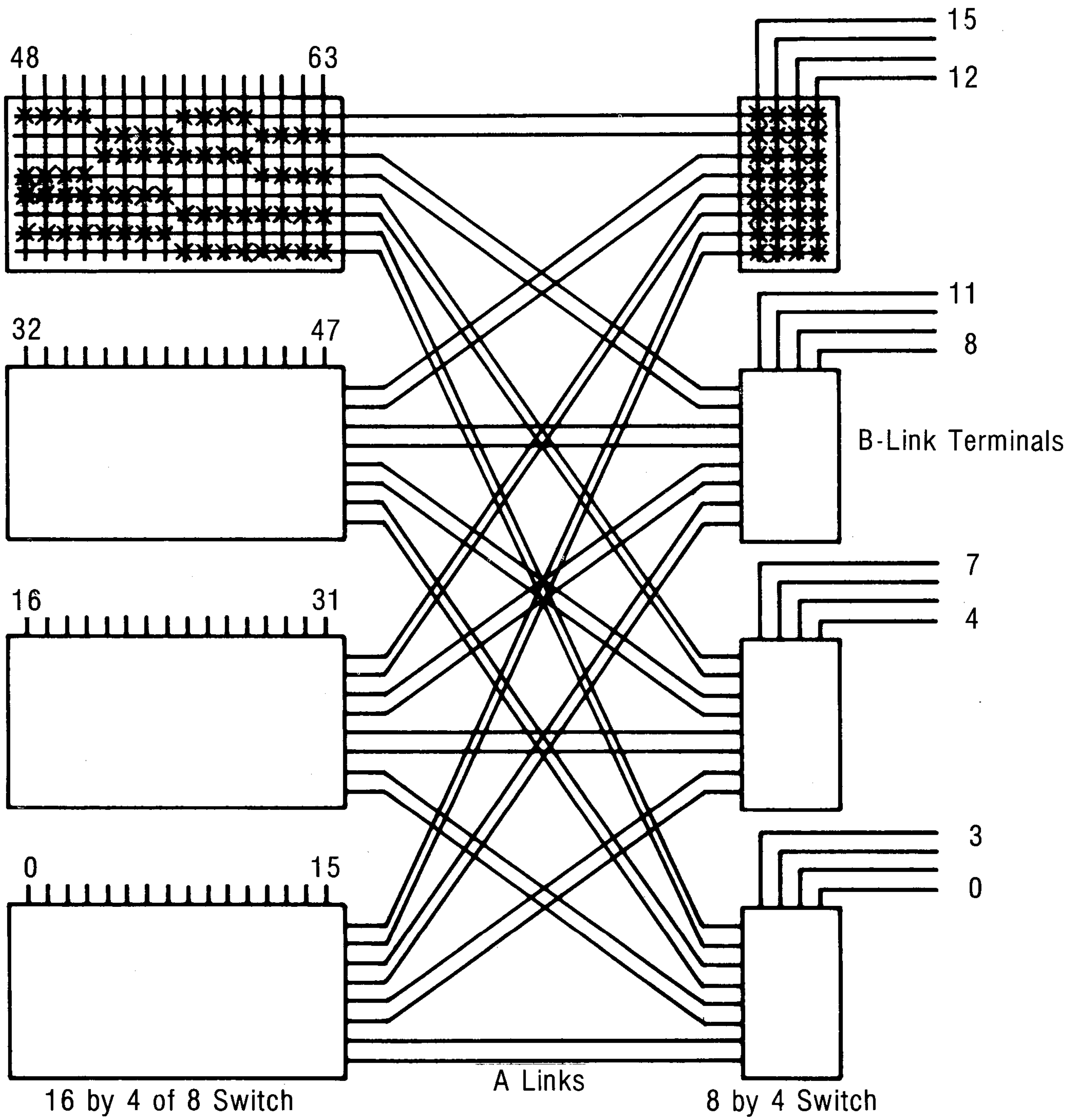


Figure 8

2 to 1 Line Concentrator

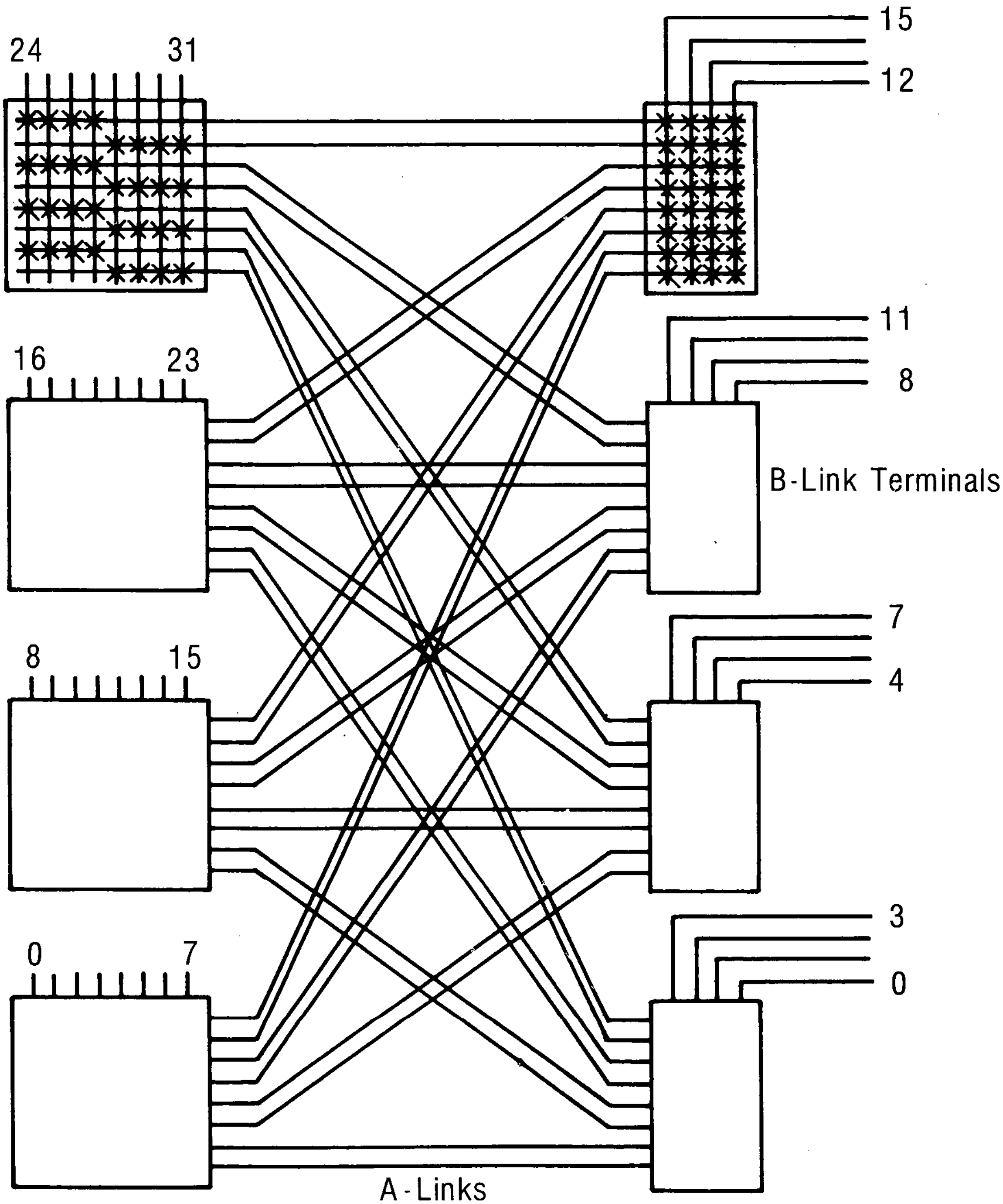
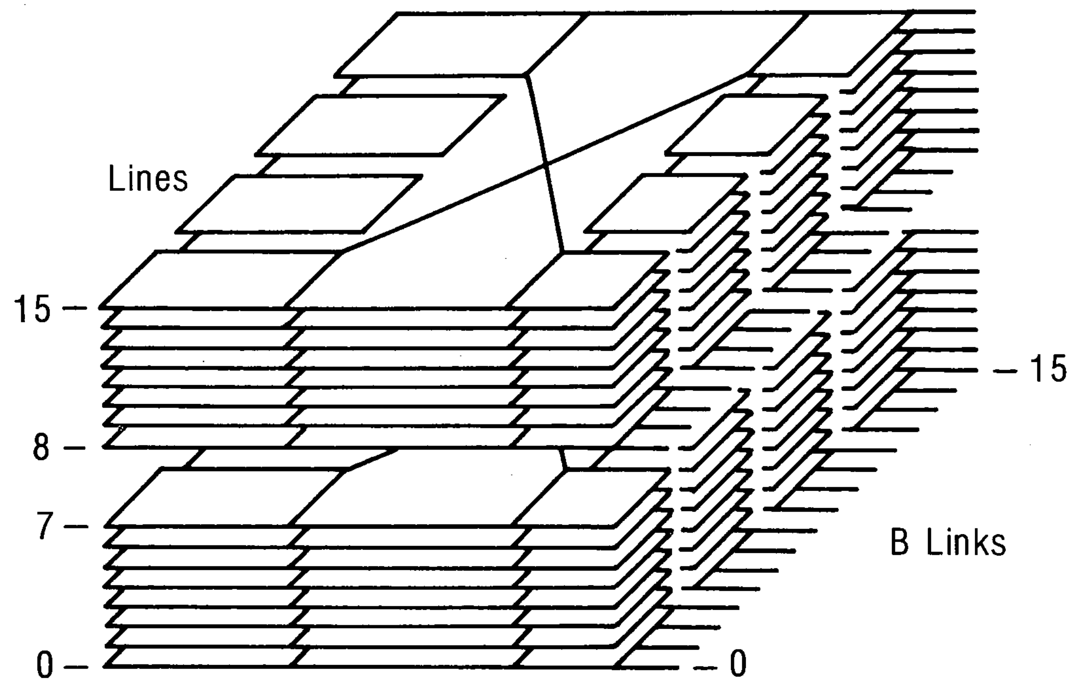


Figure 9

Line Switch Frame

16 Line Concentrators



Concentration Ratio	Input Terminals
2 to 1	512
4 to 1	1024

Figure 10

An Octal Grid

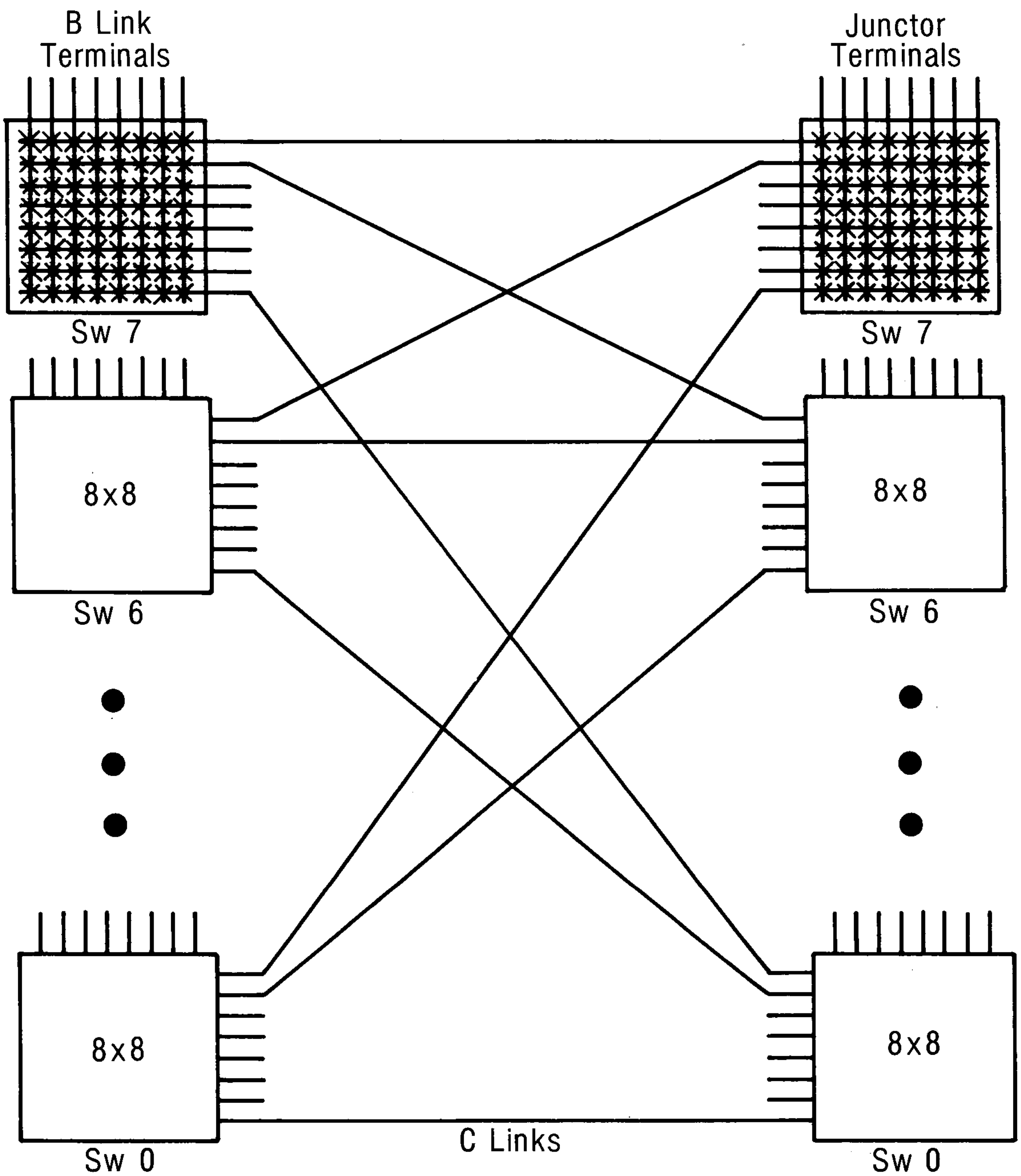


Figure 11

Trunk or Line Junctor Switch Frame

Composed of Four Octal Grids

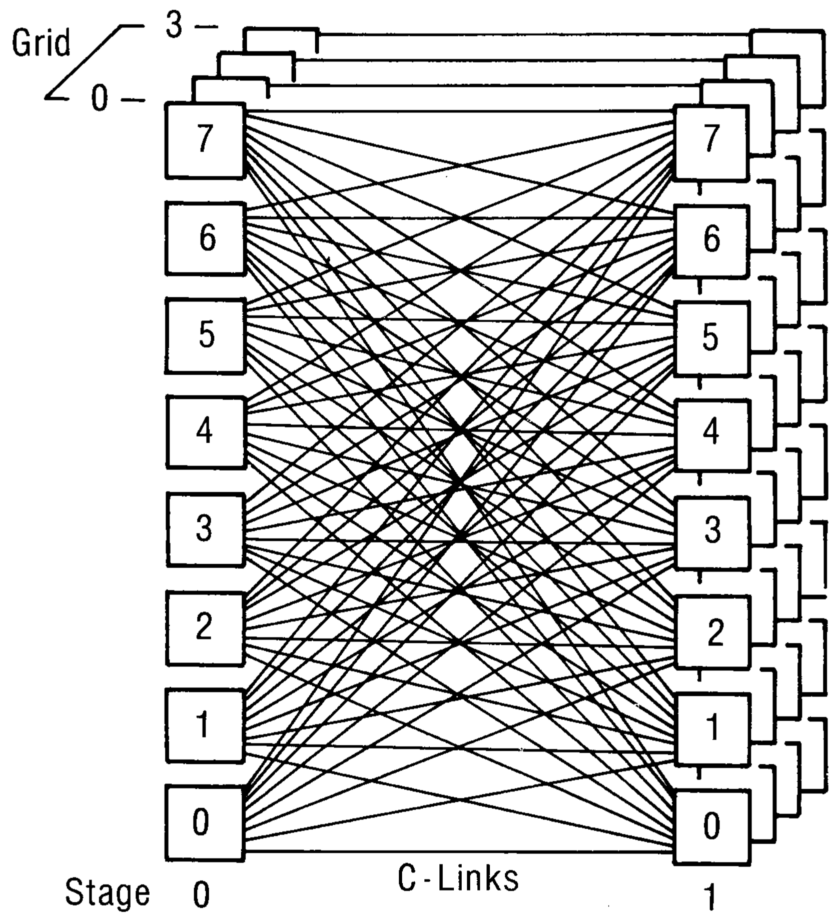


Figure 12

Line Link Network

With 2 : 1 or 4 : 1 Concentration

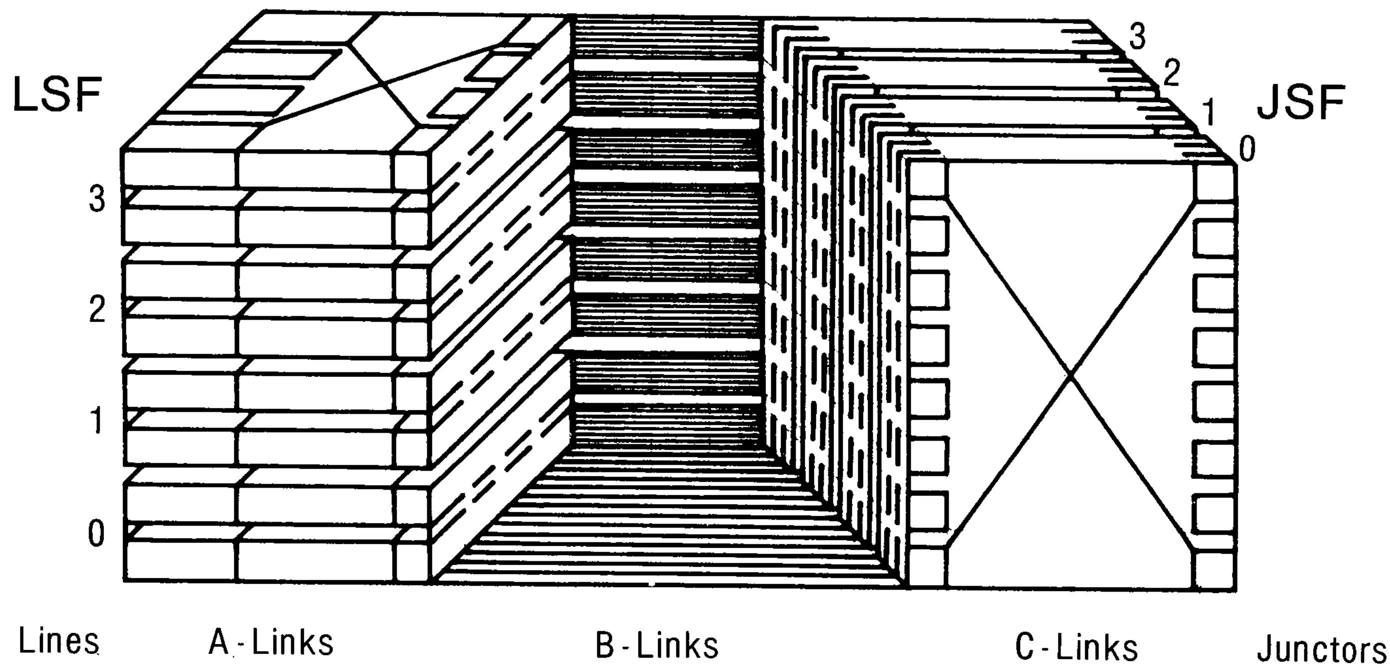


Figure 13

Trunk Link Network

1 : 1 Concentration Ratio

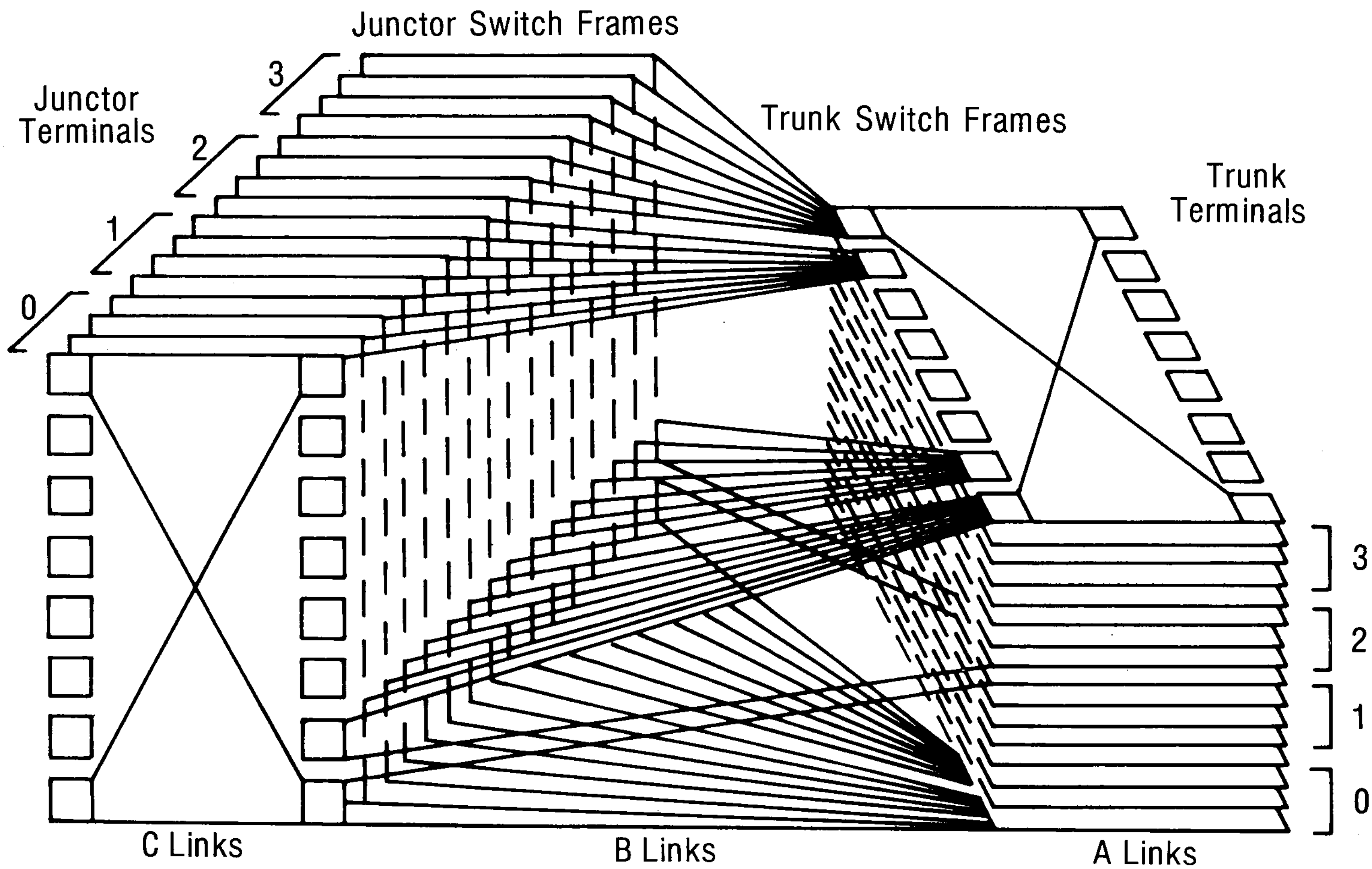


Figure 14

Partially Equipped Line Link Networks

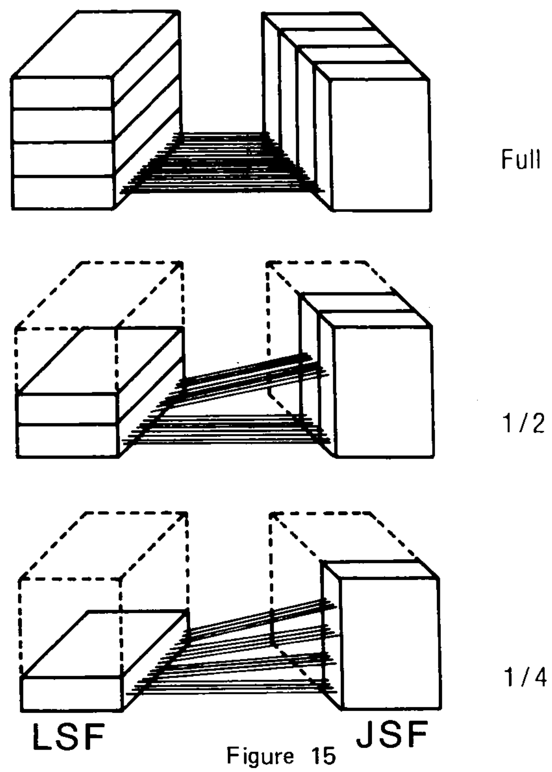


Figure 15

Fractionally Equipped Line Link Networks

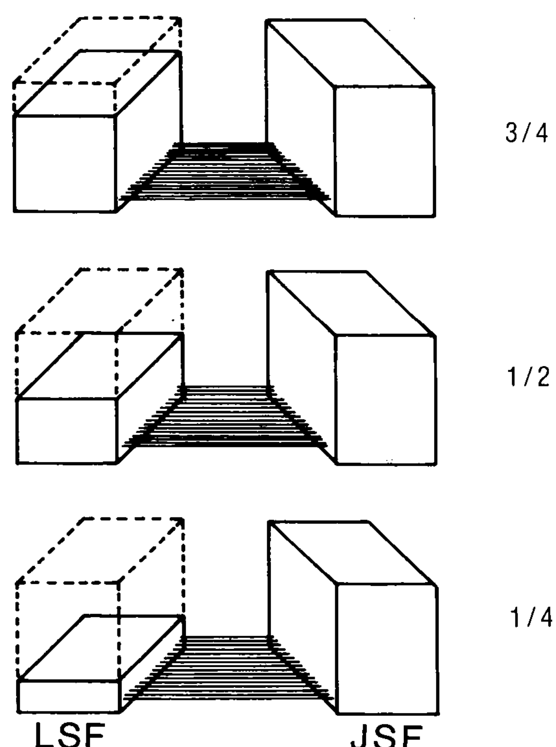
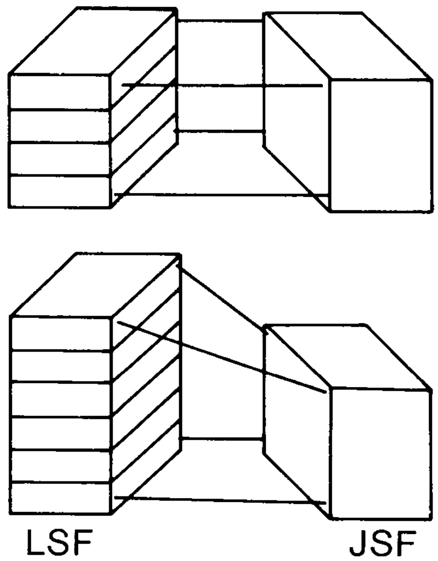


Figure 16

"Variable" Line Concentration Ratio



Net Concentration Ratio with:

2:1 LCR	4:1 LCR
2:1	4:1
3:1	6:1

Figure 17

A Difficult Interconnection Problem Made Easy

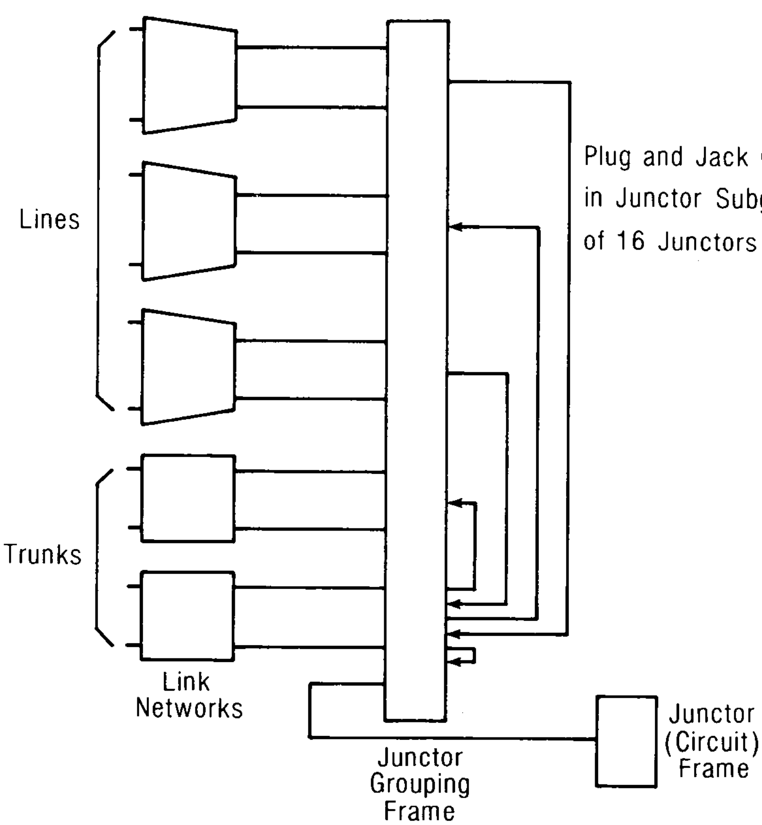


Figure 18

Line-to-Line Connection Between Two Line Link Networks

Two Junctor Subgroups Shown

Perspective View

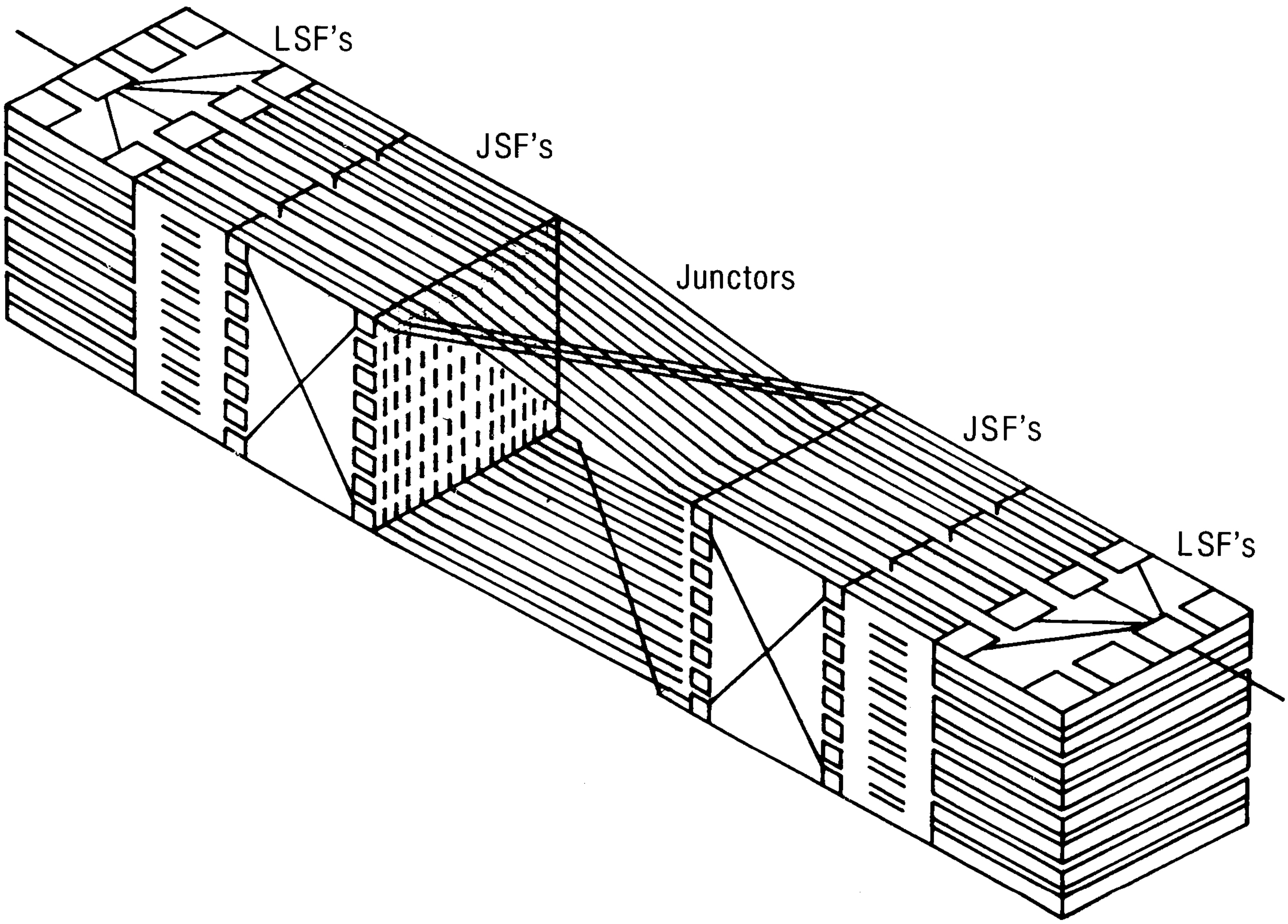


Figure 19

3 Methods of Handling Intraoffice Calls

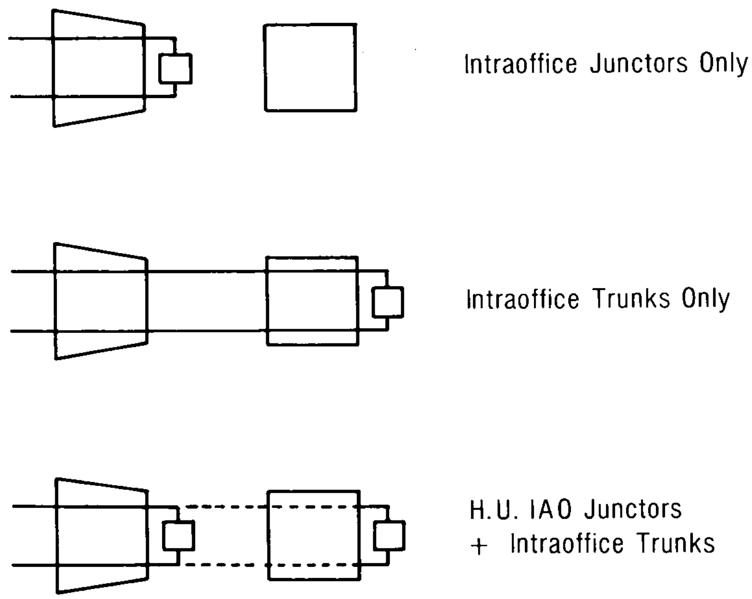


Figure 20

Customer Dial Pulse Receiver
(CDPR)

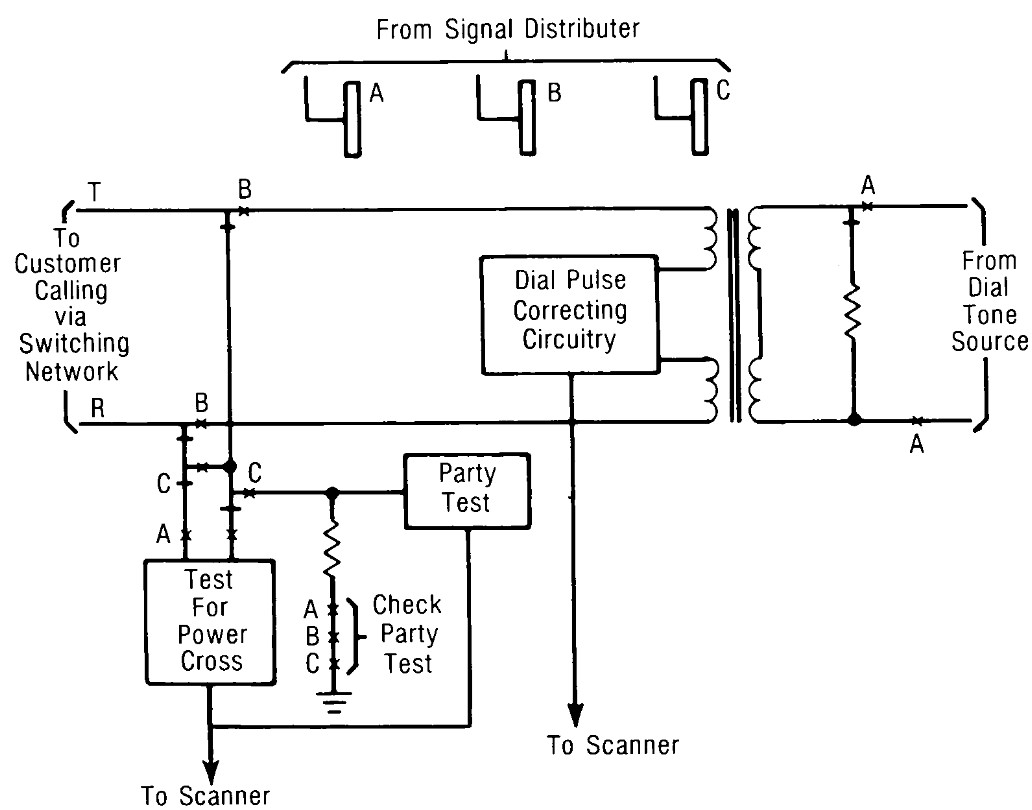


Figure 21

No. 1 ESS Switching Network

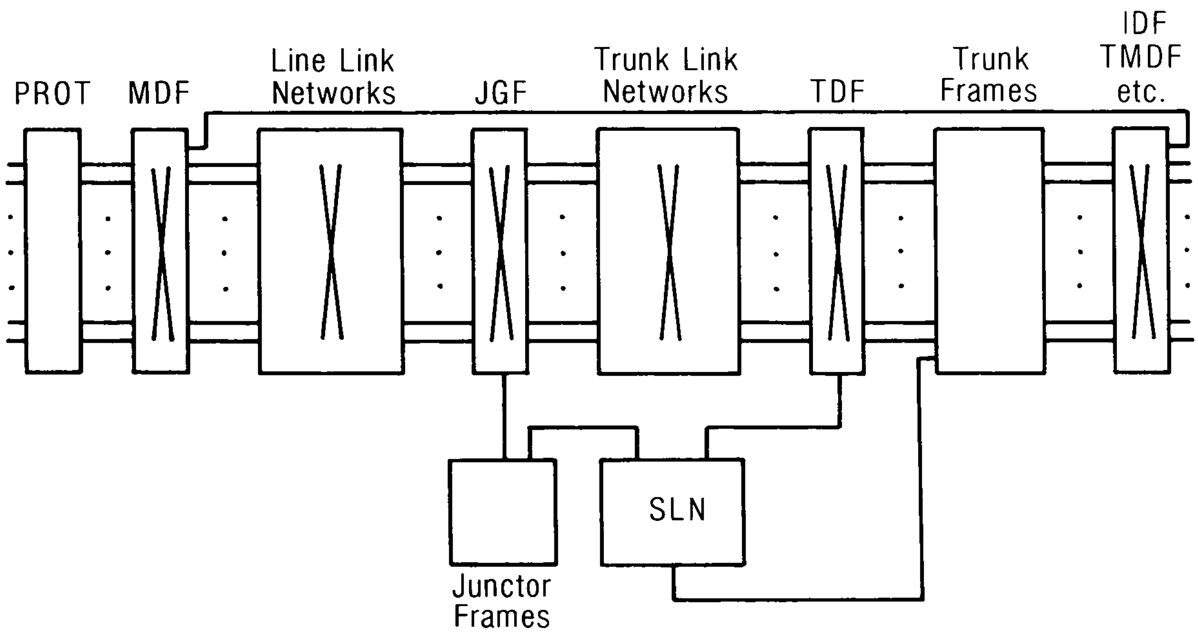


Figure 22

Incoming Terminal Call with Service Link Network

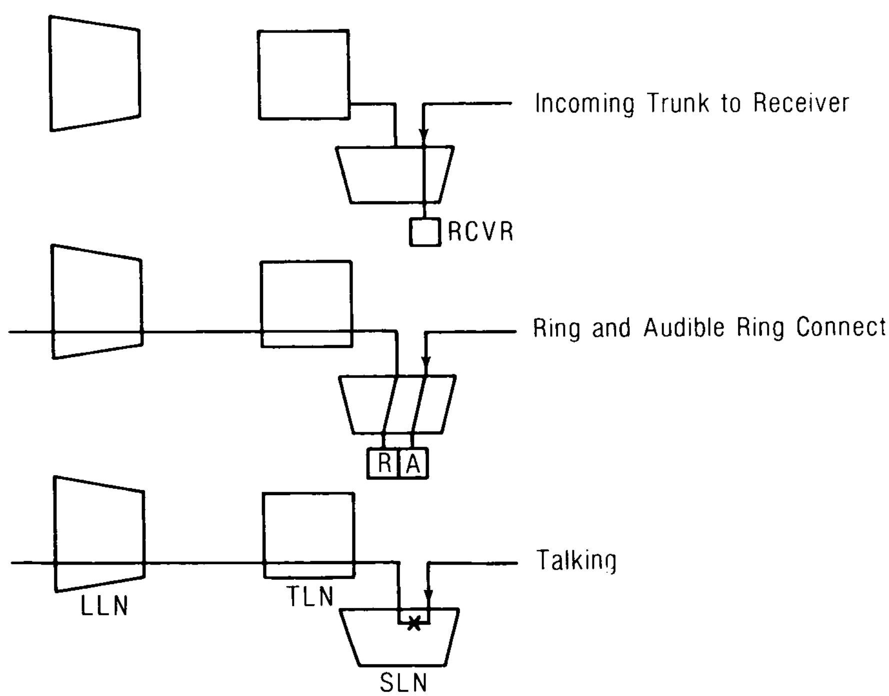


Figure 23

No. 1 ESS
Switching Network Engineered Capacity

Originating & Incoming CCS in Thousands

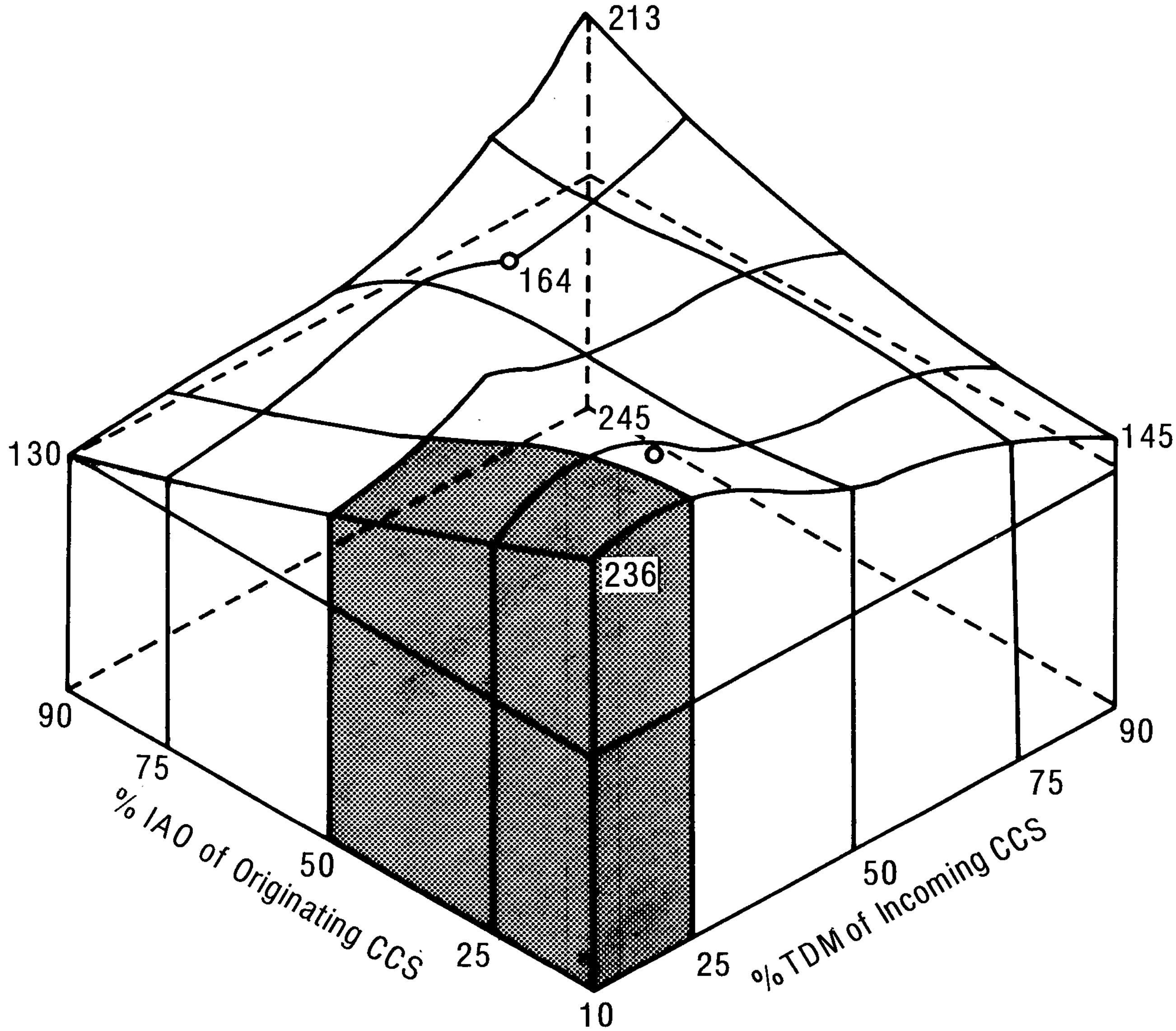


Figure 24

No. 1 ESS Trunk Link Network

2048 Terminals

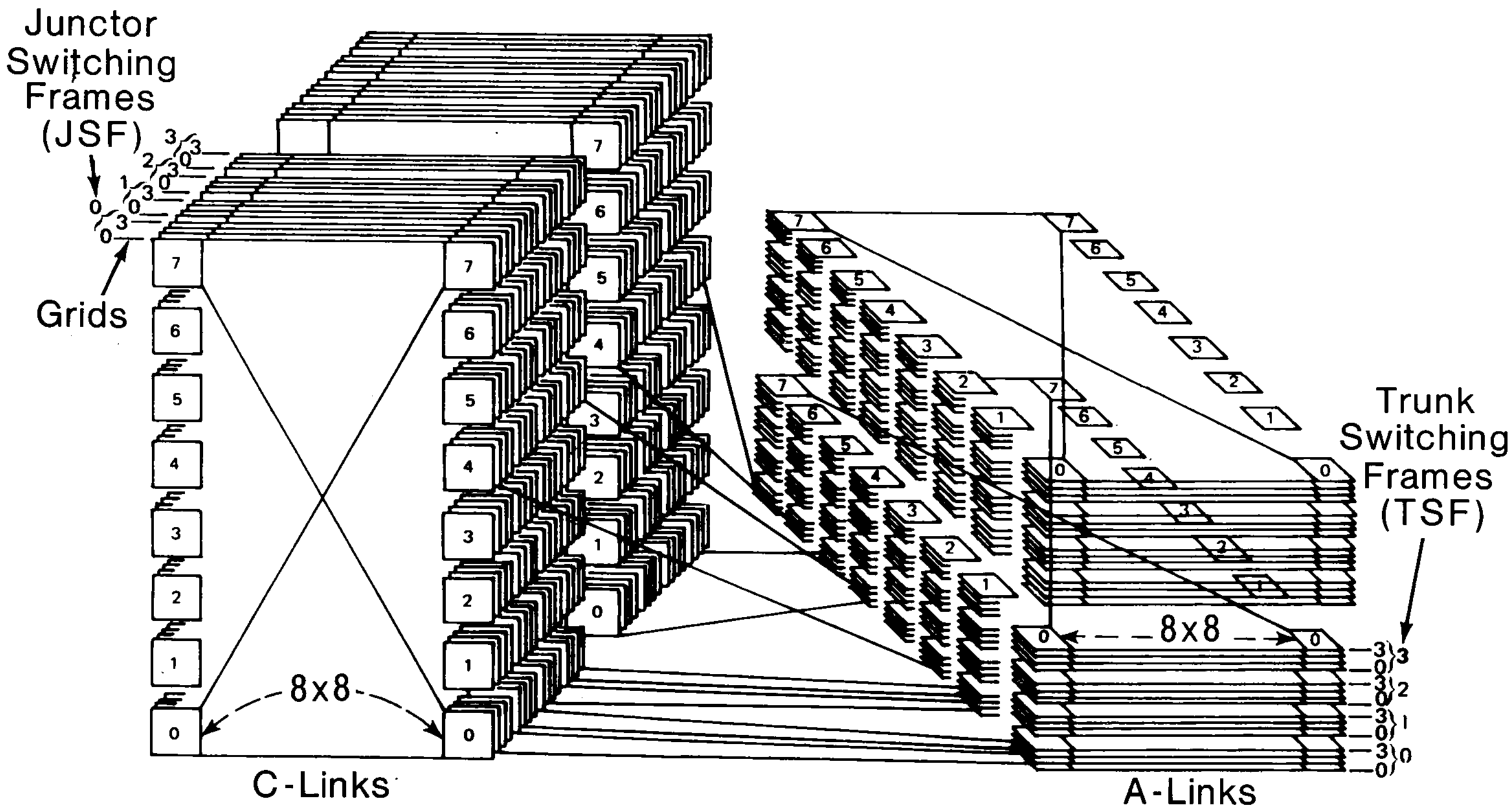


Figure 25

IV - GENERIC MEMORY REQUIREMENTS

1. INTRODUCTION

The No. 1 ESS processor may be conceptually divided into a fixed portion and a variable portion. The fixed portion would consist of the central controls (and signal processors in a large office), the master control center complex, master scanner, central pulse distributor, and certain amounts of program store and call store. The variable portion is represented mainly by the peripheral system, the program store required for office translation data, and the call store required for call processing. Although the parallel is not exact, the fixed portion of the processor may be viewed as the "getting started" factor for No. 1 ESS. This section will review the way in which this "fixed" portion of the No. 1 ESS processor has changed since the first processor was put into service in 1965.

The major factors which allow a relatively clear differentiation to be made between fixed and variable portions of the processor are the stored program concept and the generic program concept. The stored program concept, which is most basic, requires that the call processing logic (which is most apt to change as new services are designed) be placed in the stored program; the wired logic of the central control (CC) and the signal processor (SP) perform only the basic logic operations required to execute the stored program. Hence the CC and SP do not vary significantly over the years as new telephone switching features are added; only the stored program changes. The generic program concept requires that the necessary call processing, maintenance, and administrative stored programs be the same in all offices; all data relating to the engineered size of the office and to the particular features assigned to a given line or trunk are relegated to the variable areas of the processor, as is the temporary data pertaining to calls or tests in progress.

The above discussion indicates how it is possible for the fixed or getting started portion of the processor to change in size over time; as new telephone service features or maintenance/administrative aids are added to the No. 1 ESS, the amount of program store and call store required for the generic program increases.

2. THE FIRST GENERIC PROGRAMS

The first official generic program released for No. 1 ESS was the CC-1 generic. At the time of its first issue, the CC-1 generic program required 144,163 words of PS and 5600 words of CS. This program was first used in the Century City (Beverly Hills), California, No. 1 ESS in January, 1967. The earlier version of the generic program used at Succasunna, New Jersey in May, 1965, had only about 111,000 PS words.

Shortly after the release of the first generic program, Bell Laboratories completed work on two major advances in No. 1 ESS capabilities, both of which resulted in new generic programs. The first of these was Centrex service for the small No. 1 ESS office; the new generic program, called CC-CTX-1, required almost 175,000 PS words and 8100 CS words. The second major development was the signal processor; the SP gave No. 1 ESS added call handling capacity for large offices. The new generic program, called SP-1, required over 184,000 PS words and 8100 CS words. Finally, the combination of these two developments, Centrex service for the large office, was covered by the SP-CTX-1 generic program; it required about 206,000 PS words and 8100 CS words.

3. FURTHER FEATURE DEVELOPMENT BEYOND FIRST GENERICS

And so the trend became clear — as Bell Laboratories continued to develop new features, the size of the generic program continued to grow. As new features were added, systematic attention was paid to usage of both storage and real time — the resources which must often be traded off against each other in a system like No. 1 ESS. Since the early generic programs did not have sufficient call handling capacity, changes were made in the ensuing generic programs which resulted in some shifts in the balance of these two resources.

In addition to improving the call handling capacity of the No. 1 ESS, the later generic programs provided a long list of new customer and Operating Company features. These generic programs continued to grow in size up to the present CC-CTX-7 and SP-CTX-7 programs. The

SP-CTX-7 program and its associated parameters occupy 38 PS modules (311,296 words) and require 9700 CS words. The growth in the size of the generic programs is shown in Figure 1; the corresponding growth in generic CS requirements is shown in Figure 2.

Figure 1 indicates that after the CC-3 and SP-1 generic programs, the non-Centrex generic programs were no longer issued. This decision, based on the projected market for non-Centrex programs and on the administrative problems of issuing four generic programs on a planned yearly basis, also served to increase the minimum office requirements for program stores and call stores.

4. CIRCUIT DEVELOPMENTS RELATING TO PROGRAM STORE AND CALL STORE

Along with the CTX-2 generic program, the No. 1 ESS program store capacity was doubled. Although the original No. 1 ESS design included the capability of operating with 12 program stores, the need for this amount of storage appeared to be sufficiently far in the future that the initial maintenance programs and the master control center assumed 6 program stores as a limit. However, the growing size of the generic program and the plans to handle certain large offices with unusual translation requirements provided impetus to implement the full PS capability. There are now several No. 1 ESS offices operating with more than 6 program stores; it still appears, however, that the 12 program store limit will be adequate for most No. 1 ESS applications now envisioned.

Although the call store system has not undergone any capacity changes like the program store, it has changed significantly in another aspect. The original No. 1 ESS call store was an 8,192 word ("8K") ferrite sheet store which occupied a full 2-foot 2-inch frame. In 1971, a new call store with a 32,768 word ("32K") capacity was introduced; this new store used integrated circuit technology and cores as opposed to sheets for the memory element. The 32K store, with four times the capacity of the old store, occupied only one-third the space of the 8K store. The 32K call store allowed the maximum call storage for a No. 1 ESS to be housed in a fixed frame arrangement occupying only 8-foot 8-inch of lineup; the equivalent call storage lineup with the 8K call stores would have been 104 feet. In addition to the floor space savings, the 32K call store development has resulted in a significantly lower cost per word of call storage to the Operating Companies.

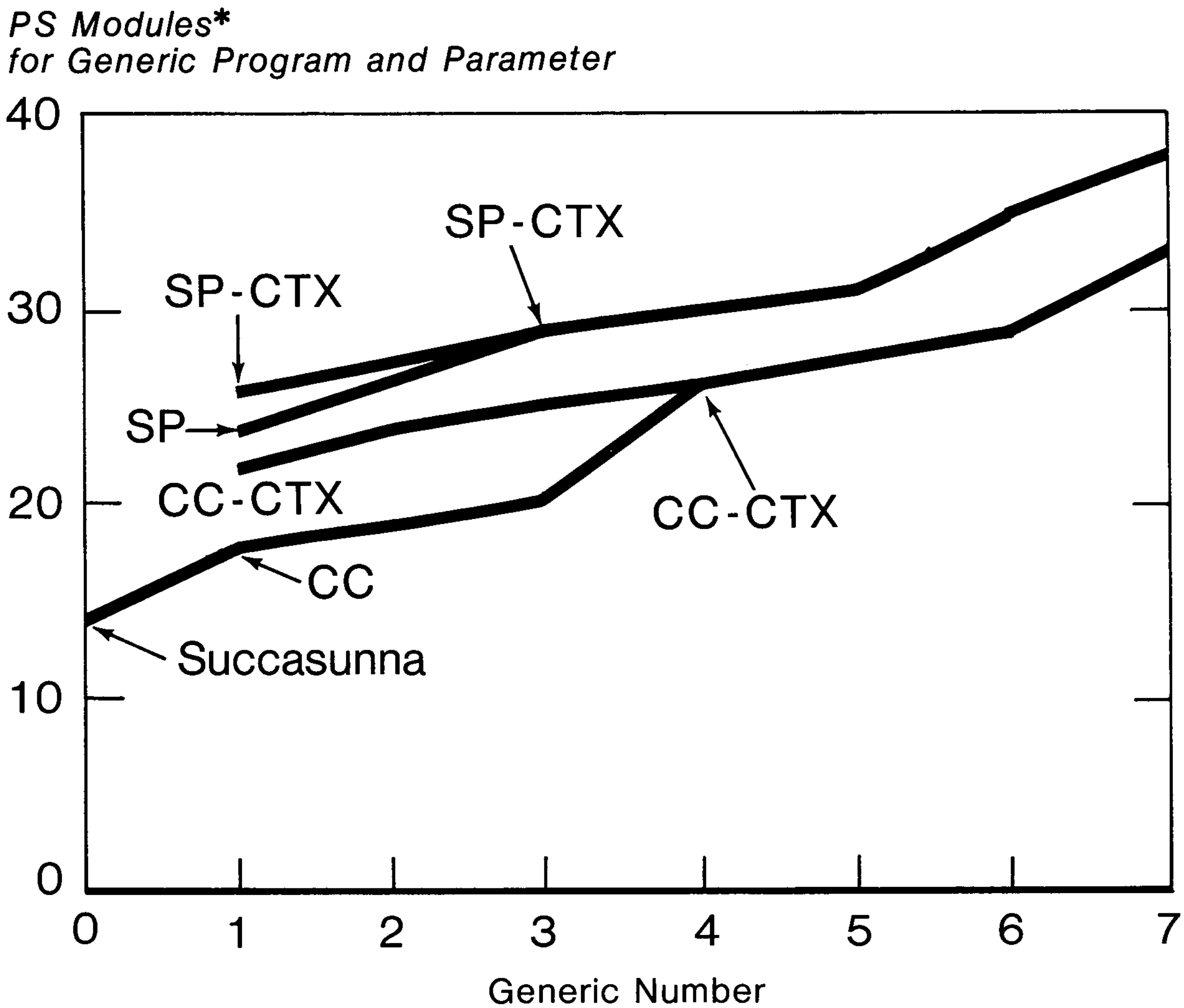
5. FUTURE DIRECTIONS IN MEMORY REQUIREMENTS

Three major factors influence the future physical size of the processor and the size of the generic storage required. The first of these is a continuation of feature development for the No. 1 ESS. Other sections in this book provide more detail about the features planned for future No. 1 ESS generics, but it should be apparent that this process of developing new features and new maintenance/administrative tools is a never-ending one. Hence, the No. 1 ESS stored program will constantly be evolving.

The second factor is that as the stored program (and computer technology in general) evolves, new methods of packaging and administering the stored program become feasible. At the present time, Bell Laboratories is investigating the possibility of "modularizing" the features of No. 1 ESS. According to this concept, certain basic features would be provided in a core generic program; the rest of the No. 1 ESS features would be put into modules according to broad functional definitions, so that a particular office not requiring that function (such as CAMA or AUTOVON) could have a total generic program which did not include it. While this investigation of modular programs is not yet completed, it can be said that such a packaging and administration plan only recently has become reasonable for detailed consideration because of the size and broadening functional capabilities of the No. 1 ESS generic program and because of advanced general computer technology; the basic concept of modular program administration was put forth in the early days of No. 1 ESS but was not feasible at that time.

The third and final major factor affecting both the physical size of the processor and the amount of generic storage is the 1A Processor. With the use of integrated circuit technology throughout, the 1A Processor will shrink the floor space required by the processor significantly. The maximum sized 1A Processor in No. 1A will require slightly over one building bay, while the largest No. 1 ESS processor (with less than half the call carrying capacity of the No. 1A ESS) would require approximately three building bays (size depends on use of 8K or 32K call stores). Another significant aspect of the 1A Processor is that it does not require primary storage (program store or call store) for all programs. Many maintenance and administrative programs are kept in secondary storage (disk) and temporarily brought into primary storage as needed. Since maintenance and administrative programs represent a significant portion of the current No. 1 ESS generic programs, it is clear that this approach saves a large number of program store words. This approach also removes the restriction of conserving primary storage when developing these programs; hence, more thorough diagnostic programs and more extensive Telco administrative programs, for example, can be written without the need to use the relatively more costly primary storage.

Growth in generic program store requirements . . .



* PS Module = 8192 Words

Note: Generic does not fill all words allocated to it.
Each type of generic is not necessarily issued every year.

Figure 1

Growth in generic call store requirements . . .

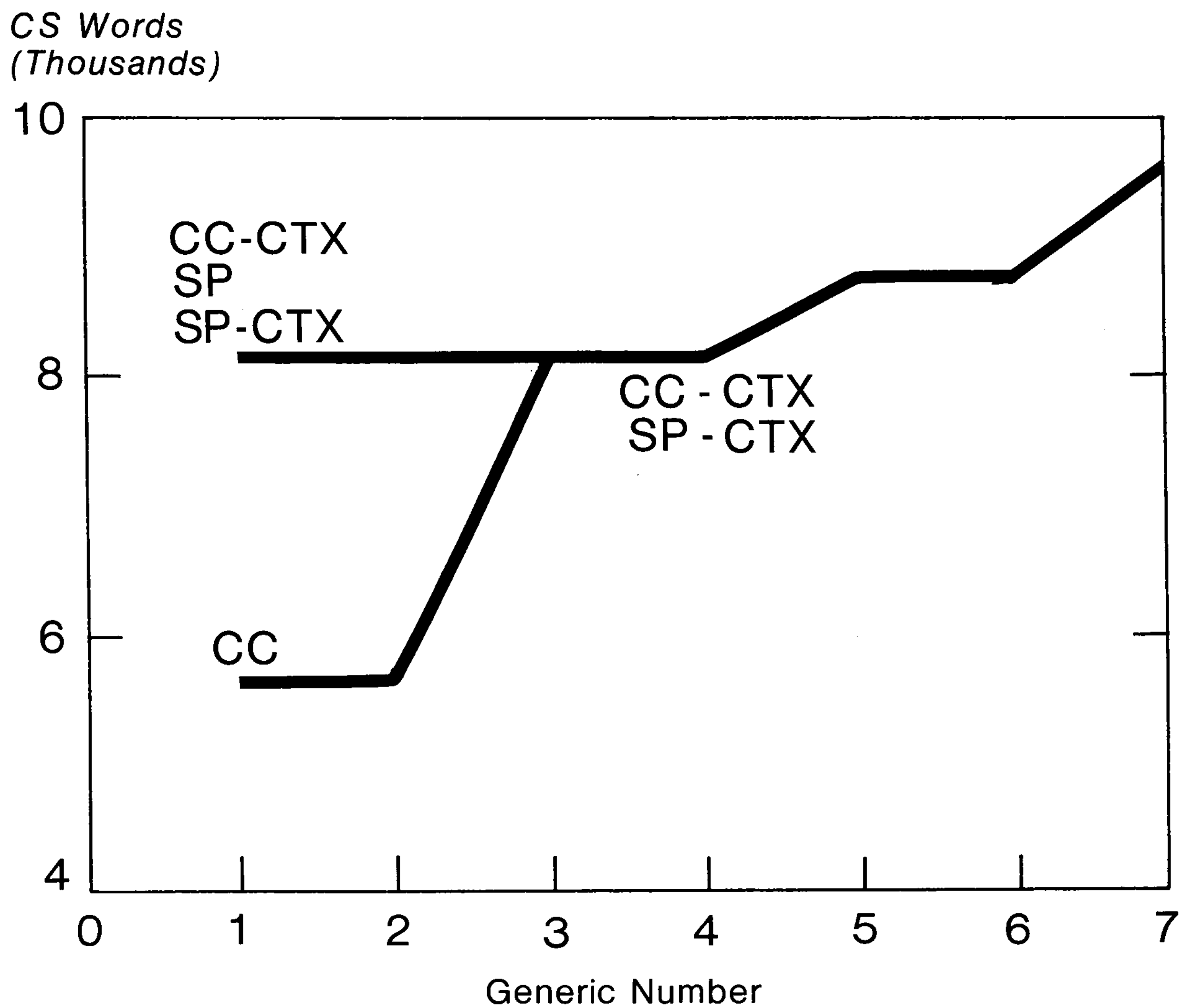


Figure 2

V - CUSTOMER FEATURES

1. INTRODUCTION

From its inception, No. 1 ESS was visualized as a system that would be continually expanding in customer feature capability. The stored program concept was basic to the planned ability to add customer features easily, on a regular basis. To provide for this orderly introduction of new features to the Operating Companies, the new features were packaged for issuance on an approximately yearly basis. Each such package was called a new "generic program," and the programs have in general been issued yearly since the first generic program, "CC-1," was issued in 1966. The programs issued to date have been:

The No. 1 ESS is now serving a wide range of individual and business customers. Custom Calling Services are being marketed now that No. 1 ESS is more widely available. Individual business customer groups served by the No. 1 ESS range from a few lines to over 12,000 lines. No. 1 ESS currently serves customers in the general business, airline, hotel/motel, hospital, education, and other industry groups; the No. 1 ESS offerings for all of these groups are currently being reviewed for completeness and being expanded as necessary. Through its stored program, No. 1 ESS has great flexibility in terms of the "packages" it can offer a customer.

Generic Program	Issued to WE for First Application	Generally Available
CC-1	1966	1967
CC-2, SP-1, CC-CTX-1	1967	1968
CC-3, SP-CTX-1	1968	1969
CC-CTX-2, SP-CTX-3	1969	1970
CC-CTX-4, SP-CTX-4	1970	1971
SP-CTX-5	1971	1972
CC-CTX-6, SP-CTX-6	1972	1973
CC-CTX-7, SP-CTX-7	1974	1974

(CC = Central Control, SP = Signal Processor, CTX = Centrex)

While the CC-1 generic program issued in 1966 clearly did not have the capability to serve all customer needs, it did provide a basic POTS capability with Custom Calling Services. The later generic programs have continued to expand both the customer and administrative feature capabilities of No. 1 ESS. Regular letters have been issued from AT&T Switching advising of the feature content of existing and planned generic programs. The SP-CTX-5 program, issued in 1971, meets the majority of customer feature needs. While many more customer features are needed and are being developed, SP-CTX-5 represented a major "plateau" in which No. 1 ESS met its original feature objectives.

Thus PBX service can be provided directly from the No. 1 ESS; Centrex is a viable offering at virtually any line size; a customer may be sold a mixture of packages for the special need of segments of the company. Since many of the No. 1 ESS features are of a "general" variety, it is frequently possible to meet a customer's need for a new service by using an existing feature in a new way or by combining features; hence, the published list of features represents a starting point in the No. 1 ESS ability to meet a customer's needs.

While new features continue to be developed for future generic programs, new concepts in the administration of generic programs are being examined. It may prove advantageous to "tailor" the program of a particular No. 1 ESS to the current market served by that office, changing the basic programmed capability of the office when the needs of the office change. Thus, an office may serve mostly POTs at one point in time and later serve a large business community, perhaps with some intertoll traffic. A change in the stored program could be used to make this basic transition possible. These concepts are now being examined to be certain that full advantage is being taken of the flexibility of the stored program.

2. CUSTOMER FEATURES — POTS

Early No. 1 ESS offices were planned to operate as Class 5 end offices. Basic telephone service to residence, coin, and PBX-CU customers in addition to certain Custom Calling Services was provided. A full complement of features was not provided because it was felt to be important that operating experience be gained with this new telephone switching office at as early a date as possible. The first few No. 1 ESS installations were, therefore, selected such that the available feature content would satisfy their needs. Upon completion of the first offices, other customer features were added to the generic program in an order which was felt to provide the greatest usefulness to Bell System customers. A new generic program, each with new capabilities, was issued at approximately yearly intervals.

Appendix I of Mr. Williamson's No. 1 ESS planning letter dated July 7, 1966, gives a list of features provided in the first generic program (CC-1) issued in 1966. This program and associated circuitry contained customer features needed for service in the office at Succasunna, N.J., and a number of other suburban and metropolitan office applications.

In 1967, the CC-2 and SP-1 generic programs were issued. Operational improvements were added to these generic programs but no additional customer features were included in them. The first centrex generic, CC-CTX-1, was also issued in 1967. In addition to the basic centrex-CO features, direct inward dialing to a PBX serving as a centrex-CU was provided in the CC-CTX-1 program. Provision of trunk-to-trunk switching added the ability for No. 1 ESS to serve as a local tandem switcher.

The CC-3 generic, issued in 1968, provided the capability for variable initial and overtime intervals for coin calls.

The 1969 generic programs, CC-CTX-2 and SP-CTX-3, included:

1. Calling line identification of customer dialed outgoing calls by comparing all outpulsed called numbers with a list of directory numbers to be traced.
2. Call waiting service.
3. Coin service improvement, including dial-tone-first service.

The CC-CTX-4 and SP-CTX-4 generics (1970) included the following customer features:

1. 4- and 8-party service.
2. Improved intercept service by providing compatibility with the Automatic Intercept System, No. 1A.
3. E-digit unblocking permitted direct dialing to Mexico City.
4. Improved service was provided for certain customers with key systems and automatic call distributors by protecting against possible cutoffs during network switching operations (OSIP).
5. The capability to directly dial station-to-station overseas calls was introduced (IDDD).
6. AMA records of calls, with billing to Centrex-CU stations, was provided with the automatic identification of outward dialed calls feature (AIOD).

The SP-CTX-5 generic was issued in 1971. The major customer features provided with this program were the following:

1. The manner in which Threeway Calling is provided was modified to conform to recommended AT&T standards.
2. Call forwarding service was also changed to correspond to AT&T recommended procedures.
3. The ability to utilize destination codes of the form N 0/1 X for office codes and NXX codes for NPA codes.
4. The ability to use 1 + 7-digit dialing for calls to an office in an adjoining NPA.
5. Use of a hotel/motel call prefix to TSPS made charge information of these types of calls more readily available to managers of such establishments.

In 1972, the CC-CTX-6 and SP-CTX-6 programs added these customer features:

1. Centralized AMA providing both operator and automatic identification of the calling subscriber's number (CAMA ONI and ANI).

2. Machine announcement at the end of initial and overtime periods for coin calls to preclude the need for coin operators for this purpose.

3. Detailed AMA entries on timed and untimed message unit type calls.

4. After two cycles of an intercept announcement provision has been made to transfer the call to an operator for additional assistance.

5. Control of 911 emergency bureau calls was added which permits the emergency bureau to hold a connection, force a disconnect to occur, to ring back on a line and to indicate to the bureau whether the calling customer has hung up.

Features now being developed for CTX-7 (1974 release to Western Electric) and in the near term beyond that are listed in Section XI — Current and Future Developments.

As the need for further customer features are demonstrated, No. 1 ESS continues to prove to be the flexible switching vehicle originally envisioned for stored program systems. The uncertainty associated with future customer needs makes the flexibility of No. 1 ESS all the more valuable.

3. CUSTOMER FEATURES — BUSINESS SERVICE

The introduction of centrex service was the first major customer feature addition to the No. 1 ESS generic program since the first office cutover at Succasunna, New Jersey, on May 30, 1965. The first CC-CTX-1 program was placed into service in February, 1968, in the Locust office, Philadelphia, Pennsylvania. This program provided the basic Centrex I and II service packages plus several optional features.

The SP-CTX-3 generic program was tested and cut into service December, 1969, in Arlington, Virginia, serving the Pentagon complex. This program provided the No. 1 ESS with the capability of a collocated and non-collocated CCSA switcher; it provided AUTOVON priority network dialing, attendant conference and the basic ability to work in a main-satellite environment.

In 1970, the CC/SP-CTX-4 programs added tandem tie trunk operation, TOUCH-TONE on incoming trunks and improved centrex console operation. The following generic program, SP-CTX-5 issued in 1971, essentially marked the completion of all major previously scheduled centrex features with the addition of busy verification of lines and trunks, camp-on, released link satellite operation, through dialing, call hold, etc. The two notable exceptions were station dial conference and dial pickup, both of which are provided with the CTX-6 programs. The SP-CTX-5 generic also brought with it the first full capability of PBX-CO service, the ability to provide PBX series features directly from the central office.

The following table reflects the development of the major centrex features in No. 1 ESS through the CTX-6 generic program.

NO. 1 ESS CENTREX FEATURES AVAILABLE THROUGH CC/SP-CTX-6

Centrex Features	CTX-Generic #
Console	1
Station-Station Dialing	1
DID	1
DOD	1
AIOD	1
Station Hunting Arrangements	
Series Completing	1
Multiline Hunting	1
Circle Hunt	6
Preferential Hunt	6
Uniform Call Distribution	6
Code Restriction	1
Toll Restriction	1
Transfer of Calls	
Attendant Transfer	1
Individual	1
Individual — All Calls	1

Centrex Features	CTX-Generic#
Add-On	1
Consultation	1
FX, Tie Lines, WATS, CCSA	1
Tandem Tie Lines	4
TOUCH-TONE on Incoming Trunks	4
Priority Network Indialing	5
Interface with AUTOVON	3
Automatic Attendant Service	6
Dial Dictation	1
Paging	1
Code Calling	1
Multilocation Service	3
Released Link Operation	5
Call Forwarding	
Variable	5
Busy Line	5
Don't Answer	5
Call Waiting	5
Call Waiting — Originating	5
Dial Hold	5
Dial Pickup	6
Station Dial Conference	6

Centrex Features	CTX-Generic#
Attendant Conference	3
Attendant Camp-On	5
Attendant Busy Verification of Lines/Trunks	5
Attendant Testing of Tie Lines	5
Attendant through Dialing	5
Night Connections	1
Night Connections, Variable	6
Trunk Answer Any Station	1

A complete listing of customer features can be found in GL71-11-015 (11/3/71), GL73-01-034 (1/18/73) and GL73-11-095 (11/19/73). More details concerning these letters can be found in Section XIV — Documentation.

The No. 1 ESS business customer feature capability is now well developed. With the latest generic programs now available, and with the existing No. 1 ESS offices located in the midst of the heaviest concentration of business customers, the Operating Companies have the tools to offer their business customers the best in telecommunications service.

VI - ADMINISTRATIVE FEATURES

1. INTRODUCTION

One of the advantages of electronic switching was to be its promise of improved administration. Through program control of measurements and flexible output arrangements, the Traffic and Plant administration could be improved in accuracy and detail and could be easily modified for special purposes. As was true of other features of No. 1 ESS, the basic features for administration of the office were provided in the early generic programs; significant improvements have been introduced in the later generic programs. The administrative capabilities of current No. 1 ESS generic programs truly represent the major step forward expected of electronic switching.

The following paragraphs describe the Traffic and Plant measurement features of No. 1 ESS. In addition, studies are regularly made utilizing the program controlled AMA capabilities of the No. 1 ESS. This flexible output device, backed up by the processing of the Accounting Center, provides the extra dimension which makes administration and planning for the entire System more accurate and timely.

2. TRAFFIC ADMINISTRATIVE FEATURES

With the advent of electronic switching, a whole new field was opened in the area of traffic measurements. No longer was there a need for the old style electromechanical counter with its high maintenance requirement and its somewhat low reliability. No longer would it be necessary to provide clerks to read registers, or cameras to photograph them. No longer would it require large investments of floor space for traffic usage recorders and traffic register cabinets in addition to the frame costs themselves. No longer would Traffic be burdened with pages and pages of work sheets in order to gather data for Dial Office Administration and Engineering.

It seemed that it was finally going to be possible to modernize a large cumbersome operation of the Traffic Department. However, all expectations were not realized when the first No. 1 ESS offices were cutover for field operation.

The first ESS offices installed provided many of the needs for data retrieval. It had the ability to store schedules in memory that would tell the machine when to collect certain counts and when to print them out on a teletype. The Traffic count data were now collected by the ESS and stored within its memory until it was to be outputted to the dial administrator. The flexibility in these schedules gave Traffic the ability to meet most of the data requirements without a great deal of "special arrangements."

The control of the schedules was placed in the hands of the Traffic Department by means of a traffic teletypewriter (TTY). This TTY provided the means of altering the schedules, verifying the schedules, and receiving the output data from the ESS machine. No cameras, no film processing, no film reading, no data sheets were required!

The Traffic TTY gave some additional features that proved to be invaluable to the dial administrator. Traffic could now, within certain limitations, change register assignments totally independent of Plant. Because Traffic assignments were stored in memory and required no cross connections, the changes in memory could be made by Traffic TTY input. For some register assignments, Traffic was no longer dependent on Plant.

The Traffic TTY also provided the ability to query certain areas of the ESS memory to verify that the translations were actually built properly. Traffic had the capability of verifying directory number translations, line equipment translations, trunk group assignments, and many other translations as they appear in memory.

In addition to the data printouts and the input capabilities already mentioned, the Traffic TTY was used by the overload program to the extent of printing out line load control and other overload information for the dial administrator's use. Traffic was given first-hand knowledge of when an office activated line load control and when it was deactivated. A new feature for toll network protection was included and associated with the line load control. This feature denied access to the toll network to all but selected customers when line load control was activated.

Line load control and toll network protection were under control of keys at the maintenance center to be operated and released by Plant.

As the development of No. 1 ESS moved forward and new generic programs were applied in the field, more advances and improvements were made in Traffic Administrative features.

Additional counts were added to the most critical schedule to tell Traffic more about the machine performance. Such things as blocked dial tone peg count, peg count of line scans, and peripheral order buffer (POB) queuing were added to the 15 minute counts. The overload printouts were expanded to include more information to aid in trouble analysis. Counts were added with the Centrex programs that provided better data for the engineering of the Centrex customers' requirements.

Additional general purpose registers have been added to allow for more special counts to be taken simultaneously, thus reducing the time required to gather data. Better data can now be furnished to the Marketing Department for establishing the individual customer's requirements.

A large step forward was achieved by placing a large portion of the traffic measurement data in the protected area of call store. No longer does Traffic lose load balance busy hour traffic data during an emergency action phase.

Dial administrators have been given the ability to perform many additional queries for verfication via the Traffic TTY. Many of these were previously only obtainable from the Maintenance TTY. Also, dial administrators now have the ability to make additional register assignments and these now become effective immediately instead of haveing to wait until routine card writing places them into permanent memory.

One of the major advances made in the later ESS programs is to place line load control under teletypewriter control with both traffic TTY and maintenance TTY able to activate and deactivate line load control. At the same time, toll network protection was divorced from line load and also placed under teletypewriter control. It is now possible for Traffic or Plant to activate and deactivate line load control and/or toll network protection as required.

The advances made thus far in the field of traffic administrative features are by no means the ultimate. The generic programs recently issued included such things as:

(a) Additional Traffic teletypewriter channel to allow for more administrative work on the TTY by splitting output print across two channels.

(b) Automatic control of TTY tape perforator according to preset schedules.

(c) Ability to interchange certain type of words in the traffic schedules.

With these improvements and others to be included in future generic programs there is clearly continuing progress in the area of traffic administrative features.

3. PATROL — A TIME-SHARED SYSTEM FOR NO. 1 ESS TRAFFIC REPORTING

Traffic measurements are essential for the proper engineering and administration of switching systems. They are required to keep equipment operating efficiently and to help determine the equipment quantities required to meet future customer demands. Measurements in the No. 1 ESS are made by the machine itself and printed on a teletypewriter at the local dial administration office. These measurements, while much "cleaner" than those from the older electromechanical offices, are voluminous and in the form of raw numbers. These numbers must be identified, summarized and turned into readable, meaningful statistics before they can be used by telephone company engineers and dial administrators. Before PATROL, most of this processing was done manually, or was not performed at all. In some offices service problems arose for which it was difficult to isolate the cause because the relevant traffic data were not being recorded.

PATROL, which stands for "Programs for Administrative Traffic Reports On-Line," was designed to eliminate the costly manual processing of the No. 1 ESS traffic data, provide rapid access to usable traffic statistics, and eliminate errors caused by manual processing. Patrol was designed jointly by Bell Laboratories Switching Studies Center and the New York Telephone Company Manhattan Engineering Department, and was made available system-wide in October, 1971. It processes H schedule (hourly) traffic data and produces traffic engineering and dial administrative reports. Implemented on the

AT&T Comptroller's VM-370 time-shared computer system, it provides dial administrators with data on service and traffic levels in near real time. The measurements are saved on disk and summary reports covering a week, a month, or any other period requested are available. A special high day busy season summary is also available. To aid in user instruction and keep the user up-to-date with changes and improvements, a set of on-line lessons is provided.

Data validation and exception reporting techniques are employed. Reports may be printed off line and mailed to minimize costs. Whenever immediate access to the data is necessary, reports may be obtained on-line at remote terminals.

The overall philosophy of using the system is as follows: After determining the probable busy hours through normal procedures, the one to three highest hours are chosen for the office. If desired, many hours of data per day may be stored, but costs will be proportionately increased. To initialize the system, the dial administrator prepares a description of the traffic register assignments in the office. This description is prepared on a special form which closely resembles the ESS 1400 form used to describe the traffic measurements for translations. This form is sent to AT&T for direct input into the computer. To enter data and obtain reports, the dial administrator schedules the ESS collect and print routines using the traffic teletypewriter. When a punched block H tape is available, it is transmitted by teletypewriter over the message network to the AT&T time shared computer location in New Jersey. Data validation is performed and items which exceed predetermined tolerance limits are indicated at the end of the transmission. These items will have to be investigated by the dial administrator and subsequent action taken. A tape entry sequence is shown in Figure 1. Also, a daily busy hour report is printed at the user's terminal. This report, shown in Figure 2, contains critical service and load measurements. It can give, in near real time, a picture of how the office performed during the busy hour.

Other reports will be automatically mailed to the designated recipient. However, if desired, immediate printouts may be requested for individual equipment groups or all groups. Once a month the traffic engineering organization, using their own time shared computer terminal and user number, can access the data files for each office and request the necessary monthly and high-day busy-season reports. These reports may be received on-line or the printouts can be mailed directly to the engineer. The data base is available at any time for inquiry. A sample monthly report on ROH announcement is shown in Figure 3 and a high-day busy-season machine load and service summary report for the same circuit is shown in Figure 4.

Higher than TTY speed data facilities can be employed. The use of a cathode ray tube terminal with hard copy attachment may be advantageous for traffic engineering organizations and other centralized groups. One company has been very successful in using a machine which includes both a high-speed printer and cathode ray tube. Others have used 30 character per second terminals at the dial administrator's location for tape entry and local report generation.

Overall costs have been estimated for an average No. 1 ESS office assuming that one block H schedule is entered for 22 days per month, and the normal daily weekly and monthly reports are required. All users access a common program and the storage charges for the common program are prorated over all current users of PATROL. In addition, computer usage for program maintenance is also prorated. The overall cost estimate, averaged for a 12 month period (to recognize the ealier months where the data files are somewhat larger), runs between $100 and $150 per office per month. These costs are significantly lower than the original costs when the system was released in 1971. Further cost reduction is expected with the planned introduction of magnetic tape input which will eliminate paper tape handling by dial administrators. PATROL costs are considerably under those for any manually administered data management process of comparable scope and will vary directly with the use made of the system by each company.

PATROL is being maintained by the Bell Telephone Laboratories and, as a result of the wide acceptance which the program has received, plans are being made to expand and improve the system. Continued improvements should make PATROL an even more useful tool in the future.

4. PLANT MEASUREMENTS

Since the common control equipment for No. 1 ESS consists of a stored program system, it has the capability for accumulating data regarding call handling ability. This capability initially was limited to a very basic and elementary data collection process whereby only total calls and transmitter seizures and timeouts were accumulated over a 24 hour period. Other data were accumulated manually from the hourly summaries and entered on the control record.

With the CTX-5 generic program issued in 1971, plant measurements underwent a major revision. The new plant measurements program enables the system to accumulate most control record data on a daily basis starting and ending at 2:30 A.M. In addition those measurements which are used in the service results plan or directly related to that result plan are accumulated over a report month, 23rd to 22nd, and printed on the maintenance TTY.

The data accumulated in the plant measurement registers were selected in order to provide plant management with a concise quantitative summary of the condition of the No. 1ESS central office, its impact on customer service and certain indicators as to the condition of other offices. This latter information comes from detailed reporting of transmitter and receiver timeouts by trunk group.

While the above mentioned data groups, daily and monthly, are printed automatically, any or all of that data can be printed upon demand via TTY message input.

The measurements, both daily and monthly are printed in an easily read format and subdivided into meaningful categories. In addition each data block printed is arranged in page length arrays for easy filing.

The data format is divided into 4 blocks. The first block is the base measurements which includes items such as originating calls. The second block is the service measurements which includes items such as emergency action phases. The third block is the performance measurements which includes items such as number of 100 second intervals a central control has been out of service. The last block is the other measurements which includes items such as transmitter time outs.

A general presentation of the actual measurements is contained in E.L. 2303/P.L. 2633, TG1A division 3-Section 4F, and BSP 231-120-302.

Patrol

```
REQUEST = ENTER

** TAPE MAY BE STOPPED AFTER THE HIGHEST ODF REGISTER LINE

SET UP PAPER TAPE -- WAIT FOR A'•' PROMPTER THEN START TAPE

 • 45 BLOCK H 000532  11:30 4/25/1973@
 (0)
023554  001675  000080  005025  000000  000003  000739  000000  000161  000000@
 (1)
022994  000003  002007  000218  001535  000000  000000  000103  000071  000000@
 (2)
063083  000003  008165  055402  069104  090895  000638  000027  000000  000000@
                                    •
                                    •
                                    •
FINISH
```

THE FOLLOWING CIRCUITS WERE FLAGGED ON A HOLDING TIME BASIS

		USAGE		PEG	HT	STATED RANGE		OFL	CAPACITY		
						MIN	MAX				
		TRFFC	MB	COUNT	SEC.	HT	HT	%	%	CCS	NCI
DP REG TLN	*	22	0	213	10.52	5.50	8.00	0.0	49	46	6
DP TRANS	*	5	0	79	6.33	3.90	6.20	0.0	11	46	6
CN CONTROL	*	0	0	2	0.0	0.0	999.00	0.0	0	27	6
CONF CKT 3P	*	66	***	214	30.84	60.00	450.00	0.0	5	2091	81

DATA ON OFFICE 000532H FOR 4/25/1973 11:30
HAS BEEN PROCESSED AND RECORDED

Figure 1

Patrol

000532H NO.1 ESS SUMMARY OF TRAFFIC DATA FROM 4/25/1973 TO 4/25/1973
HOUR ENDING 11:30

	O+T	O+I–TAN	TOTAL	O+I	AVERAGE	STATIONS IN SERVICE			
	CCS/MS	MSCR	CCS	PG CNT	HLD TME	TOTAL	POTS	CTX	COIN
OFFICE COUNT	4.03	2.66	65169	46548	166.6	16175	15224		951

	DIAL PULSE			TOUCH-TONE			WGHTED	BLOCKED	
	STA.	TEST	%DELAY	STA.	TEST	%DELAY	%DELAY	D-T	COUNT
DIAL TONE	12852	739	0.00	1469	161	0.00	0.00		0

	INCOMING-TAN			OUTGOING			INTRAOFFICE		
	MSCR	CALLS	%M-LOSS	MSCR	CALLS	%M-LOSS	MSCR	CALLS	%M-LOSS
MATCHING LOSS	1.20	19452	0.02	1.36	22019	0.00	0.09	1535	0.00

Figure 2

Patrol

000532H NO. 1 ESS SERVICE CIRCUITS AND SPECIAL TRUNKS
DETAILED HOURLY DATA FROM 02/21/1974 TO 03/20/1974
HOUR ENDING 11:45

ROH ANNC

	PER STATION		USAGE		PEG	HT	OFL	OCC	CAPACITY		
	CCS	CALLS	TRFFC	MB	COUNT	SEC.	%	%	%	CCS	NCI
02-21-74	0.0072	0.035	118	0	576	20.81	1.9	36	112	105	9
02-22-74	0.0072	0.034	119	0	554	21.54	0.4	37	113	105	9
02-25-74	0.0076	0.039	125	0	641	19.67	0.9	39	119	105	9
02-27-74	0.0079	0.035	129	0	580	22.28	0.2	40	123	105	9
02-28-74	0.0072	0.035	118	0	582	20.38	0.5	36	112	105	9
03-01-74	0.0069	0.034	113	0	553	20.54	0.4	35	108	105	9
03-04-74	0.0071	0.038	116	0	616	18.96	0.5	36	111	105	9
03-05-74	0.0066	0.035	108	0	579	18.75	0.2	33	103	105	9
03-06-74	0.0074	0.038	122	0	623	19.66	0.3	38	116	105	9
03-07-74	0.0057	0.035	93	0	579	16.13	0.0	29	89	105	9
03-08-74	0.0070	0.035	115	0	571	20.14	0.4	35	109	105	9
03-11-74	0.0077	0.038	126	0	623	20.42	0.8	39	120	105	9
03-12-74	0.0078	0.032	129	0	528	24.71	1.5	40	122	105	9
03-13-74	0.0104	0.039	171	0	641	27.50	3.1	53	163	105	9
03-14-74	0.0102	0.035	167	0	581	29.54	2.6	52	159	105	9
03-15-74	0.0118	0.036	193	0	595	33.84	4.2	60	184	105	9
03-18-74	0.0109	0.035	179	0	572	32.14	2.8	55	170	105	9
03-19-74	0.0059	0.032	97	0	530	18.38	0.0	30	93	105	9
AVERAGE	0.0079	0.036	130	0	585	22.52	1.1	40	124	105	9

Figure 3

Patrol

000532H NO. 1 ESS SERVICE CIRCUITS AND SPECIAL TRUNKS
TRAFFIC MACHINE LOAD AND SERVICE SUMMARY – 04/18/1974
HOUR ENDING 11:45

ROH ANNC

	PER STATION CCS	CALLS	USAGE TRFFC	MB	PEG COUNT	HT SEC	OFL %	OCC %	RA/BS	FIT-RAT
HIGH DAYS:										
07-18-73*	0.0145	0.038	236	0	613	46.83	17.8	131	1.77	1.44
01-10-74	0.0119	0.038	195	0	627	32.70	4.8	60	1.45	1.36
03-15-74	0.0118	0.036	193	0	595	33.84	4.2	60	1.44	1.32
10-03-73	0.0110	0.042	176	0	675	27.02	3.4	54	1.35	1.30
03-18-74	0.0109	0.035	179	0	572	32.14	2.8	55	1.33	1.28
01-09-74	0.0107	0.037	176	0	605	30.28	4.1	54	1.31	1.26
01-11-74	0.0104	0.044	171	0	719	26.23	9.3	53	1.27	1.25
03-13-74	0.0104	0.039	171	0	641	27.50	3.1	53	1.27	1.23
04-15-74	0.0103	0.041	166	0	672	25.31	2.2	51	1.25	1.22
03-14-74	0.0102	0.035	167	0	581	29.54	2.6	52	1.24	1.21
01-17-74	0.0101	0.037	165	0	613	27.47	2.0	51	1.23	1.20
08-24-73	0.0100	0.038	161	0	608	26.74	1.2	50	1.22	1.20
10-09-73	0.0100	0.040	159	0	643	25.61	3.6	49	1.22	1.19
01-14-74	0.0099	0.042	163	0	687	24.17	1.9	50	1.21	1.18
10-15-73	0.0099	0.039	158	0	628	25.62	1.9	49	1.21	1.18
AVG 10 HD	0.0108	0.039	176	0	630	29.20	3.9	54	1.31	1.29
MONTHLY AVERAGES:										
10-73	0.0087	0.039	138	0	629	22.41	1.8	43	1.06	
02-74	0.0080	0.035	131	0	577	22.99	1.2	40	0.97	
03-74	0.0079	0.036	130	0	585	22.52	1.1	40	0.97	
AVG BS	0.0082	0.037	133	0	597	22.64	1.4	41	1.00	
11-73	0.0079	0.042	125	0	666	19.03	1.1	39	0.96	
01-74	0.0079	0.035	129	0	580	22.43	1.4	40	0.96	
09-73	0.0077	0.039	124	0	628	20.08	1.1	38	0.94	
12-73	0.0073	0.038	117	4	610	19.50	1.3	37	0.89	
05-73	0.0073	0.039	118	0	622	25.13	23.5	66	0.89	
04-74	0.0071	0.035	116	0	576	20.35	0.8	36	0.87	
08-73	0.0070	0.037	113	49	598	20.00	5.3	84	0.85	
06-73	0.0067	0.040	108	0	636	20.67	17.7	60	0.82	
07-73	0.0064	0.038	106	1	621	20.60	16.5	59	0.79	

Figure 4

VII - MAINTENANCE AND RELIABILITY

1. INTRODUCTION

The No. 1 ESS has been designed to provide continuous and accurate telephone switching service throughout the design life of the system. A high degree of system dependability and maintainability have been considered extremely important design objectives during the development of No. 1 ESS.

The basic dependability objective for No. 1 ESS was, and is, to design a system whose downtime would not exceed 2 hours* over its 40-year life while handling fewer than 0.02 percent of all calls incorrectly. In order to achieve this objective, it was realized that, in addition to being inherently reliable, the system would also have to be highly maintainable. Since the No. 1 ESS would have to compete economically with existing systems, the cost of maintenance would have to be minimized. Hence, the basic maintainability objectives of No. 1 ESS were to design a system in which troubles could be located and repaired easily and rapidly and which could be left unattended for extended periods of time.

In the following sections, after a brief review of the basic No. 1 ESS maintenance plan, various aspects of No. 1 ESS field experience related to reliability and maintainability will be discussed. Specifically, hardware failure rates, the downtime history, and the quality of service experienced in No. 1 ESS will be examined. Finally, maintenance improvements which have been implemented and which are being developed will be reviewed.

2. OVERALL MAINTENANCE PLAN

Use of a stored program controlled central processor in the No. 1 ESS has centralized the control functions. Although this centralization has many advantages, it can make the system more vulnerable to complete failure, if not properly handled. For example, if redundancy was not provided in the No. 1 ESS, a single fault in the central control (CC) could cause complete failure of the system. The following paragraphs outline major aspects of the No. 1 ESS maintenance plan which contribute substantially to the dependability of the No. 1 ESS. An overview of the extent to which the various segments of the maintenance plan have achieved their basic objectives is detailed in Section 3, which describes No. 1 ESS field experience.

*Initially, it was assumed, incorrectly, that most of the system downtime would be contributed by duplicate hardware failures.

2.1 Reliable Hardware

Long-life components and conservative circuit design are used to achieve an intrinsically reliable system. Reliable silicon and magnetic devices have been used throughout No. 1 ESS and liberal margins have been provided between component ratings and actual operating conditions. Also, reliance on field adjustment of circuits has been minimized.

2.2 Duplication

Duplication of units and other forms of redundancy are used throughout the system so that an operational system will exist in the presence of any component failure. All equipment whose failure would cause a loss of service to a substantial number of subscribers is duplicated. Thus, in No. 1 ESS, unlike its predecessors, redundancy is provided primarily for dependability rather than to increase the traffic handling capacity of the system.

2.3 Fault Detection and Switching

In No. 1 ESS, circuits are provided for trouble detection and switching of duplicate units, and fault recovery programs are provided whose objective is to identify the faulty unit and to control the switching to enable the system to recover from component failures rapidly and automatically.

Detection of faults in the CCs is primarily accomplished via circuits which match internal logic points within the duplicate CCs as they operate in parallel. Matching is also the main fault detection method used in the signal processors.

Redundant codes, enable-verify signals, internal checks which control all-seems-well (ASW) signals, and various other hardware trouble detection mechanisms are used throughout the system. Trouble detection circuits monitor each system action such as reading or writing a memory word, setting up a network path, pulsing a distributor point, interrogating a scan point or placing AMA data on tape. When a check circuit detects a trouble, it causes the CC to transfer program control from the call processing programs to the appropriate maintenance fault recovery program.

The primary function of fault recovery programs is to quickly identify an operational system configuration, establish it by appropriate switching of duplicate units, and then return to call processing. To minimize the length of call processing interruptions, duplicate units can be switched at speeds comparable to the cycle time of the unit. In most cases, the fault recovery programs can complete their function before the interruption has interfered with call processing. In addition to performing the switching actions related to system recovery, the fault recovery programs identify suspect units and request exhaustive diagnostic tests to be performed on the units on a deferred basis, interleaved with call processing.

2.4 Diagnostic Programs and Circuit Modularization

Diagnostic programs are provided to automatically test a suspect unit, provide fault location information, and verify repairs. Diagnostic tests are performed by applying a series of inputs and observing the normal outputs of a unit and/or monitoring special test points located strategically in the unit. Test results are printed out on the maintenance teletypewriter and the pattern of failed and passed tests defines for the craftsperson the circuit pack(s) to be replaced. The system translates a pattern of test results into a 12-decimal digit trouble number which maintenance personnel look up in a trouble locating manual (TLM) to identify suspect circuit packs. On request, the system will also print the raw test results for analysis by maintenance personnel. Diagnostic programs are interleaved with call processing on a noninterfering basis. Hence, diagnostic programs do not require service interruptions when they operate.

Use of standardized circuit packages and plug-in techniques in conjunction with diagnostic programs has minimized the repair time of No. 1 ESS units. This, in turn, has increased the dependability of the overall system (see Section 3.4).

2.5 Routine Exercise Programs

Exercise programs, which may be initiated periodically by the system or on demand by other programs or by maintenance personnel, are provided to supplement the fault recovery and diagnostic programs. Like diagnostic programs, exercise programs are run interleaved with call processing. Exercise programs routinely test trouble detection circuits, circuits that are not fully self trouble detecting, and circuits that may not be exercised by normal system traffic. In this manner, exercise programs prevent the buildup of latent faults in the system.

2.6 Hardware Emergency Action Facilities

The fault recovery programs depend on correct program execution to accomplish their recovery function. Hence, a reasonably "sane" basic central processor is required by the fault recovery programs as a starting point. A hardware emergency action facility is provided to back up the fault recovery programs so that recovery can be accomplished in situations where the active central processor becomes "insane" due to the appearance of a fault. When trouble is detected within the CC, program store or call store, an emergency action timer is started and the proper fault recovery program is entered. If the fault recovery program is not able to recover the system before the timer times out, the emergency action circuit is activated.

The emergency action circuit establishes, one at a time, all combinations of CC, program store bus, and essential program store without reliance on program instructions. Program instructions are then used to determine whether or not the assembled central processor complex is sane. A sanity timer is used to back up this program. If the new basic processor complex is insane, the emergency action circuit is activated again and another combination of basic processor units is tried.

2.7 Call Store Memory Audit and Data Validation

Many different types of data appear in the No. 1 ESS call store. Blocks of memory called hoppers are used to buffer data between the input/output programs and the base level call processing programs. Records of the busy/idle status of equipment units (path memory, links, trunks, lines, etc.) are maintained in call store. In addition, various call store memory blocks (call registers, path memory annexes, etc.) are seized and assigned to calls being processed by the system. The interrelationships between the various items of call store data are dynamic and complex.

A set of audit programs and individual checks strategically placed throughout the program system verify the consistency of call store data on a continuous basis. Checking of call store data is necessary since errors can be introduced into the data by program bugs, bad translation data or hardware faults which mutilate data before action is taken by the fault recovery programs. When an audit detects a trouble, it reports the trouble via a TTY message and takes corrective action.

Audits prevent the propagation of invalid data throughout the system and also restore "lost" resources to service. For example, if an audit finds a busy block of call progress memory that is not assigned to an active call, an invalid state, the audit idles the call processing resource in question.

Each audit program is designed to treat certain types of memory mutilation. If an audit suspects incorrect data that is outside its sphere of influence, it places the memory in a limbo state, if appropriate, and calls the proper audit to check the suspect memory on a deferred basis. However, if certain critical checks encounter a problem which is severely curtailing the call processing capability of the system, call processing is suspended and the appropriate audit is run immediately. These critical memory checks are called data validations.

2.8 Software Emergency Action Facilities

Various levels of system software initialization are provided which can be instituted automatically or manually. Widespread mutilation of call store data (indicated by situations such as repeated system interrupts, continued absence of a resource [memory, trunks, etc.] needed for call processing or lack of proper main program cycling) can result in an automatic software emergency action.

Software emergency actions are arranged in a numbered hierarchy, called phases. Higher numbered phases involve more complete system reinitialization than lower numbered phases. No automatic phase will disconnect simple calls in the talking state.

A "fast phase" (phase 3) has been introduced in the CTX-6 generic program. This new fast phase is equivalent to the existing phase 4 but lasts about one-fifth as long (see Section 4.4).

3. Field Experience

How has the No. 1 ESS performed from a reliability/dependability standpoint in the approximately 500 offices installed in the field since 1965? To answer this question the following areas which contribute to the overall reliability picture of the No. 1 ESS will be examined.

(a) Device reliability
(b) Downtime history
(c) Quality of service (code 5s)
(d) Fault location and repair

First, a word is in order to identify the source of some of the data contained in this section. To begin with, BTL in cooperation with the Operating Companies has maintained records of all reported downtime in No. 1 ESS offices. In each instance, effort is made to pinpoint and categorize the cause of downtime so that trends can be recognized early and effort brought to bear to correct any problems.

Although studies had been conducted in several individual offices to gather information on hardware failure rates and various maintenance parameters, the need became apparent for a rigorous, enlarged, detailed study of all maintenance aspects of the system. The No. 1 ESS maintenance evaluation study was organized in late 1969 to fulfill this need. The study has several parts which are in various stages of completion. Data given in Sections 3.1 and 3.5 are taken from the hardware failure analysis portion of the study and represent data from 18 offices collected during a one-year period. Other phases of the No. 1 ESS maintenance evaluation study include:

(a) Detailed work characterization (how does the maintenance craft force spend its time in an operating central office?)
(b) Machine stimulus study (evaluates TTY messages, audible alarms, etc.)
(c) Trunk and line test panel usage
(d) Documentation evaluation
(e) Broadbase cost study

The first three phases have been completed and have resulted in recommendations which should help to improve the man-machine interface in No. 1 ESS offices. The documentation evaluation is currently being restructured after an initial trial, and the broad base cost study is in progress.

3.1 Device Reliability

The cornerstone of reliable hardware design for any electronic system is reliable components. In the initial system design of No. 1 ESS, every effort was made to get the best possible devices and to use them in very conservative circuit designs. Extensive life tests were conducted to predict failure rates and these numbers were then used to compute the probability of simultaneous failures in duplicated processor units. This established that the hardware would meet the overall service objective.

Table A lists component failure rates observed during the first half of the aforementioned hardware failure analysis phase of the No. 1 ESS maintenance evaluation study. Along with this most recent data are listed estimated failure rates and those observed during a previous study of the Chase, Maryland, office (March, 1966 to September, 1968). The obvious conclusion is that no component had a failure rate significantly greater than expected. In fact, as Table A indicates, observed failure rates of many components are considerably less than predicted. Hence, as we shall see in Section 3.2, system downtime due to duplicate hardware failures substantially betters the No. 1 ESS system objective.*

One cannot conclude, however, that No. 1 ESS has been without its share of device problems. Circuit and device problems are primarily brought to light by the BTL Quality Assurance Center, the WE Product Engineering Control Center, and through direct contact with No. 1 ESS offices in the field. A number of device and circuit problems have been identified in the years since the first No. 1 ESS office went into service. In some cases, extensive programs were undertaken to eliminate marginal or potentially faulty product in the field. One such program was replacement of early vintage 311A reed relays (used primarily in A29 and A33 circuit packs) which exhibited a tendency towards sticky contacts. Circuit and manufacturing changes were introduced to alleviate the problem, and an office-by-office replacement program was carried out between December, 1967 and May, 1969, in all existing No. 1 ESS offices, which at the time numbered 54. Results show a marked decrease in observed failure rates (see Table A); the 311A is now well within specification.

A more recent program was undertaken in early 1969, after it was discovered that about 2 percent of the 447A logic diodes exhibited excessive leakage under high bias conditions and were causing marginal operation in certain circuits. The 447A diode had been rated manufacture discontinued in early 1966, and was replaced by the 458C. Nevertheless, it was necessary to test about 100,000 circuit packs in 43 offices to screen out potentially troublesome 447A diodes. This program was completed in early 1970.

These are just two examples which demonstrate continuing vigilance on behalf of the BTL/WE/AT&T/Operating Company team to insure good performance at the component level.

* Although the low number of failures observed for some components in these studies places fairly wide statistical confidence limits on the average failure rates, the overall performance of all No. 1 ESS offices (1.4-million service hours in 1971) is statistically significant.

3.2 Downtime History

For No. 1 ESS, any system failure that affects more than 100 calls is considered "service affecting" and contributes to the accumulated downtime. In almost all cases, such failures are in the processor, so for all practical purposes office dependability and processor dependability are equivalent.

An overview of No. 1 ESS field experience is shown in Table B. Data is given for all offices in service during each of five periods. Unplanned interruptions to service have been accumulated for each period and are shown in the column labeled service affecting hours. Planned restarts associated with hardware additions and program updates have been omitted because they are scheduled for periods of very low office activity and take less than 5 minutes. Calculations of downtime in 40 years and percent uptime are also shown. The figures show a steady improvement in dependability.

Table C groups all 1971, 1972 and 1973 downtime into categories. Duplex hardware failure accounted for only four percent of the total downtime incurred in 1971, ten percent of the downtime in 1972, and six percent of the downtime in 1973. This is less than 1 hour in 40 years — well within the original design specification of two hours in 40 years.

Note that the downtime for each incident has been divided into two parts: the time required to reinitialize memory and restart the system, and the additional time occasionally needed to first remove the trouble which caused the outage. In 1971, about 60 percent of the downtime was in the restart procedure, so this aspect of the downtime has received considerable attention. The time required to restart varies from a minimum of about 10 seconds for a simple case to as much as 5 minutes if all the memory has to be compared with the physical state of the network. Ways have now been found to speed up some of the restart programs, and, in other cases, initialization tasks can be deferred until after service is restored.

Two categories of trouble accounted for a substantial portion of the incidents and downtime in 1971 thru 1973. The first is concerned with system recovery from single hardware failures. Normally, when a fault is detected, system recovery programs and hardware take the faulty unit out of service, thereby preventing an interruption to call processing. However, sometimes the recovery system calls for system reinitialization to effect a smooth recovery, and at times manual intervention is required. For example, if a fault occurs in an active call store, lack of an up-to-date duplicate copy of the data due to tests involving an adjacent store will force a system reinitialization. Other reasons which can cause fault recovery systems to resort to reinitialization are program bugs, inadequate circuit access necessary to isolate the faulty units, and single hardware faults that disable duplex units and, hence, the whole processor. Generally, these problems are very subtle and require a particular set of circumstances before they will cause the system to fail. As they are identified, design changes are issued, and through this feedback process the frequency of such incidents has steadiy decreased. It should continue to do so.

The other major source of incidents is human error. Examples are: incorrect insertion of data describing the office configuration or program memory, turning power off at an active unit, manual reconfiguration of the system to include a faulty unit instead of its mate, and inserting memory cards or circuit packs in the wrong locations. The initial reaction to this experience was, of course, to review training procedures. It turned out, however, that in general the craft force was doing about as well as could be expected considering the complexity of the job. In addition, the number of incidents attributable to growth activities is increasing; these represented about one-third of the number attributed to human error.

This realization led to two new developments. First, better procedures have been established for verifying input data before it is inserted in the machine and more checks have been built into the input data processing programs. Second, centralized maintenance is being implemented (see Section 4.2). Switching offices will be monitored and controlled via telemetry and data links from a central location. This will permit continuous observation of each office by personnel who are highly skilled in ESS maintenance activity. The high dependability realized from electronic switching systems in the field creates a paradox. Although the training programs for ESS personnel have improved greatly in quality over the past few years, the low level of troubles in an ESS cause craft people assigned to a single office to lose proficiency through lack of opportunity to exercise skills. Centralization of maintenance activity for a multiplicity of No. 1 ESS should increase proficiency of the maintenance force. These two developments, plus others aimed at better documentation and reducing the probability that a single human error will interrupt service, are expected to substantially reduce the downtime caused by procedural problems in the near future.

The other two categories of downtime are those due to program bugs and office growth. Several years ago software problems were the dominant source of all system downtime. A strong attack was made on this problem and the results have been very encouraging. Since 1965, many hundreds of program problems have been identified and solved, but bugs continue to show up since the software system is still evolving and new features are constantly being added. Addition of the programmed electronic call simulator (PECS) to the test laboratory allows automatic, thorough testing of even the most complex call sequences. Since program additions are thoroughly tested in the system test laboratories under a wide range of conditions before being released to the field, it is now relatively rare for a program problem to result in downtime.

Frequently, No. 1 ESS offices are in the process of growing; that is, new equipment such as memories and network frames is being added to the office so that it can handle more subscribers. In general, growth entails connecting a new unit, testing it without activating it, changing processor memory to recognize the new unit, and then activating the unit. The process is complicated and can result in a service interruption if a mistake is made. The growth procedures have, therefore, been very carefully planned so that growth involves taking a few simple steps from one safe stopping point to the next. If something goes wrong during installation, it is easy to back up to the previous checkpoint. The relative lack of downtime attributed to growth testifies to the thoroughness of this planning.

3.3 Quality of Service (Code 5s)

Customer trouble reports assigned to a central office or main frame are called "code 5s." Code 5 statistics provide an important measure of a switching system's performance. Figure 1 depicts code 5 statistics for all No. 1 ESS offices and was constructed using data obtained from the AT&T No. 1 ESS service results report.

Figure 1 shows that the code 5 statistic for No. 1 ESS is trending downward, as desired. Improved generic programs, improved hardware, and an increasing familiarity with ESS on the part of the Operating Companies are responsible for the downward trend in code 5s. The maintenance system improvements described in Sections 4.2 through 4.4 will further improve the code 5 picture. In addition, improvements in the recent change program are being implemented which will permit better coordination of the wiring change/translation change associated with a service order via an improved delayed recent change facility. Lack of coordination during the implementation of service orders is a source of code 5s.

New No. 1 ESS offices tend to have a higher incidence of code 5s than older offices. At present, No. 1 ESS is essentially a new system; over one-fourth of all No. 1 ESS offices in existence at the end of 1973 were cutover in 1973. Thus, as the number of new offices becomes a smaller fraction of the total number of offices, the code 5 statistics will tend to improve.

Since there are relatively few No. 1 ESS offices, if one or two offices have a poor month as far as their code 5s are concerned, the overall statistic can be affected substantially. For example, the central office code 5 peak shown in Figure 1 for April, 1971, was due to two offices. Two of 144 reporting offices were responsible for 2,048 of the 5,130 code 5s reported in April, 1971.

3.4 Fault Location and Repair

As we saw in Section 2, the No. 1 ESS maintenance plan provides for extensive use of programmed diagnostics and trouble locating manuals (TLMs) to aid in the repair of each subsystem. Repair time can greatly affect the system downtime since downtime varies as the square of mean repair time.* The major objective of automatic diagnosis is to keep the mean repair time within bounds since long repair times increase the probability of simultaneous failures in mate units. Table D depicts the effectiveness of the diagnostics and TLMs in aiding the repair process.

In Table D, diagnostic detection level is the fraction of faults actually detected by the diagnostic. TLM accuracy refers to the fraction of detected faults which can be located by the TLM system (exact match, phase, and cell). Field study data results are generally in the same ball park as laboratory derived data, although the number of actual faults incurred during the study was quite small. BTL has a very high degree of confidence in the laboratory derived statistics since they are based upon physical insertion of all possible single hard faults.

Note in Table D that two sets of data are given for the CC TLM: CC (old) and CC (new). It was recognized in 1969 that the quality of the CC TLM had degraded since Succasunna due to hardware and program changes. Hence, considerable time and effort was expended by BTL to reinsert all 91,000 possible CC faults and redo the TLM. At the same time, tests were added to known weak sections of the diagnostic program to raise the fault detection level to almost 90 percent. Basic circuit design limitations and diminishing cost effectiveness restrict increasing CC fault detection level further.

* Downtime in 40 years due to subsystem

$$i = N_i \left(\frac{MRT_i}{MTBF_i}\right)^2 \quad (350{,}400) \text{ hours}$$

N_i = Factor proportional to the number of duplicated units in subsystem i.

MRT_i = Mean repair time for units in subsystem i.

$MTBF_i$ = Mean time between single failures of units in subsystem i.

Data from the hardware failure analysis study suggests that the diagnostic programs can detect about 95 percent of processor troubles encountered in a typical office* and that 77 percent of these troubles can be located in the TLMs. The equivalent figures based on laboratory evaluation are 81 percent detection and 94 percent location in TLM. One reason for the observed higher (than predicted by laboratory evaluation) detection levels is that all troubles do not occur with equal probability and the diagnostic programs are designed to be most effective on higher probability faults. On the other hand, TLMs are less effective in the field due to small differences between machines that result in slightly different test results than observed in the laboratory where the TLMs were made and due to intermittent faults that only fail a subset of the tests applied. The observed repair time for the 120 processor troubles encountered during this study was approximately four hours.

There are two major reasons for average repair times being larger than the two hours initially assumed. First, in many cases there is a long interval between the time the fault first is detected and the time maintenance personnel start repair procedures. This is mainly because most offices are unattended, at least part of the day, and help has to be dispatched when an alarm occurs. Second, some troubles are intermittent or give inconsistent trouble symptoms and hence are very difficult to locate. Most of the time the unit will run properly, but occasionally a fault will occur. In both cases, centralized maintenance, which is discussed later, should help reduce occasional occurrences of very long repair intervals and hence reduce the average repair time.

Another development which will further improve the diagnostic performance picture is the development of the new diagnostic program for the 32K call store. Key features of the 32K CS diagnostic are:

1. Improved circuit access and maintenance features leading to a 95 percent logical fault detection level for that unit.

* Typical processor configuration: two CCs, two SPs, five PSs, 20 CSs (8K).

2. Ability to margin check circuits under program control.
3. Improved software organization and features to aid in detection of marginal and intermittent faults.
4. Improved raw data printout (PK) and TLM.

Many of the features and methods pioneered with the 32K CS diagnostic will be utilized on new hardware designs.

4. MAINTENANCE AND RELIABILITY IMPROVEMENTS

Since cutover of the Succasunna office, Bell Laboratories and Western Electric Company have continued to make both hardware and software improvements which have enhanced the overall reliability and maintainability of the No. 1 ESS. This section covers some of the key maintenance oriented features recently incorporated in the system or soon to be added to the system.

4.1 Hardware

No. 1 ESS device performance has been covered in Section 3.1. In addition to device improvements, many circuit packs have undergone design changes to increase performance margins. In 1969, Western Electric initiated a system for investigating circuit pack anomalies and complaints (SICPAC), and reports are issued monthly. BTL monitors the SICPAC report as well as direct complaints to ascertain required circuit pack improvements. Design changes are made on approximately ten codes each year to improve margins. Substantial improvements have been made recently in the circuit pack test and repair procedures by the Western Electric Company. A new computer controlled test set (Figure 2) now in operation at the Arlington, Virginia, service center is capable of handling about 65 percent of all No. 1 ESS circuit pack codes.

Improvements at the subsystem level can also be seen. The 32K call store has already been mentioned. The remreed network has a number of features which enhance its reliability relative to its ferreed predecessor:

1. The controller and path selection matrix depend heavily on semiconductor technology rather than on electromechanical design, thereby eliminating relay contact chatter problems which have caused intermittent failures in the ferreed networks.
2. General simplicity of design has reduced the amount of point-to-point wiring required and facilitates the use of automatic machine wiring techniques.
3. Improved resolution of control and pulse path faults by the diagnostic program.

4.2 Centralized Maintenance

The centralization of maintenance of a group of offices permits a concentration of highly skilled maintenance personnel who can, because of their greater experience, respond more quickly to correct problems, even the more exotic ones that a person confined to a single office would very seldom encounter.

Many operating companies have made initial steps toward centralizing their maintenance activities through implementation of technical assistance centers or TACs. Until recently, this has consisted principally of gathering in one area remote teletypewriters connected to the maintenance channel of each of the offices being monitored.

To benefit more fully from the advantages of centralization, Switching Control Centers (SCCs) are being designed. The SCC has the capability for remote surveillance and control of those functions at the maintenance control center of a No. 1 ESS that are necessary for system recovery in an emergency situation. A computer is provided as part of the SCC arrangements to process much of the large quantities of data outputted by the ESSs and generates appropriate exception reports, thereby reducing the number of TTYs required, and helping to mechanize the administration functions.

Successful field trials of various components of the SCC arrangements have been conducted in Chicago, New Brunswick and Philadelphia. The first No. 1 ESS application of standard SCC equipment did occur in Miami on June 17, 1974.

An additional facet of centralized office operation is the capability of testing trunks and sectionalizing trouble from a remote location. Together with circuit order work these two items are the principal reasons for manning a working office, so these facilities will be provided as soon as possible after CTX-7. Of course, use is made of the recently provided ability to diagnose trunk circuits from a remote location via TTY input as well as to make them busy or restore them to service.

If an office is unattended, calls directed to the trunk test positions will be transferred to a remote location. The remote location will be able to originate test calls on a particular trunk and send and measure tones to sectionalize trouble on the trunk. The combination of these features will allow almost all trunk maintenance procedures which can be performed at a central office trunk test position to be performed from a remote location. Maintenance personnel need be dispatched to the unattended office only to make some rarely used measurements and to effect repairs on trunk circuits.

A new development, which may be co-located with SCC, referred to as centralized automatic reporting on trunks (CAROT) will be able to survey, by measurement, the condition of trunks in a number of offices, both electronic and electromechanical. This is made possible by developments discussed in the section on improved test facilities. In addition to looking at specific problems, CAROT will be able to make routine transmission measurements on all its interfacing offices (as well as other types of measurements).

4.3 Line Trunk and Peripheral Maintenance

A significant portion of the maintenance effort in a central office is directed toward maintenance of lines, trunks, and peripheral units. Also, troubles in these areas directly affect the quality of service received by the customers of the central office. Hence, improvements in facilities related to maintenance of lines, trunks, and peripheral units are being actively pursued by Bell Laboratories.

Automatic Transmission Measuring System

Of the many developments that make it possible to operate and maintain an office remotely, the development of an automatic transmission measuring system is one of the most important. New designs of automatic originating and terminating transmission test equipment, such as tone sources of various frequencies and balanced terminations, all remotely controllable, together with precision measuring devices make it possible to make 2-way overall measurements of loss, noise, and gain slope on trunks with the 105 test line. One-way measurements are possible with simple test lines such as the types 100 and 102. Additional program modifications and test access will make it possible to sectionalize troubles with a single person. The new development that makes this possible is the remote office test line (ROTL) and the program controlled interrogator (PCI) for No. 1 ESS. With this equipment one person trunk testing for an office can be initiated locally or remotely.

Trunk Diagnostic Improvements

The trunk and service circuit diagnostic program has been rewritten in a new data table driven format. The 37-bit data word tables, which comprise the diagnostic tests, are generated from a set of functionally descriptive macros. Major advantages of this new format are: 1) reduced program size required for current and future trunk diagnostics, 2) improved raw data analysis, and 3) a simplified method of making program changes for new or modified trunks. The latter is particularly important since trunk circuit designs, and therefore trunk diagnostics, are very often affected by the introduction of new features.

Line Testing

Expansion of the automatic line insulation test (ALIT) facility to improve identification of a line in trouble, perhaps before the customer realizes that service is inadequate is being studied. Another piece of equipment also being studied is the Line Status Verifier, which can make some tests that ALIT cannot. Bell Laboratories is now determining which equipment (modified as necessary) can provide the best service to the customer and the most help to the service bureau.

The CTX-6 generic programs provide the ability to request, via the TTY, testing of a line or a group of lines using the ALIT test facilities.

Network Maintenance

As the No. 1 ESS establishes the various network connections required to process a call, the system performs a number of checks to ensure proper handling of the call. Possible test failures include:

Power Cross (PX) — A commercial (60 Hz) power cross has been detected on an originating or a terminating line.

Showering Line (SHWL) — A marginal tip-ring line resistance exists which appears off-hook at the line ferrod but on-hook at the receiver. If not treated specifically by the system, a "shower" of false originations would result from the line.

Low-Line Resistance (LLR) — A low-line resistance check made before ringing is applied to prevent false ring trip has failed.

Ringing Current (RC) — A check to determine whether or not ringing current has actually been applied to a terminating line has failed.

False Cross and Ground Failure (FCGF) — A check for false cross or grounds on the tip ring within the network has failed. This check is made as a new network connection is established to detect faults causing "Y" connections in the network.

Supervisory Scan Failure (SUPF) — A transfer of supervision scan has failed. A "SUP" scan is made when a new network connection is established to ensure network path continuity.

Initially, a number of nonfault situations caused the system to print network failure messages. For example, switchhook manipulation could cause SUPFs. This made it difficult for personnel to identify true trouble. Software improvements have been implemented which eliminate most false SUPF failures. The CTX-6 generic programs contain further improvements in the network maintenance facilities. Improved TTY output message formats, elimination of redundant failure messages, and increased sectionalization of detected faults contribute to simplify the job of identifying and correcting network and line troubles.

Network Pulse Path Matrix Faults

Due to the destructive mark nature of the No. 1 ESS ferreed network, a short circuit in a pulse path selection relay matrix can result in cutoffs occurring on established calls. Network matrix faults of this type are presently difficult to track down. An attack on this problem is being made.

The UNIGRO (auxiliary program for network growth) tests for the detection and location of shorts in network pulsing paths have been extended so that they can be applied to in-service networks. This test feature is being introduced in an auxiliary program package which will be available to the operating companies.

4.4 Maintaining Continuity of Service

Considerable progress has been made in protecting service even during major system outages. Initially, any system reinitialization phase of four or higher disconnected all calls in progress. Today, no automatic reinitialization of the system will disconnect simple calls in the talking state. Additional improvements in this area are described in the following paragraphs.

Fast Memory Reinitialization

A new memory reinitialization phase has been introduced in the CTX-6 generic programs. The design objectives of the new phase were to develop a phase having a probability of recovering system sanity equal to that of the existing phase 4 while holding the phase execution time to 30 seconds or less. The relatively long execution time of the phase 4 (as much as 3 to 4 minutes in a heavily loaded large office) precipitated the design effort.

High probability of recovery is achieved by leaving only stable talking calls established and setting the rest of the system to idle. This is the same initialized state that results from a phase 4. Speed is achieved through program streamlining and time-sharing a portion of the initialization with call processing.

Data Mapping Feature

Certain No. 1 ESS procedures such as generic program retrofits and the introduction of new parameters have required planned office restarts which involved a phase 6 reinitialization (office placed in completely idle state) and the zeroing of recent change information. Although these planned restarts were scheduled for off-hours, some calls were disconnected and certain customer services were lost until the recent change area could be rebuilt.

The data mapping program XMAP has been developed to minimize the disruption caused by planned office restarts. Use of the XMAP program preserves calls in the talking state and certain recent change information (e.g., customer call forwarding lists) through the restart. XMAP has been released to the field as an auxiliary program.

Recent Change Information Protection

Originally, when recent change information caused a system outage, the recent change area had to be zeroed to insure system recovery. A feature has been added to the system which permits the recent change information to be disjoined from the active system under manual control without requiring zeroing of the recent change area. This feature permits correction of a phase producing recent change problem without requiring rebuilding of the entire recent change area.

The ability to dump the recent change area onto magnetic tape or rebuild the recent change area from magnetic tape has been provided by the auxiliary program XDRI.

4.5 Recovery From Duplex Failure

Duplication of common control equipment has been used in No. 1 ESS to prevent a total system outage when a fault occurs in any single unit. Although the probability of failure of a unit and its duplicate (duplex failure) is very small, this event is possible. Techniques for recovering from duplex failures have been investigated and are being implemented.

Duplex Call Store Failures

"Split" duplication (Figure 3) has been used in the call store system so that growth increments of one store are allowed. Each store contains two blocks of data and a given block of data is duplicated in adjacent stores. The original design of both the 32K and 8K call stores in No. 1 ESS provided a program controlled access name (K code) for half (one data block) of each store. The call store fault recognition program has been modified to take advantage of this variable name feature when both call stores normally containing a memory block fail. When adjacent call stores fail, the variable named half of another call store will be substituted for the missing memory block. Thus, recovery from most duplex call store failures will be fully automatic. This feature was first introduced in the CTX-6 generics.

Other Duplex Failures

Standard procedures are also being developed for recovering from duplex central control, signal processor and central pulse distributor failures. Call store and program store duplex failures were attacked first since field experience indicated that these subsystems, although very reliable, were more prone to failure than other processor units.

4.6 Miscellaneous Maintenance Improvements

Many maintenance and reliability improvements in addition to those already described have been and are being added to the No. 1 ESS system. Several of the more recent developments are mentioned below.

Auxiliary Program Test Facility

The auxiliary program feature provides access to infrequently used but valuable maintenance and special purpose programs in an ESS office without incurring the cost of dedicated space in the ESS permanent magnet twistor program store for these programs. This is accomplished by temporarily replacing one copy of the CC diagnostic program with a module containing the auxiliary programs. Thus, when an auxiliary program module is inserted (replacing module 05 of PS00 or module 15 of PS01), the program stores contain one copy of the CC diagnostic and one copy of the auxiliary programs. The program store configuration is controlled via teletypewriter commands and/or automatically by the system so that the system has access to either the auxiliary program or the CC diagnostic as required.

Since all auxiliary programs would not fit into one program module, several auxiliary program module editions or packages have been developed. Each package contains a set of programs which provide related maintenance or administrative features. A control program has been developed to simplify and standardize the interface between individual auxiliary programs and the ESS generic program. This control program is provided in all auxiliary program modules. Maintenance and reliability auxiliary program features which have been developed are:

1. Bus test program which can be used to place a pattern on the program store, call store or peripheral unit enable and address buses in conjunction with oscilloscope testing of these buses.

2. Translation check program which checks the consistency of translation memory assignments.

3. Data retrieval and insertion via the AMA tape unit which can be used to protect recent change information (see Section 4.4.).

4. Data link diagnostic program.

5. Call store data mapping program which preserves calls in the talking state and certain recent change information during planned office restart (see Section 4.4.).

6. Network matrix short test (see Section 4.3)

7. Automatic board-to-board test program which reduces manual effort and total interval required to verify lines before cutover.

Fault Recovery Program Data Printout

When a fault occurs in the system, the prime responsibility of the fault recovery program is to establish a working system configuration. Identification of the fault has been viewed as the diagnostic program's responsibility. Hence, fault recovery programs print little information related to the fault identity; it was assumed that if the recovery program sees a fault, the diagnostic program would also see the fault and be in a position to print more comprehensive information identifying the fault. However, the strategy does not work in the case of marginal faults, which disappear before the diagnostic tests are applied, or in the case of faults which are missed by the diagnostic (all tests pass). With the introduction of the CTX-7 generic program, fault recovery programs will collect and print more data related to the state of the system hardware and memory when a fault occurs. Additional snapshot and data saving programs will be able to be activated on request for particularly difficult problems.

Peripheral Error Analysis

A marginal fault in a peripheral unit, which disappears before the peripheral recovery program retries the failing order or during the recovery program's sequence of retries over different configurations, can foil the program's recovery strategy. Although occurrence of a fault of this type is extremely rare, a phase 5 system reinitialization can result from such a fault. The CTX-6 programs include a comprehensive peripheral error analysis routine which backs up the basic peripheral recovery programs. If the basic recovery strategies do not clear a problem, peripheral configurations which eliminate one of the units which could be causing the trouble are established and tried until the problem is cleared. The last unit switched out (presumably responsible for the problem) is printed out at the TTY.

NO. 1 ESS COMPONENT RELIABILITY

COMPONENT	PREDICTED FITS †	OBSERVED IN CHASE (1966-68) FITS	HARDWARE FAILURE ANALYSIS (1971) FITS
29A XSTR	10	7.8	4.4
20D/20L XSTR	100/30	188(20D)	32(20L)
‡Diodes	5	0.5	0.33
‡Resistors	1	0.5	0.38
‡Capacitors	5	7.5	3.9
Transformers	20	13	1.5
311A Relays	100	41(1250)*	45

* Early vintage 311As.

† FIT = failures in 10^9 hours.

‡ Weighted average failure rates on all devices in class.

Table A

No. 1 ESS Uptime

PERIOD	NO. OF OFFICES	SERVICE HOURS	SERVICE AFFECTING HOURS*	DOWNTIME IN 40 YEARS (HOURS)	PERCENT UPTIME
5/65 through 5/69	1-47	0.45M	60	47	99.987
6/69 through 12/70	47-127	1.12M	77	24	99.993
1/71 through 12/71	127-209	1.40M	50	13	99.996
1/72 through 12/72	209-315	2.31M	73	11	99.997
1/73 through 12/73	315-427	3.20M	82	9	99.997

* Excluding planned restarts.

Table B

Downtime in 1971

CAUSE	PERCENT OF INCIDENTS	PERCENT OF DOWNTIME DUE TO: RESTART SYSTEM	OTHER
Hardware Failure in Duplicated Units	2	1	3
System Recovery from Single Hardware Failure	35	20	21
Program Bugs	11	6	1
Human Error	35	21	17
Growth	3	2	0
Unresolved Troubles	14	8	0
Total	100	58	42

Downtime in 1972

CAUSE	PERCENT OF INCIDENTS	PERCENT OF DOWNTIME DUE TO: RESTART SYSTEM	OTHER
Hardware Failure in Duplicated Units	21	0.3	9.7
System Recovery from Single Hardware Failure	31	11	24
Program Bugs	13	4	4
Human Error	26	9	18
Growth	8	3	1
Unresolved Troubles	21	7	9
Total	100	34.3	65.7

Downtime in 1973

CAUSE	PERCENT OF INCIDENTS	PERCENT OF DOWNTIME DUE TO: RESTART SYSTEM	OTHER
Hardware Failure in Duplicated Units	1	0.3	5.7
System Recovery from Single Hardware Failure	36	10	20
Program Bugs	3	1	3
Human Error	36	10	29
Growth	14	4	7
Unresolved Troubles	10	3	7
Total	100	28.3	71.7

Table C

Diagnostic and TLM Evolution

	LABORATORY EVAUALATION		FIELD EXPERIENCE*	
SUBSYSTEM	DIAGNOSTIC DETECTION LEVEL	TLM ACCURACY	DIAGNOSTIC DETECTION LEVEL	TLM ACCURACY
CC (old)	0.85	0.85		
			0.95	0.75
CC (new)	0.89	0.98		
SP	0.88	0.91	1.00	1.00
CS (8K)	0.78	0.93	0.96	0.80
PS	0.67	0.97	0.84	0.63
Network Control	0.91	0.89	0.72	0.75

* Hardware failure analysis study, small data samples.

Table D

No. 1 ESS code report history . . .

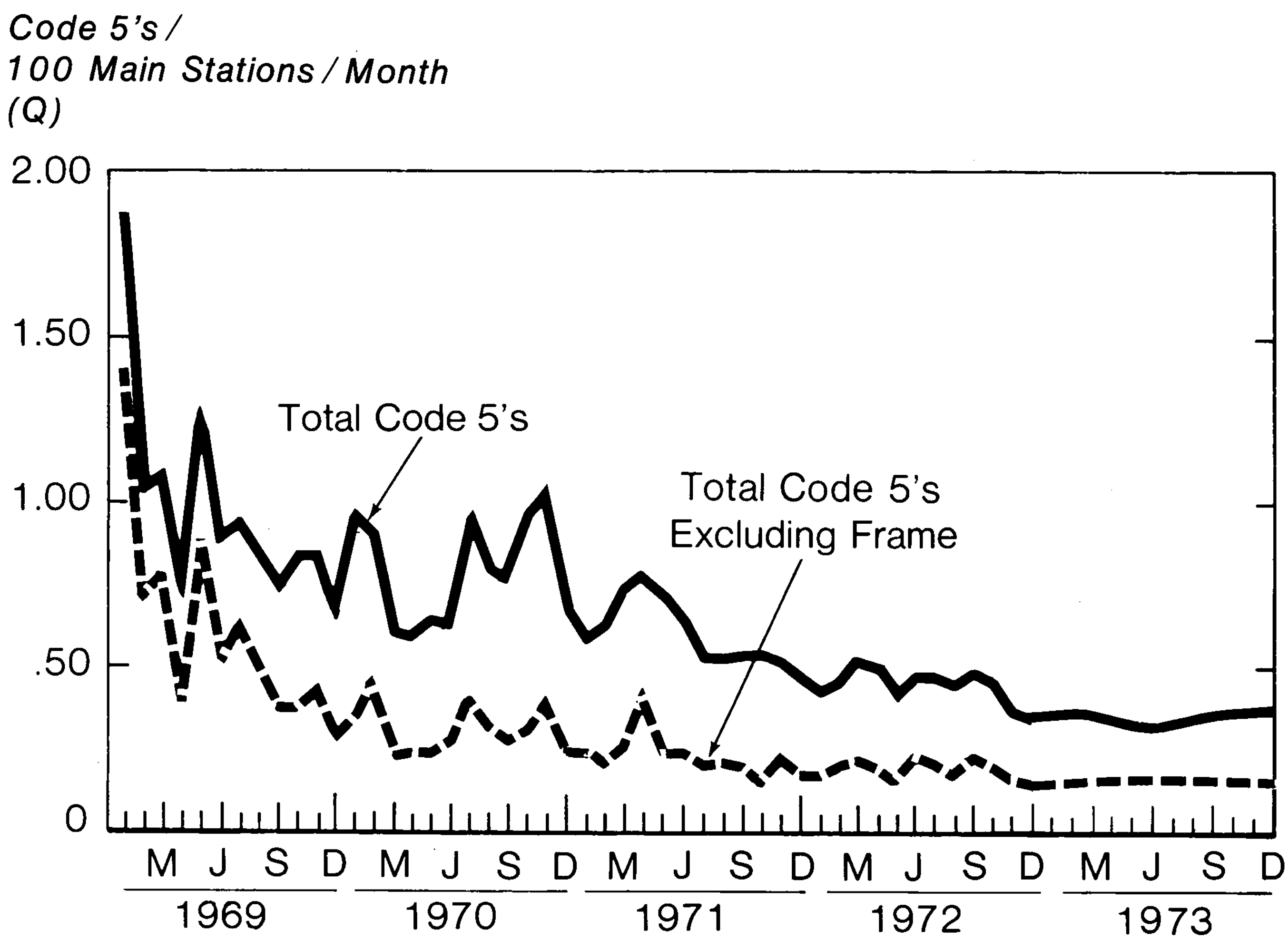


Figure 1

Computer Controlled Test Set

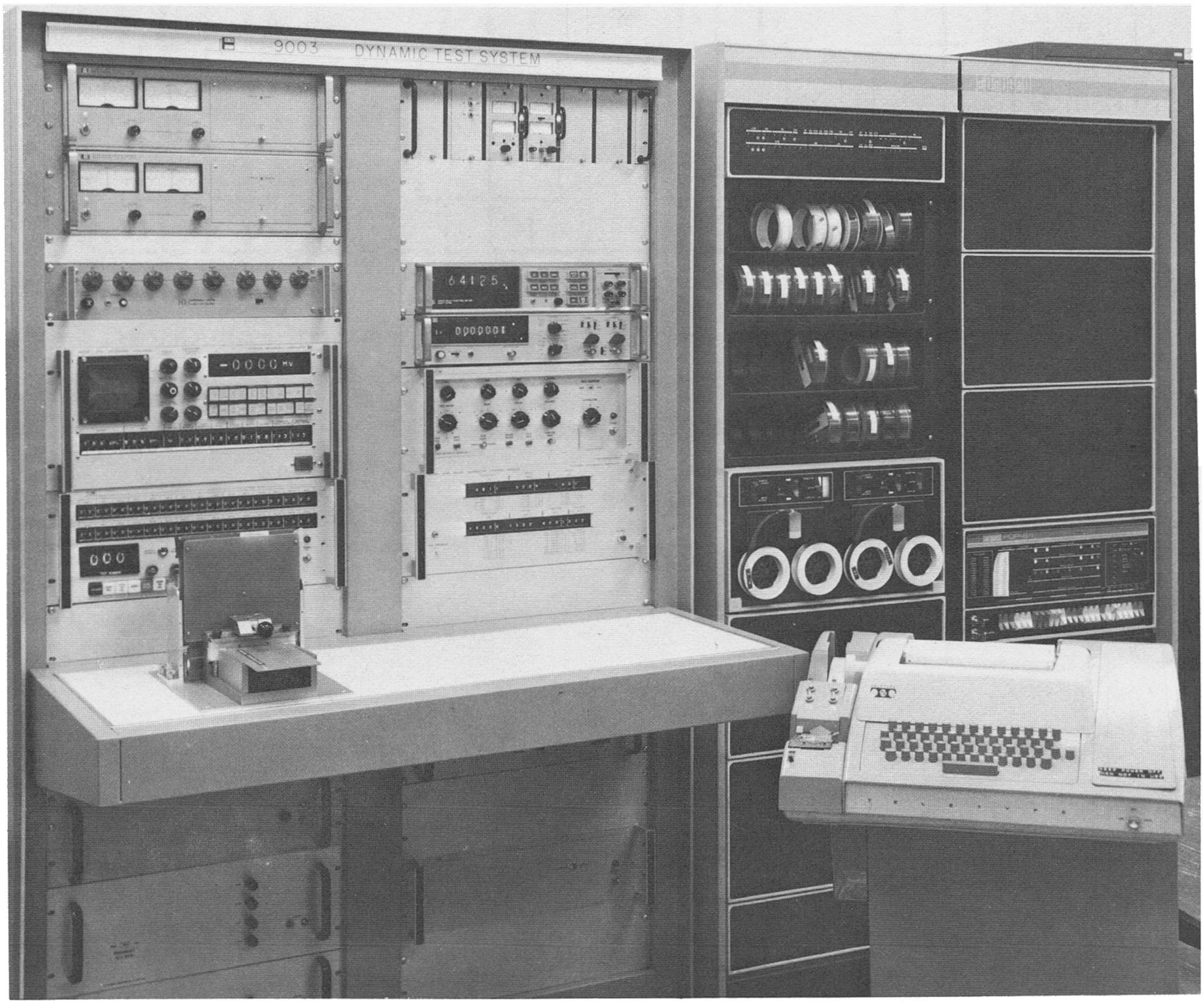
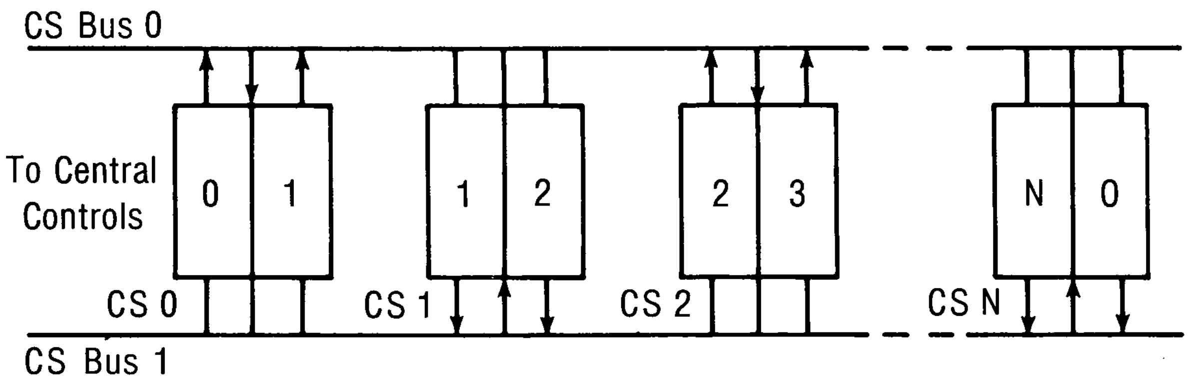


Figure 2

Call Store Duplication Scheme



Normal store configuration shown for even number of call stores

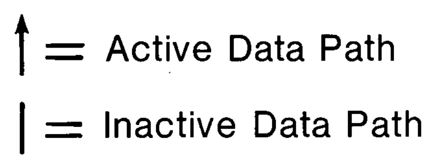


Figure 3

VIII - PRICE

1. INTRODUCTION

This section discusses the price history of No. 1 ESS. Major emphasis is placed on the current view of No. 1 ESS prices. In addition to the Western Electric bill for material, engineering, and installation (often denoted as EF&I; engineered, furnished and installed), floor space costs and operating company charges associated with installing a new No. 1 ESS switching system are discussed. To provide a basis of comparison, No. 5 Crossbar EF&I prices, floor space, and operating company charges for similar type offices are also presented.

There continues to be considerable Bell Laboratories and Western Electric effort devoted to No. 1 ESS cost reduction. Current development projects that appear to contain potential for future cost reductions on No. 1 ESS are also described.

The information given in this section indicates that on an EF&I basis, No. 1 ESS is less expensive than No. 5 Crossbar above about 15000 lines for low traffic and 13000 lines for high traffic offices. When floor space and operating company charges associated with installation of new equipment are considered in addition to the EF&I bill, No. 1 ESS becomes less expensive than No. 5 Crossbar above 12000 lines in low traffic cases and above 11000 lines in high traffic situations. No. 1 ESS becomes economic at even lower line sizes when special features like Centrex-CO and Custom Calling Services are considered.

Recent price trends have shown that No. 5 Crossbar prices are increasing at a greater rate than No. 1 ESS prices. This trend plus the continuing effort to reduce No. 1 ESS costs indicates that No. 1 ESS in the near future will also become economic when compared to No. 5 Crossbar for lower line size nonbusiness type offices.

2. NO. 1 ESS PRICE HISTORY

The system design and expected price relationship of No. 1 ESS to No. 5 Crossbar were monitored by BTL, AT&T, and WE from the beginning of the No. 1 ESS project in the late 1950's. Periodic formal reports of these initial price studies were made to the Tri-Company Joint Committee on ESS (now called the No. 1 ESS Tri-Company Committee).

The method first used to analyze system price was to price out typical actual No. 5 Crossbar offices and engineer and price out No. 1 ESS equipment to provide similar service as the No. 5 Crossbar equipment actually used. Comparisons were made between the No. 5 Crossbar and No. 1 ESS prices for each study office. The Western Electric Company bill for material furnished, engineering and installation (EF&I), was derived for each study office. In addition, floor space costs and potential operating company expenses associated with each office were estimated. Thus, the total price to the operating company was estimated for each office. The office prices were broken down into subcategories to identify potential areas for No. 1 ESS cost reduction.

These initial studies were intended to help make design decisions and were not for use in predicting the price of real No. 1 ESS offices. Objective prices for No. 1 ESS based on estimated No. 1 ESS production quantities in 1968 were used. Miscellaneous equipment items common to No. 5 Crossbar and No. 1 ESS were omitted from these studies.

The first BTL price study using a No. 1 ESS equipment configuration and technology essentially as it is today was completed in December 1961. This early study showed that on an EF&I basis No. 1 ESS would be less in price than No. 5 Crossbar above 10,000 lines and would save considerable money for higher traffic larger line size offices (Figure 1). The addition of building space and telco charges made ESS look even more favorable compared to No. 5 Crossbar. The last price study of this early series in mid-1963 indicated that on an EF&I basis No. 1 ESS would price out less than No. 5 Crossbar only for higher traffic offices above 20,000 lines (Figure 2). However, on a total price basis ESS was less expensive for offices above 11,000 lines.

Since by mid-1963 the hardware design was essentially chosen, the formal Tri-Company monitoring of price performance was discontinued. However, an informal study in late 1964 of the same offices was done by Bell Laboratories after the Western Electric Company published its first price list for No. 1 ESS equipment. The prices per frame were increased from the previously used 1968 objective price values used in the Tri-Company studies to reflect both the latest design information and WE start-up costs for the new technology in No. 1 ESS. The frame price increases resulted in about a 10 percent increase in overall system prices from the last Tri-Company study.

By late 1964 it became apparent that even on a total price basis No. 1 ESS would not price out less than No. 5 Crossbar except for larger line size higher traffic type offices (Figure 3). However, No. 1 ESS still would provide many features not available on No. 5 Crossbar and would be easier to administer and would save considerable floor space over No. 5 Crossbar equipment.

There were several reasons for the change in No. 1 ESS prices relative to No. 5 Crossbar. First, the total feature requirements desired on No. 1 ESS continually increased as the development progressed. Hardware component needs were increased to provide these additional feature requirements. At the same time, however, component costs with the new electronic technology continued favorable with decreases in cost for most new devices.

When detailed writing of the stored program began, it became obvious that more program words than initially expected would be required to provide all the call processing functions needed as well as provide the level of maintenance capability desired on No. 1 ESS. As a result, additional memory storage, both call store and program store, was required as the development progressed. In total, the price of a No. 1 ESS installation increased relative to No. 5 Crossbar as these initial price studies progressed.

2.1 Informal Studies — 1964-1967

Pricing studies of No. 1 ESS were continued by Western Electric and AT&T with some Bell Labs involvement. A different set of study offices were used in these new studies. Offices having traffic characteristics of suburban areas and offices characteristic of metropolitan areas were hypothesized. Both No. 1 ESS and No. 5 Crossbar equipment was engineered and priced out for each study office. Comparisons of No. 1 ESS and No. 5 Crossbar prices were made for both the high traffic and low traffic offices. These hypothetical offices along with contracts for actual No. 1 ESS offices were used to derive a No. 1 ESS EF&I planning price curve published for Operating Company use in April, 1966 (Figure 4). These curves were intended to accurately reflect the Western Electric bill to the Operating Company for No. 1 ESS installations. They were higher than the previously performed comparison studies with No. 5 Crossbar where only relative differences were important.

During 1966 and 1967 an intensive effort was made to more accurately establish the price relationship of No. 1 ESS and No. 5 Crossbar. The results of the study were to be used by AT&T to publish a comprehensive comparison in both first cost and annual charges of No. 1 ESS and No. 5 Crossbar. The seven previously used hypothetical offices were augmented by five additional hypothetical offices and also by nine actual No. 5 Crossbar offices for which No. 1 ESS equipment was engineered. The results of the study were published in an AT&T letter in April, 1968. (Figure 5.) This study showed No. 1 ESS to be more expensive on an EF&I basis than No. 5 Crossbar except for high traffic metropolitan offices when only one entity of No. 1 ESS was required but two entities of No. 5 Crossbar were needed. However, the addition of maintenance savings, Custom Calling Features, floor space, and Operating Company administration savings resulted in No. 1 ESS looking favorable on an annual cost basis above 8,000 lines in metropolitan applications and above 15,000 lines in suburban applications (Figure 6.) This was again a comparison study between No. 5 Crossbar and No. 1 ESS and no use of real No. 1 ESS bills or contracts was made. The absolute EF&I price levels for high traffic ESS offices were similar between the 1966 and 1968 AT&T letters. However, the low traffic No. 1 ESS price curve was substantially less in 1968 than in 1966.

2.2 Tri-Company Cost-Price Review Team Studies — 1968-Present

In late 1967 a formal Tri-Company structure to monitor the price of all new products from the design stages through first applications in the field was again established; this structure continues in existence. These committees are called Cost-Price Review Teams (CPRT) and are composed of representatives from WE and BTL.

The first No. 1 ESS price study done under CPRT direction was finished in early 1969. This study used a subset of the hypothetical and actual No. 5 Crossbar offices from the April, 1968 AT&T study. The office equipment lists were updated to reflect the current equipment needs of No. 1 ESS and to reflect the latest engineering practices for No. 5 Crossbar. Included in this study was not only the current equipment configuration but also potential cost reductions possible on No. 1 ESS due to new equipment designs and WE manufacturing improvements. The results of this first study were less favorable than reported in the April, 1968 AT&T letter. However, the price comparisons including potential price reductions were much more favorable to No. 1 ESS. This indicated that if all improvements could be realized, No. 1 ESS would price out less (including building space and telco charges) than No. 5 Crossbar in high traffic offices above 6,000 lines and in low traffic offices above 15,000 lines (Figure 7).

The price picture for No. 1 ESS POTS offices deteriorated somewhat in 1969 due to two factors. One was the decision to utilize one set of generic programs making all new offices purchase the program containing centrex features. This increased the requirement for program stores in POTS offices. In addition, price increases had occurred on both the No. 1 ESS and No. 5 Crossbar systems.

2.3 Comparison of CPRT Results and Actual Operating Company Bills

During 1970 and 1971 studies of actual Operating Company bills for No. 1 ESS indicated that the CPRT studies were not including all the charges actually being incurred by the Operating Companies in purchasing No. 1 ESS machines. The idealized assumptions of CPRT studies were minimizing the true Operating Company charges being incurred on all installations as well as not including the extensive charges due to more liberal engineering practices and supplemental orders to WE for engineering changes to initial orders. Since these additional charges were more extensive on No. 1 ESS than on No. 5 Crossbar, the resulting price picture as seen by the Operating Companies was considerably worse for No. 1 ESS than predicted by the CPRT results. (The CPRT studies were aimed at long-term relative price relationships suitable for making design decisions. However, the near term inaccuracies were upsetting to all involved). Attempts to establish a more meaningful short term price comparison of No. 1 ESS and No. 5 Crossbar was begun in 1971 and has been updated for this report as shown in Section 4.

3. CURRENT VIEW OF NO. 1 ESS PRICES

A single formula for estimating the EF&I prices for No. 1 ESS installations is difficult to derive due to the wide variation in features and traffic found in different No. 1 ESS offices. In addition, the purchase of line network concentration ratios based on long-term economic considerations rather than current CCS/line values affects the initial cost of the network and complicates the accurate prediction of total office price. The wide variation in the use of No. 1 ESS (from replacement of older equipment in complex metropolitan buildings to growth units in new buildings) creates wide variation in installation charges and further complicates the prediction of EF&I price for a potential installation.

A study was conducted by Bell Telephone Laboratories of actual No. 1 ESS bills (actual Operating Company records of charges against No. 1 ESS) from 1969 and 1970 cutovers. From these bills a price profile equation was derived useful in predicting the approximate price of a No. 1 ESS installation.

3.1 Price Profile Equation Form

The price profile is:

EF&I PRICE = getting started cost + (a) x number of equipped lines + $ (C) x number of Centrex main stations + $ (C') x number of Centrex tie trunks.

The getting started cost, which is the same constant for all offices with the same generic program, the two coefficients (C and C'), and the parameter "a" (determined by the concentration ratio) are given constants; the user provides the number of equipped lines, the number of Centrex main stations, and the number of Centrex tie trunks. The equation was developed for the EF&I price charged to the ESS capital account which is referred to as the 77C account. This account includes the prices for material, WE engineering, WE installation, power (emergency power is excluded), and includes supplemental charges in addition to the initial contract charges. Some of the offices went in as new starts and the others as replacements. The amount of Custom Calling provided in the offices (in most offices less than 10 percent of engineered lines) was included. The getting started cost and the coefficient "a" were determined by curve fitting to a sample of actual No. 1 ESS Price data.

The Centrex portion of the price profile is given in terms of a price per Centrex main station plus a price per Centrex tie trunk. It should be noted that the profile only estimates the central office switching machine portion of Centrex; no customer premise equipment (Centrex consoles, etc.) is included.

A study of Centrex costs was made using actual No. 1 ESS price data. This data was from real No. 1 ESS offices installed in 1969 and 1970 which provide Centrex service. Curve fitting techniques were used to derive an average price estimate for a Centrex main station.

The price per Centrex tie trunk was derived by considering the material price of a 4-wire Centrex tie trunk and the associated material required. The material price for this trunk is given in the WE Broad Gauge Price Book. Adjustments were made to this price to reflect associated charges including the installation charge. The price including adjustments come to about $350 per Centrex tie trunk.

3.2 Price Profile Equations

The current EF&I price profile equation is:

CC (Central Control) Generic Program

$$\text{EF\&I PRICE} = \$1125K + \$(a) \times (EL) + \$40 \times MS_C + \$350 \times T_C$$

SP (Signal Processor) Generic Program

$$\text{EF\&I PRICE} = \$1450K + \$(a) \times (EL) + \$40 \times MS_C + \$350 \times T_C$$

Where,

- K — thousands.
- "a" — network concentration ratio coefficient from line link network TABLE I.
- EL — number of equipped lines, also often referred to as number of installed line terminations, (EL is approximately equal to the number of working lines at the end of the engineering period divided by the objective network fill).
- MS_C — number of Centrex main stations.
- T_C — number of Centrex tie trunks.

TABLE I
LINE LINK NETWORK

	Concentration Ratio	Coefficient "a"
Heavy (H)	2:1	169
	3:1	122
Regular (R)	4:1	82
	6:1	59

Results from testing the profile on recent actual No. 1 ESS EF&I bills indicate that the profile estimate is within ± 10 percent of the actual value for about 90 percent of the bills. In addition, an investigation was made for the offices which had profile estimates outside ± 10 percent of the actual value. The results of the investigation indicated that special circumstances contributed to the large errors. Figure 8 shows a plot of the estimated prices for No. 1 ESS non-Centrex offices for various network concentration ratios.

3.3 Current Estimate of No. 1 ESS Total Prices

The price to an Operating Company for a No. 1 ESS machine is composed of several parts. The major part is the EF&I bill from Western Electric for the equipment. However, in addition to the EF&I bill are the Operating Company expenses associated with planning, ordering, engineering, and testing a new machine and the building floor space required to house the new machine.

3.4 Operating Company Expenses

Associated with purchase of new switching machine are various Operating Company expenses. Included in Operating Company (Telco) expenses are:

planning engineering
equipment engineering
traffic engineering, including translation engineering
plant expense (precutover)
interest during construction (shipment to cutover)
taxes (if any)

The Operating Company expenses vary from installation to installation depending on the complexity of the job and the experience of the people involved. An estimate of the Telco expenses associated with No. 1 ESS was obtained from a survey of 70 actual No. 1 ESS installations cutover during 1969 and 1970. This survey resulted in the distribution of Telco expenses shown in Figure 9. The average expenses were 17 percent of the EF&I bill. In all likelihood the extremely low and extremely high Telco expense percentages are either data errors or special situations unlikely to reoccur.

Telco charges on No. 1 ESS should decline as more experience with the system is obtained. Plant and Engineering charges currently are large due to the inefficiencies associated with training people to utilize new technologies. Current estimates are that 14 percent of EF&I price is a satisfactory average value for future offices using the remreed network.

3.5 Floor Space

A real advantage of No. 1 ESS is in reduced floor space requirements for offices above 5,000 lines. Figure 10 shows a comparison of the floor space required for a No. 1 ESS type machine and No. 5 Crossbar machine as a function of line size. The recent availability of the remreed network reduces the No. 1 ESS floor space needs significantly. At the current average cost of about $60 per square foot for new floor space in metropolitan areas, No. 1 ESS has a significant advantage over the No. 5 Crossbar system.

3.6 Total Office Price

Representative cost curves for No. 1 ESS for a typical traffic situation (4 CCS/line) showing the EF&I, Telco charges (14 percent of EF&I) and floor space ($60/sq. ft.) components of the total price are shown in Figure 11.

4. COMPARISON OF NO. 1 ESS AND NO. 5 CROSSBAR PRICES

Since No. 5 Crossbar offices normally are not started at large line sizes like No. 1 ESS, it is not possible to gather enough real office data to determine an accurate price characteristic. However, a source of price data for No. 5 Crossbar offices similar to No. 1 ESS offices is available in the Cost Price Review Team studies of No. 1 ESS. In these studies No. 5 Crossbar new start offices are engineered and priced for installations varying from 2,000 to 20,000 working lines. The office characteristics of these study offices are chosen identical to No. 1 ESS offices to ensure an accurate comparison of No. 5 Crossbar to No. 1 ESS.

4.1 EF&I Price

A current EF&I price estimate for No. 5 Crossbar non-Centrex offices derived from the December, 1972 CPRT study is

No. 5 Crossbar
EF&I Price = $320K + $38 x working lines + $16 x total CCS + $266 x total interoffice trunks

K = thousands
CCS = originating plus terminating CCS

4.2 Operating Company Charges and Floor Space

Similar to No. 1 ESS, real bills were analyzed to determine the amount of Operating Company expenses associated with installing a new No. 5 Crossbar machine. A distribution of Operating Company expenses as a percent of EF&I price is shown in Figure 12. The average expenses are 12 percent of the EF&I bill. The exceptionally high and low Telco charge percentages are probably data errors or exceptional situations. An estimate of floor space requirements for No. 5 Crossbar are as previously shown in Figure 10.

4.3 Total Office Price

A sample price characteristic for No. 5 Crossbar showing the components due to EF&I, Telco expenses and building floor space is shown in Figure 13.

4.4 Comparison of No. 1 ESS and No. 5 Crossbar Prices

Using the data from the preceding sections, Figure 14 shows a comparison of the EF&I prices for No. 1 ESS and No. 5 Crossbar for 3 and 5 CCS per line. The average line capacity for the No. 5 Crossbar and No. 1 ESS at these traffic values is also indicated. If the Telco charges and floor space at their average values are also considered a total price comparison shown in Figure 15 can be derived. These results indicate that No. 1 ESS is less expensive on an EF&I basis for office greater than about 15,000 lines, and less expensive on a total price basis above about 11,000 lines.

There are several points that should be remembered when using Figures 14 and 15. One is that the No. 1 ESS EF&I prices represent the average prices derived from real bills while the No. 5 Crossbar prices are results from CPRT studies. It is possible that in real situations the No. 5 Crossbar price curve could be slightly higher by perhaps 5 percent, thus making a more favorable comparison for No. 1 ESS. The second point to remember is that No. 5 Crossbar Telco charge estimates come from offices that are not replacements. If No. 5 Crossbar were used for replacements it might well have higher average Telco charge percentages more nearly like the No. 1 ESS which includes many offices installed as replacements.

Because of these uncertainties of real bills versus CPRT results and the different applications of No. 1 ESS and No. 5 Crossbar, it is felt that Figures 14 and 15, if anything, give a conservative view of the current price relationship between No. 1 ESS and No. 5 Crossbar.

In addition to first cost alone, the other advangates inherent in ESS technology versus electromechanical systems should be considered, when selecting a new switching machine. Section 5 discusses in some detail the price effects of the feature advantages of No. 1 ESS over the No. 5 Crossbar System.

5. QUANTIFIED ADVANTAGES OF NO. 1 ESS

No. 1 ESS, by virtue of its stored program control, has a significant advantage over its electromechanical counterparts in its ability to easily and economically provide services and features for which it was not specifically designed. This flexibility often becomes the basis for qualitative arguments recommending the purchase of ESS if the tangible factors have failed to show the plan to be economical. The results of an effort to quantify some of the components of this flexibility, using the No. 5 Crossbar system for comparison, are presented in the following paragraphs.

Estimates of the additional EF&I cost of providing each of several features on the No. 5 Crossbar system as opposed to No. 1 ESS are given in Tables 2 and 3. The numbers thus represent credits which may be applied to a No. 1 ESS plan. Two sets of credits are shown. One assumes that the need for the various features are anticipated at the time the machine is ordered so that modification costs are minimized. The other assumes no anticipation and, therefore, generally higher modification costs, particularly for the No. 5 Crossbar system. The latter set of credits applies to the cost of providing these features on in-service machines rather than new starts. They are suggestive, however, of the savings which may be expected in providing new features likely to come along during the lifetime of a machine installed today.

In order to make proper use of these credits in first cost studies, the credits should be applied individually at the time they are expected to be realized. Even unanticipated features should have some dates (probably reasonably far out in time) associated with them. These credits should then be discounted to the time of purchase of the machine and applied as a single discounted first cost credit.

The total credits given in Tables 2 and 3 are undiscounted and therefore represent upper bounds on the credits available to a 15,000 line office. These total credits will be approached as features are applied nearer to the time of purchase.

The features listed in Table 2 are designated as universal since they apply to all machines in an area where the feature is to be provided. For instance, every local switching machine in an area to be served by a Traffic Service Position System (TSPS) or Automatic Intercept System (AIS) must interface with these systems. The total undiscounted credit for all of these universal features in a typical 15,000 line office is approximately $115,000 if all the services are anticipated and $214,000 if not anticipated.

The features listed in Table 3 are designated as selected features since they apply to certain classes of line service and generally are not required in every machine serving a given area. For instance, it may be possible to serve all Centrex customers from just one of the entities in a multientity building. Incidentally, the credit shown for CTX-CO, if unanticipated, is based on a single incidence in which a working No. 5 Crossbar system had been modified to provide CTX-CO service. Such a modification is now generally recognized as uneconomical in most situations. The $500,000 credit is considered to be modest. If the services are anticipated, the total effect of credits for the selected features may range from about $110,000 in a residential environment to $320,000 in an environment where two-thirds of the lines are classified as business lines. This latter category will be referred to later as "high business." The undiscounted credit ranges from $150,000 to about $730,000 if the services are not anticipated.

The features for which credits have been obtained do not exhaust the list of features which can be easily provided by ESS. However, they are sufficient to suggest the magnitude of the quantifiable advantages for most applications. It should also be noted that only capital expenditures for equipment have been treated. The effect of any savings anticipated with ESS for maintenance, administration, and building space should, of course, be included in any comparative economic study. These items may vary considerably with the particular situation, and applicable experience should be the basis for estimating relative costs.

The credits which should properly be given to No. 1 ESS for its flexibility in accommodating new features can be significant, particularly in a business environment. The credits developed under the assumption that the features cannot be anticipated is admittedly somewhat academic in the case of the features considered. However, they do illustrate the inherent flexibility of a stored program system, and are meaningful if it is assumed that the unforeseen features likely to come along will be comparable in complexity and rate of introduction to those considered.

6. POTENTIAL COST REDUCTIONS FOR NO. 1 ESS

Over the past few years new developments which will reduce costs have been introduced into No. 1 ESS and additional cost saving developments are continually being evaluated. These new developments in general are able to reduce costs because they take advantage of new technologies such as integrated and thin film circuits. All of these new designs also provide substantial floor space reductions as well as lower installation intervals and costs. The major projects are the 32K Call Store, remreed networks, 1A Processor, and small trunks.

6.1 32K Call Store

A new 32K Call Store has been designed to replace the 8K call store. The 32K call store is a 24-bit, 32,768-word memory which mounts in a two-bay frame. Up to six 32K call stores can be accommodated in this frame, five associated with the central control and one associated with the signal processor. Two such frames will be required for each No. 1 ESS office, providing up to 9 central control call stores, and 2 signal processor call stores. These two frames with this complement of 32K call store units will supply all the call store capacity requirements for No. 1 ESS offices.

The new store provides many attractive features. The first is a modest reduction in the price of temporary memory. As manufacturing technology improves, its cost can be expected to decrease even further. The floor space saving is significant also. A maximum equipped office will require only 8' 8" for 32K call stores, 1/12 that required by 8K stores (see Figure 16). In addition, the power required is also 1/12 of that required for 8K stores. Much of the present office wiring has been included on the frame and the remaining has been fully connectorized, greatly reducing the installer wiring and hence the cost and time required for call store installation. The store and its associated 20A memory are completely connectorized so that field installation and growth is a very simple and convenient process. The 32K call store includes improved circuit and physical design which provides greater operating reliability. Diagnosability and fault detection is considerably improved also.

The first office utilizing the 32K call store was cut into service at Alton, Illinois on April 4, 1971. Since the beginning of 1972, all new office shipments have included 32K call stores.

6.2 Remreed Network

A new series of switching networks to augment the existing ferreed networks now used in No. 1 ESS is currently under development. This development stems from a breakthrough in sealed reed technology which allows the manufacture of a switch which is more compact than the present ferreed switch. The new remreed switch is operated with an electronic controller instead of a relay controller.

The combination of the new smaller switch for the network crosspoints with new device and packaging technologies for the control circuitry provides a significant reduction in the size of network components. For example, the first network (see Figure 17) that has been designed is a 1:1 1024 trunk link network. This network is incorporated completely within a 6' — 6" long frame. This compares with the frame lineup of 26' which is required for the corresponding ferreed network (see Figure 18). The remreed network occupies therefore, only 1/4 of the floor space required for the existing ferreed network. Similar reductions are expected in the floor space requirements for other network components (e.g. 9'9" instead of 30' 4" for a 2:1 2048 terminal LLN). The line link networks will also utilize a redesigned ferrod scan element, which will be built into the switch package.

Since the size of the network has been so drastically reduced, a substantially larger proportion of the network wiring will be accomplished in the factory. This wiring will also be tested during manufacture. The installation effort required to wire and test network frames will be reduced accordingly.

The remreed network development will result in significant cost savings in both the manufacturing and installation areas. These new networks will also require reduced maintenance. All apparatus is replaceable on a plug-in basis. This feature coupled with the increased reliability of the new technology devices and packaging systems should substantially reduce the maintenance efforts required on these frames.

The first office utilizing a remreed TLN (Detroit, Michigan) was placed in service in June, 1973. Since the beginning of 1974, all new offices have been shipped with remreed TLNs. The first remreed LLN is scheduled to ship in July, 1974.

6.3 1A Processor

A new high-speed, integrated-circuit, stored-program processor, named the 1A Processor, is now being developed for use in high-call capacity systems including No. 1 ESS. When used with a No. 1 ESS periphery, the system will be known as No. 1A ESS.

The 1A Processor will provide a number of improvements over the No. 1 ESS Processor, the most important of which is a factor of about 2-1/2 increase in call handling capacity. The use of electrically writable memories will also permit more rapid program and translation changes. In addition to space and installation interval reductions, the 1A Processor will provide improved ault detection and maintenance, and significantly increased dependability. The structural similarity to a No. 1 ESS processor and standardized I/O message formatting will minimize the additional training required for experienced ESS personnel.

The 1A processor interface with the switching network will be compatible with the No. 1 ESS network interface, thereby making it feasible to retrofit the 1A Processor into operational No. 1 ESS offices in order to increase the call handling capacity of the office.

The 1A Processor requires only one-half the floor space of the No. 1 ESS processor (see Figure 19). A fixed floor plan will be used which will minimize operating company and WE regional job engineering effort. The buses and other frame interconnections are connectorized to reduce installation effort and reduce the interval to turnover.

The first No. 1A ESS is presently scheduled for service in early 1977. It is expected that the 1A Processor will be introduced at a price level no greater than the No. 1 ESS Processor price level at the time.

6.4 Other Cost Reductions

The No. 1 ESS universal trunk frame is currently being redesigned to achieve cost reduction and a 2/3 savings in floor space (Figure 20). The new 2'2" home frame houses a maximum of 128 "small trunk" units. Each of the high runner trunk codes mounts two trunk circuits per unit.

The "small trunk" plug-in package makes extensive use of miniaturized, less costly components mounted on a printed wiring board. In particular, the components include miniature magnetic latching wire spring relays, mini-inductors and transformers, and a multicapacitor pack. In addition to the lower material cost of the new components, significant cost reduction is realized in unit wiring. The result is a trunk circuit that is less expensive, takes less space, and has better transmission characteristics than the present trunk.

The redesigned universal trunk frame also includes a repackaged scanner and signal distributor, both of which contribute to overall frame size reduction.

Design work is also being initiated on miscellaneous trunk and service circuits. This area offers not only savings in material cost and size, but large reductions in installation and engineering intervals as well.

No. 1 ESS vs No. 5 Crossbar prices . . .

December 1961 Study Results

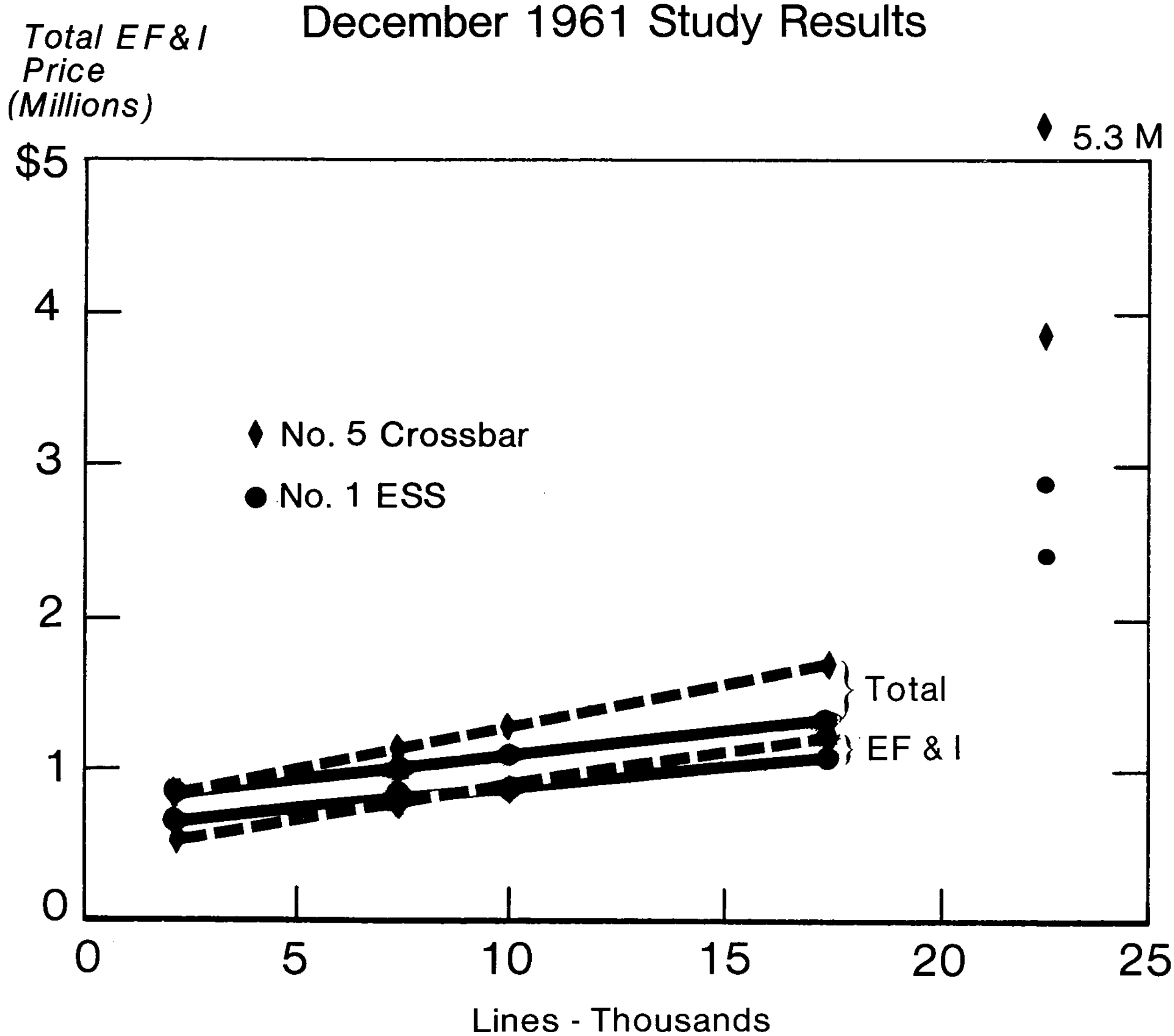


Figure 1

No. 1 ESS vs. No. 5 Crossbar prices . . .

July 1963 Study Results

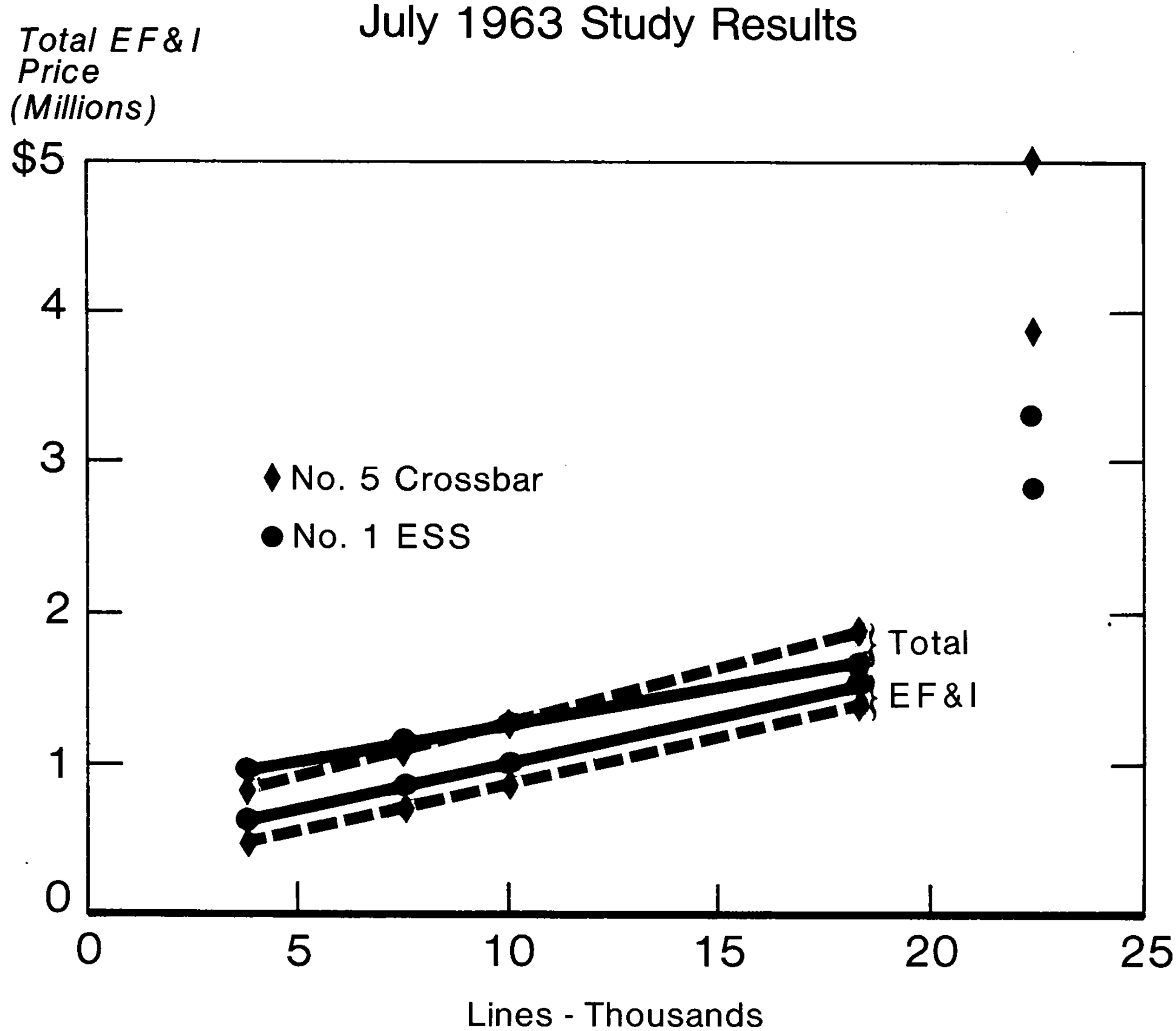


Figure 2

No. 1 ESS vs No. 5 Crossbar prices . . .

October 1964 Study Results

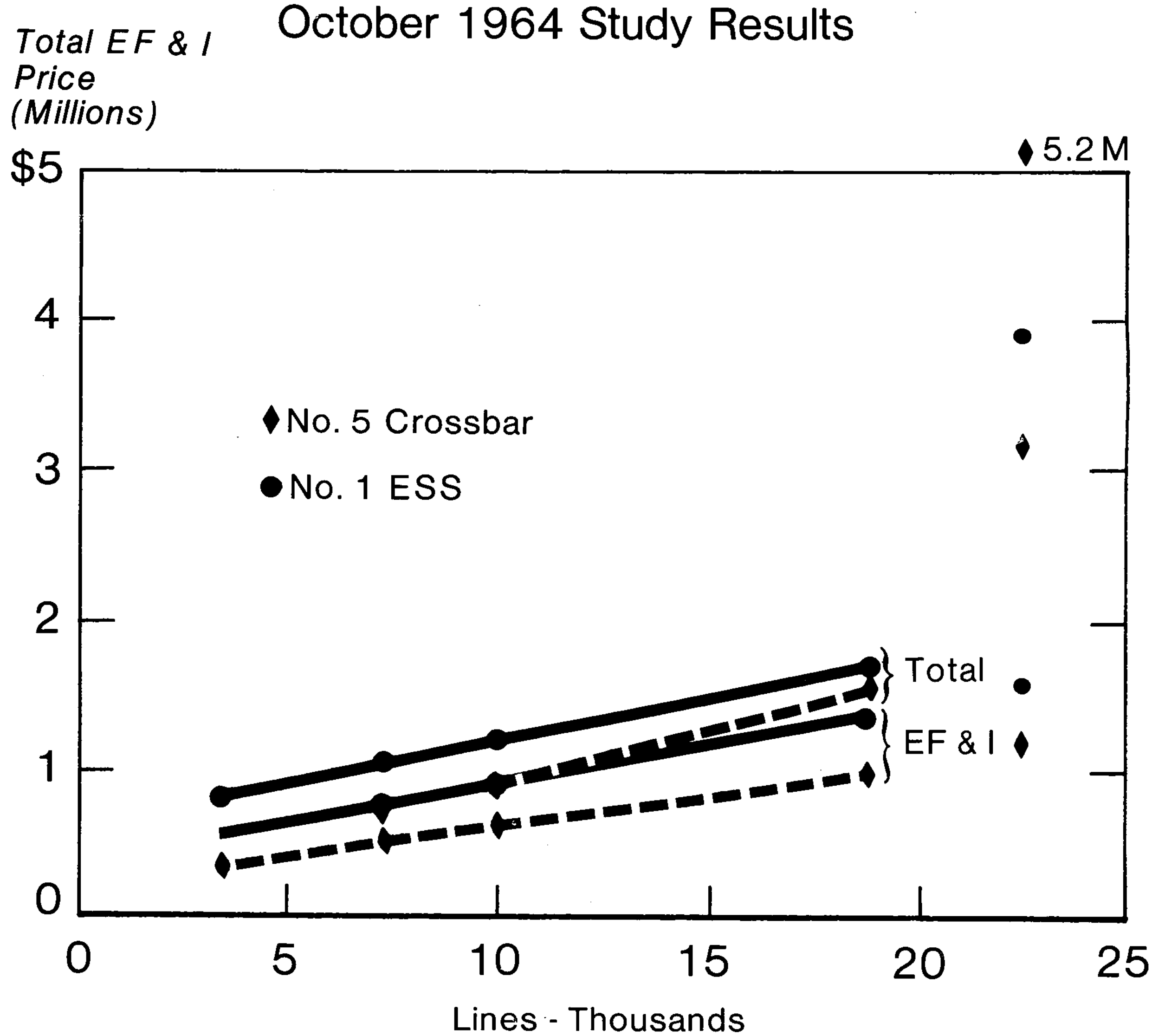
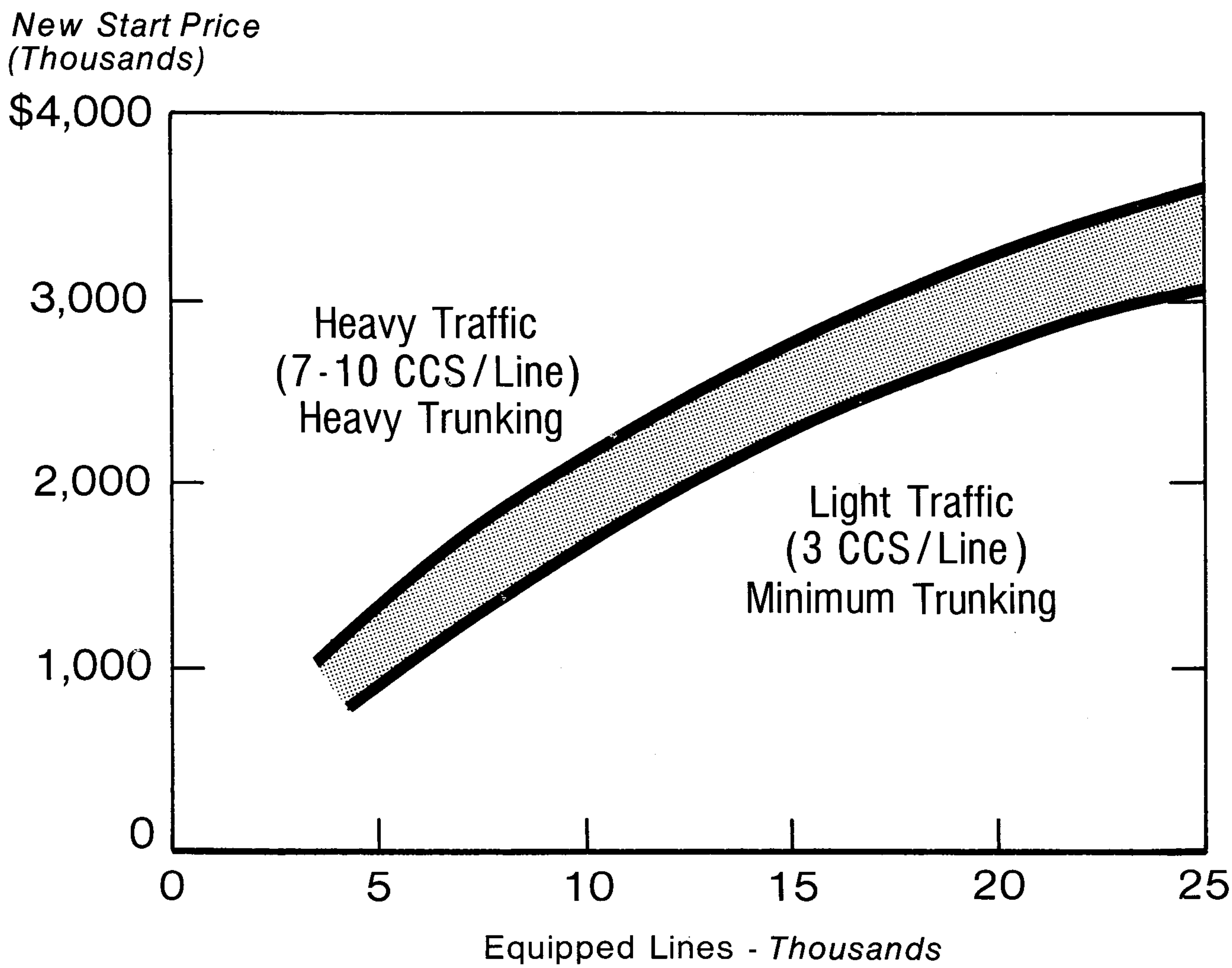


Figure 3

Planning Data - No. 1 ESS* . .

Western Electric Company Material, Eng., Install.

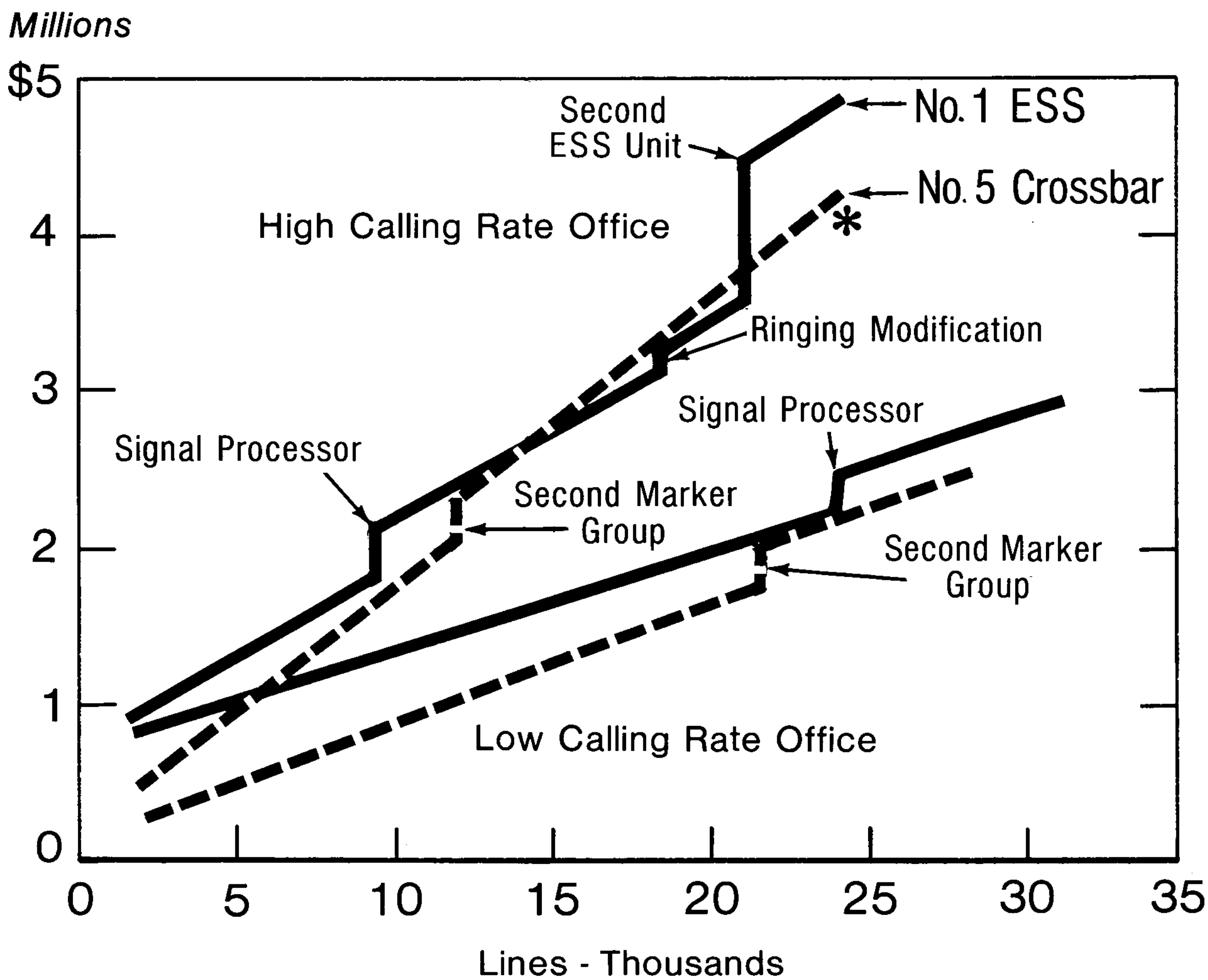


*AT&T Letter to Chief Engineers, C. R. Williamson, April 26, 1966

Figure 4

No. 1 ESS vs No. 5 Crossbar Installed Cost**.

Including - Material, WECO, Eng., & Installation

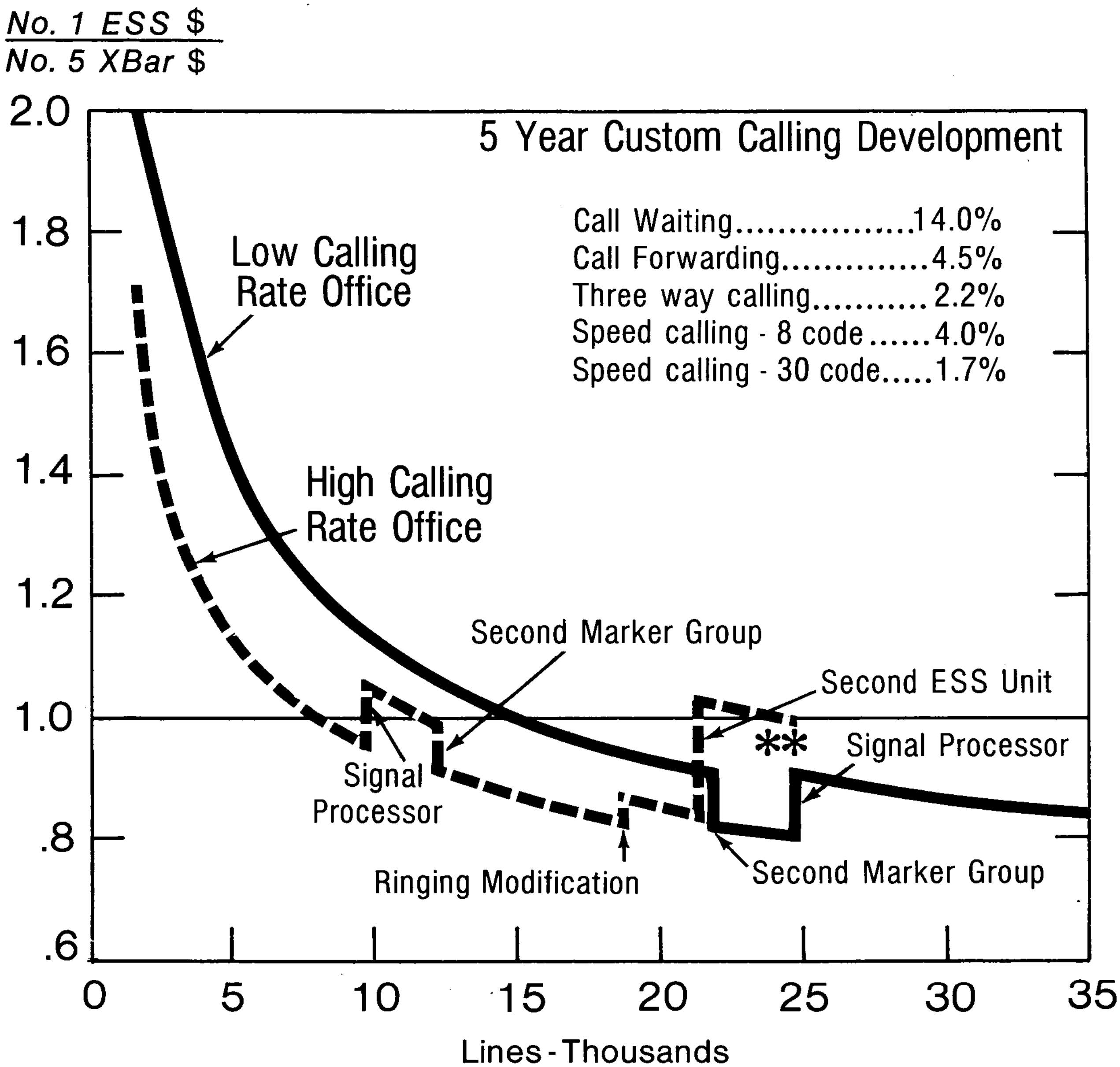


* Third No. 5 Crossbar Marker Group would be required. Because of various alternatives, specific plan should be evaluated and applied to this study.

**AT&T letter to Chief Engineers, C. R. Williamson, April 16, 1968

Figure 5

No. 1 ESS vs No. 5 Crossbar annual cost with Custom Calling*. . .



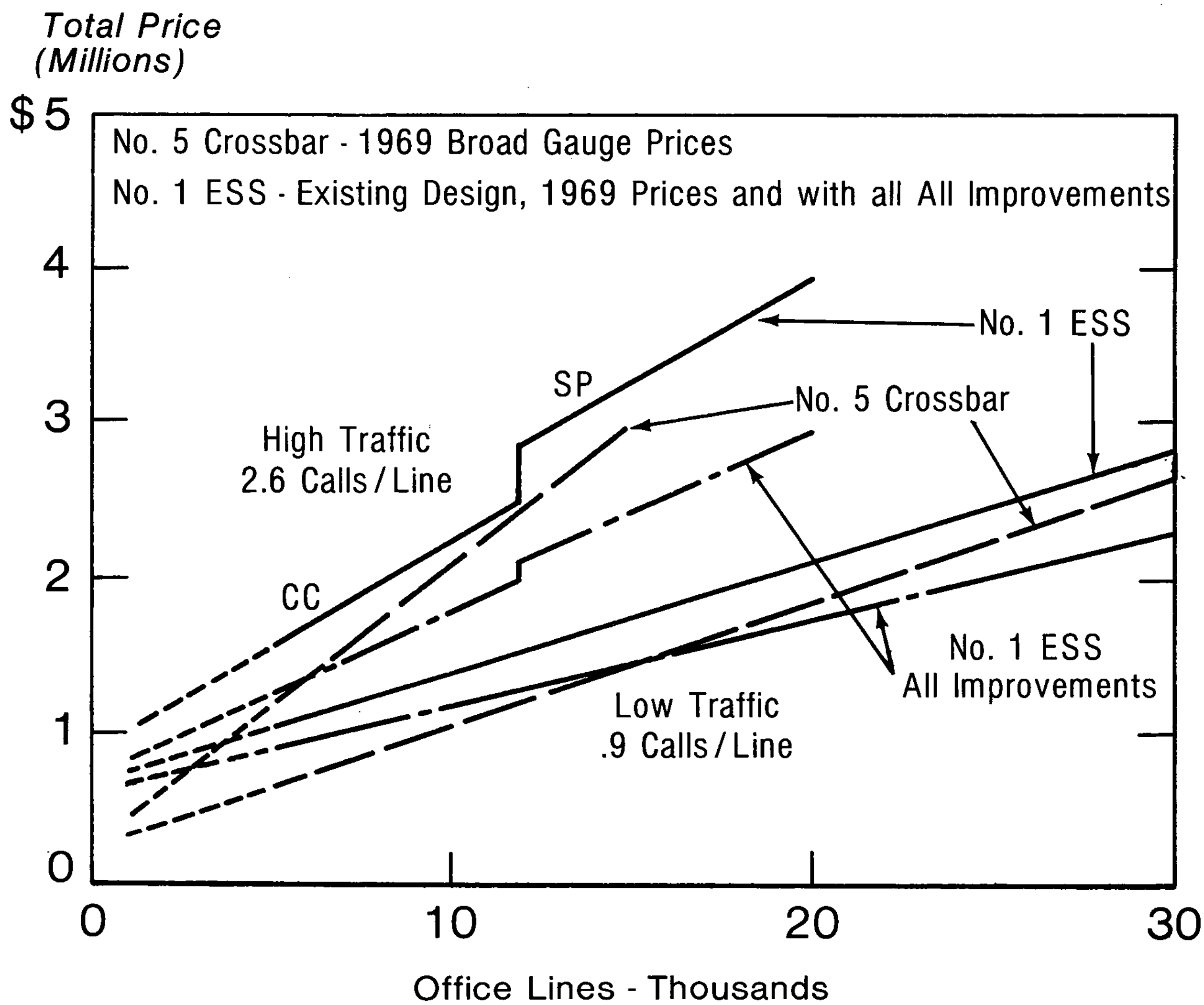
*Including - Total Investment in Plant, Building, Maintenance, & Custom Calling. AT&T letter to Chief Engineers, C. R. Williamson, April 16, 1968

**Third No. 5 Crossbar Market Group would be required. Because of various alternatives, specific plan should be evaluated and applied to this study.

Figure 6

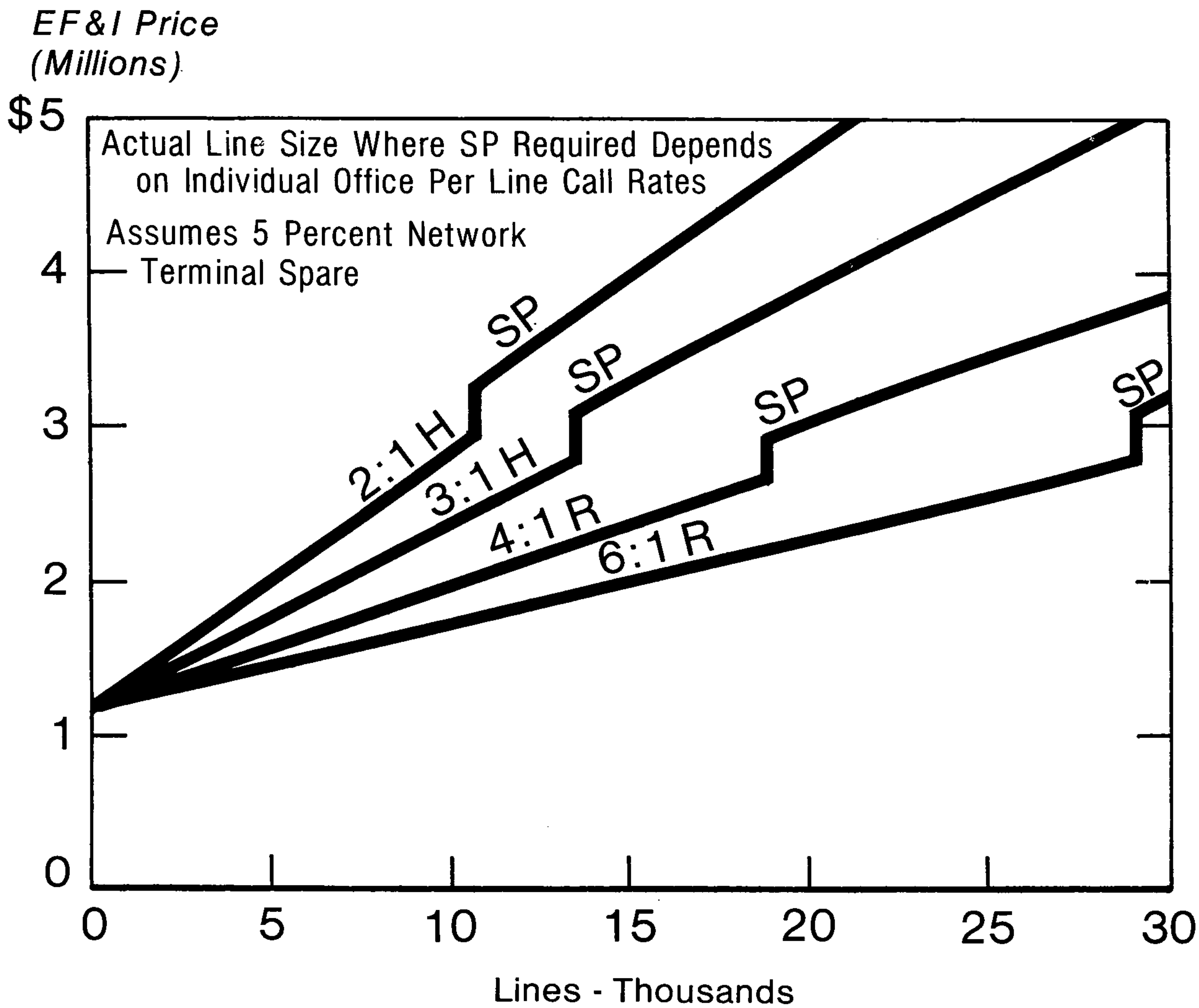
Comparison of No. 1 ESS and No. 5 Crossbar price characteristics*

Include Equipment, WECO Engineering and Installation, Telco Expense and Building Space



*No. 1 ESS CPRT Study 1970

Estimates of No. 1 ESS EF&I price non centrex offices*



*No. 1 ESS Price Profiles for Initial Jobs GL 72-05-198, May 26, 1972.

Figure 8

Distribution of No. 1 ESS Telco Expenses as a Percent of E F & I Price From 70 Actual Installations

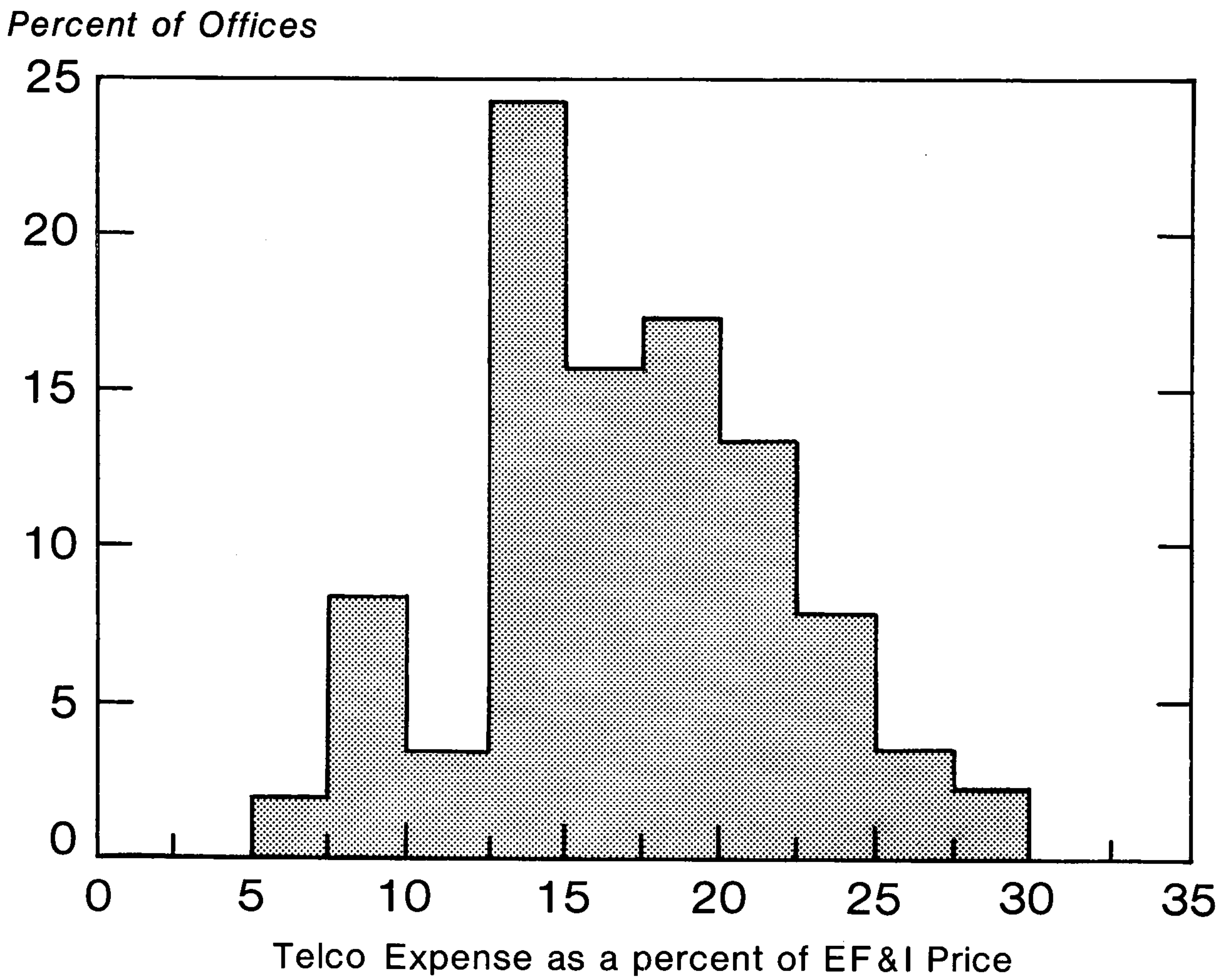
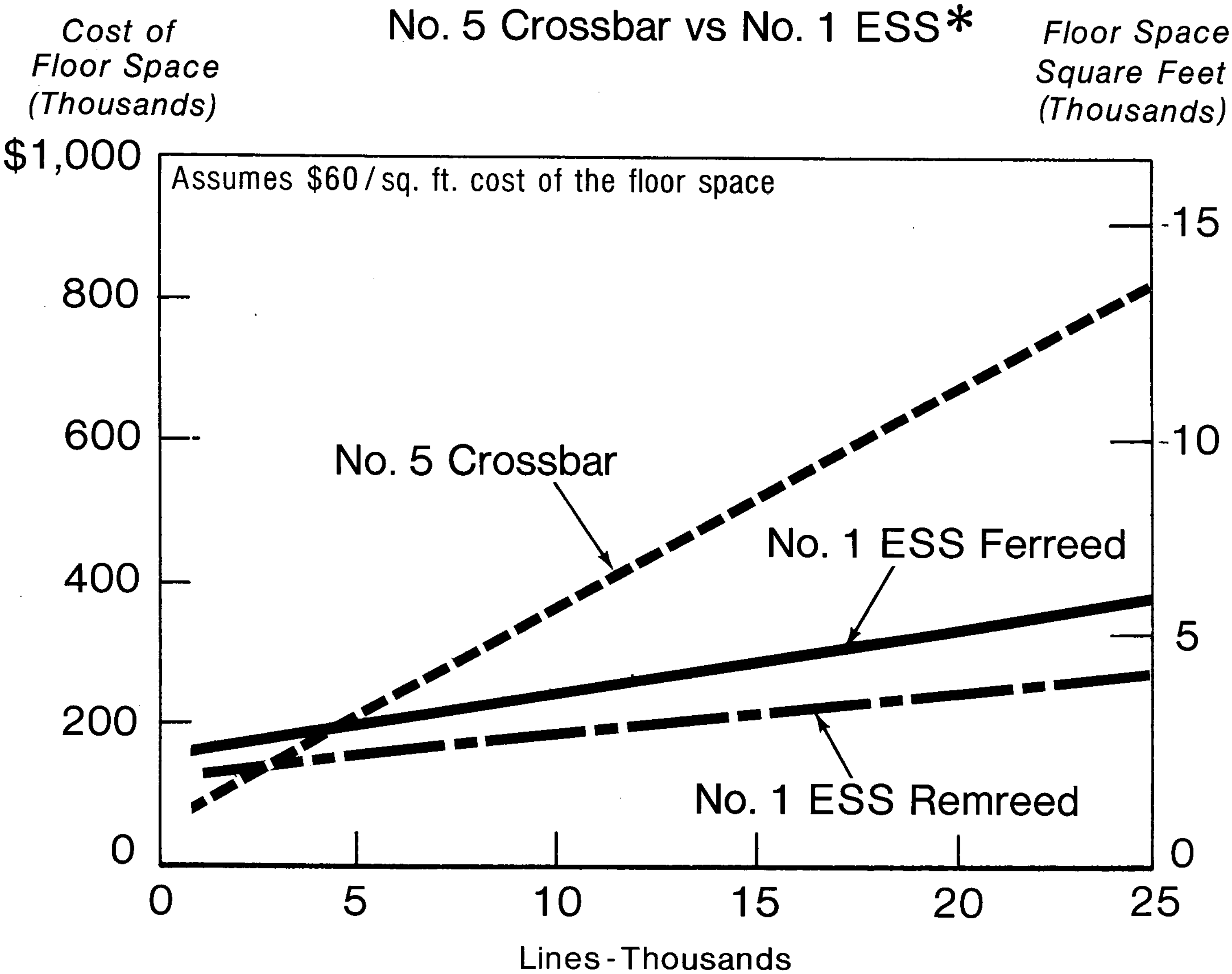


Figure 9

Switching equipment floor space . . .



*Updated from AT&T letter to chief Engineers - No. 1 ESS - Cost study comparing No. 1 ESS and No. 5 Crossbar prices April 16, 1968.

Figure 10

Estimate of components of No. 1 ESS office price for 4 CCS/line traffic with remreed network . . .

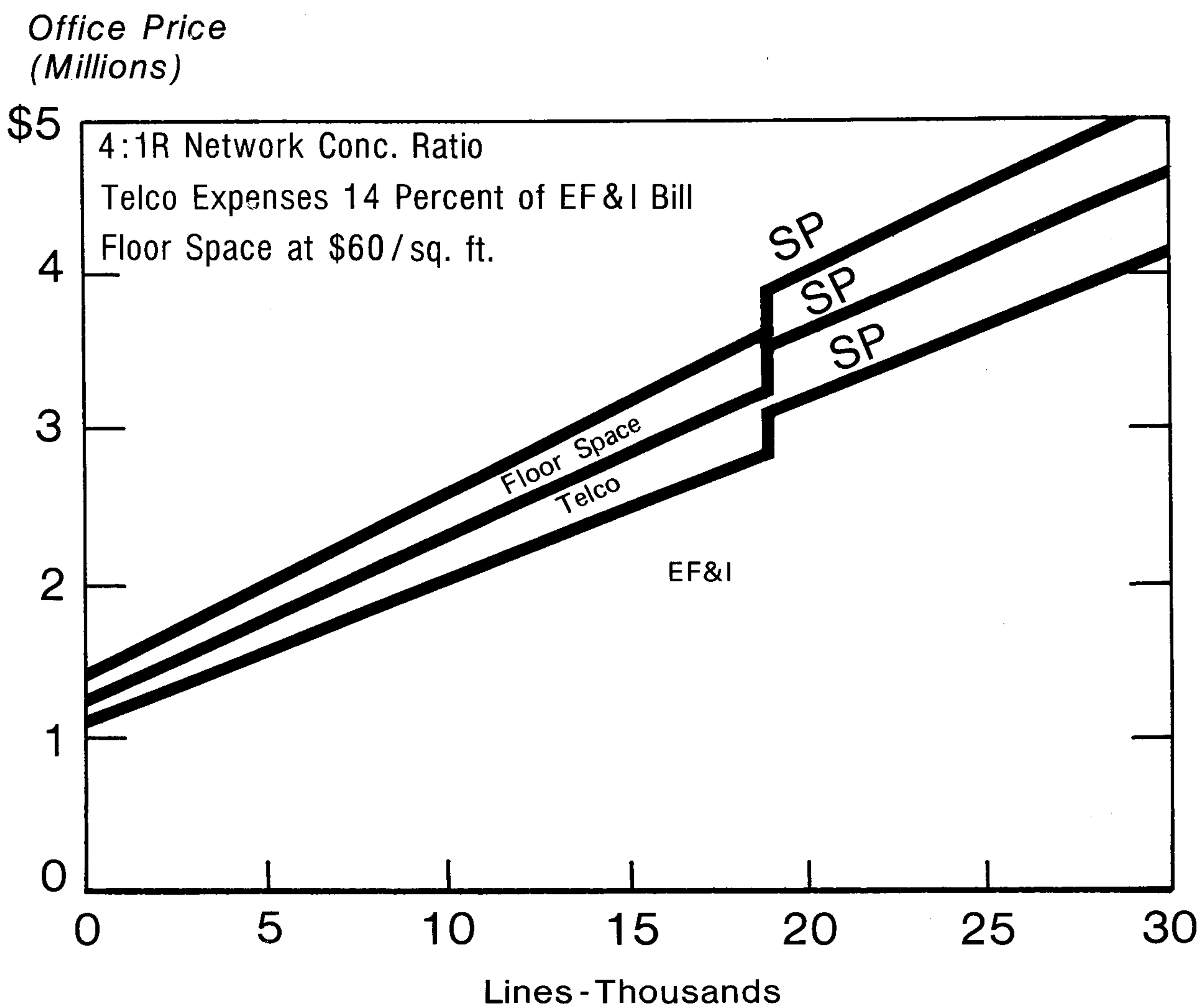


Figure 11

Distribution of Telco Expense as Percent of EF&I Price from 30 actual Installations

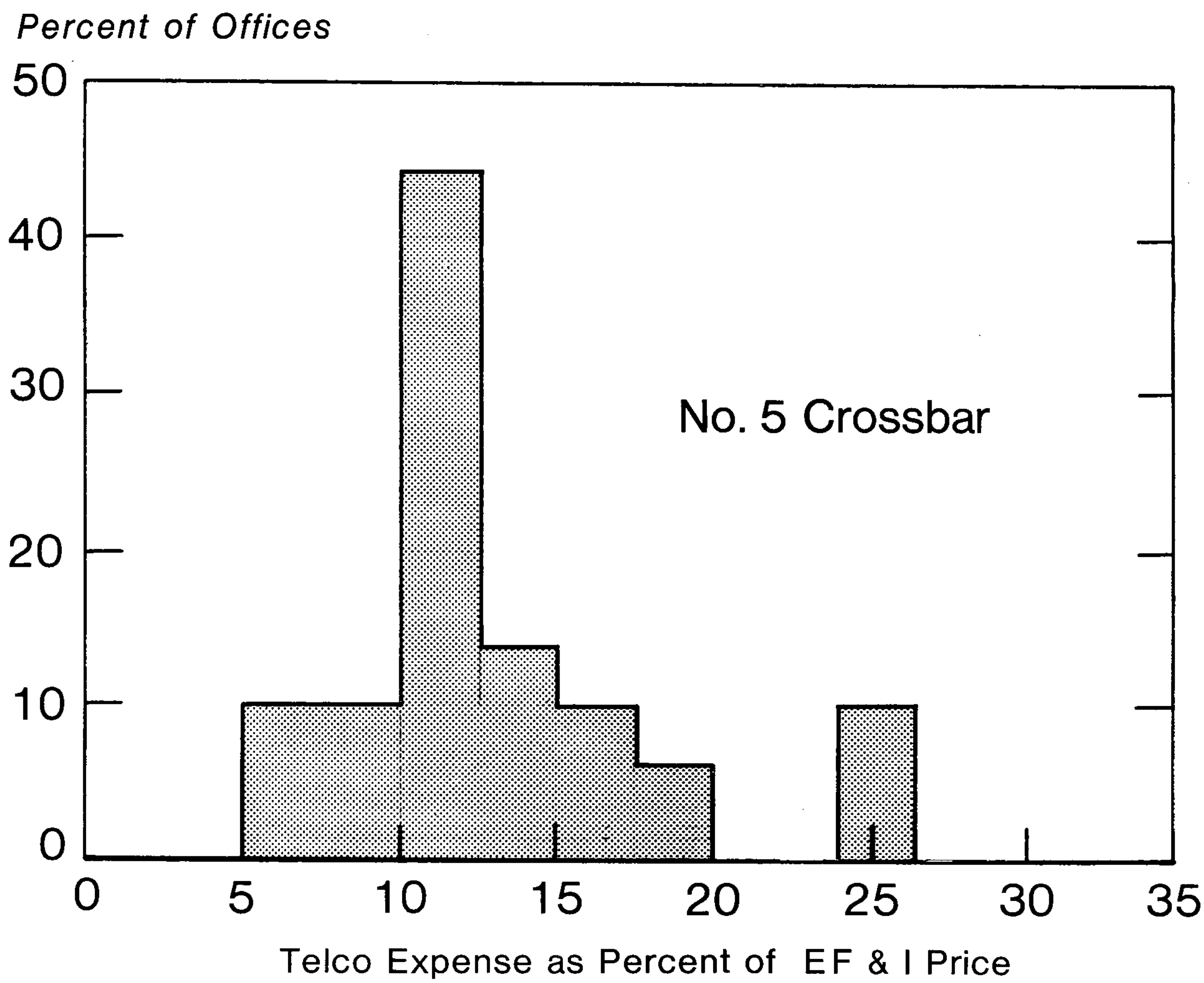


Figure 12

Estimate of components of No. 5 Crossbar office price for 4 CCS/Line traffic

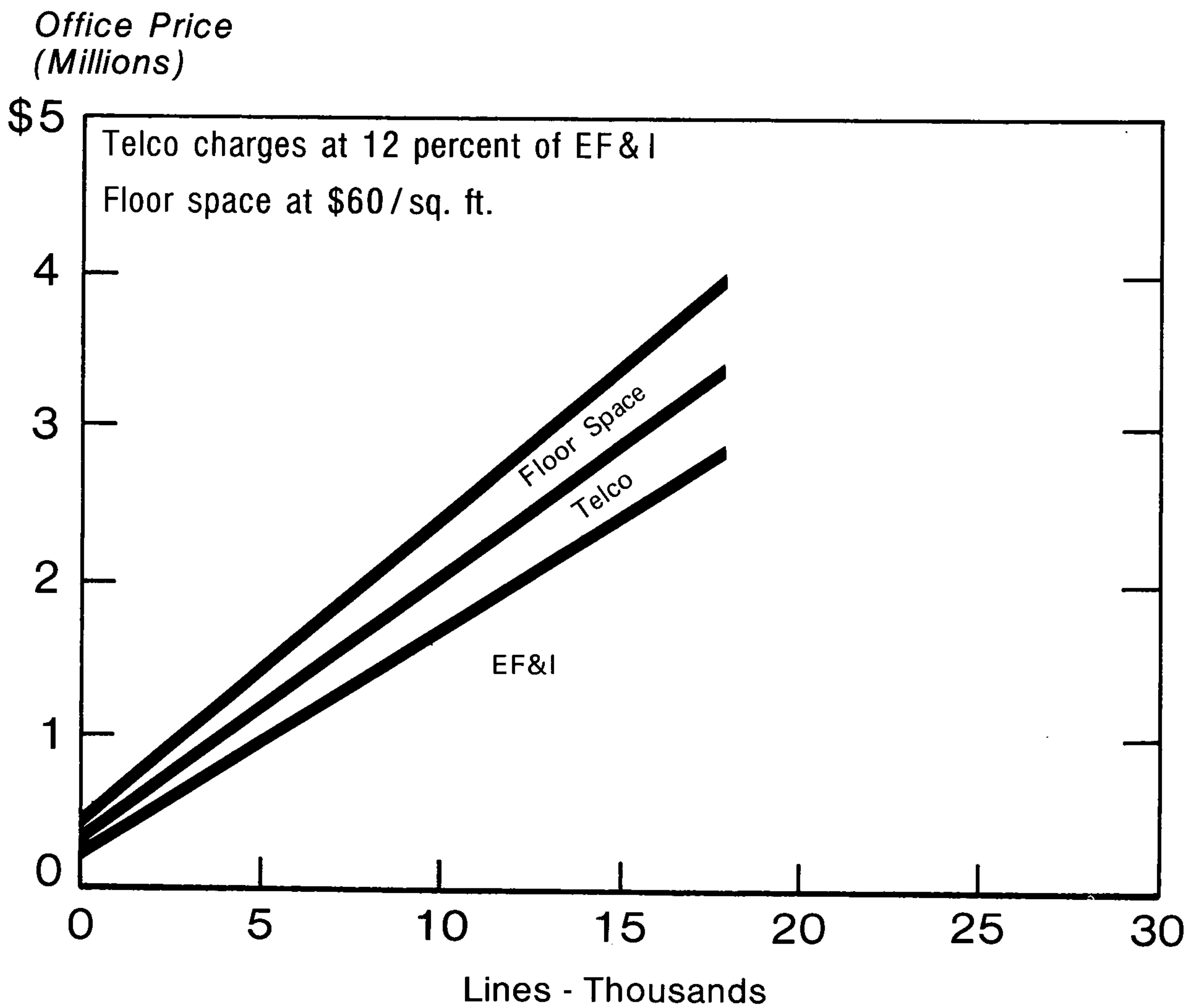


Figure 13

Comparison of No. 1 ESS and No. 5 Crossbar EF&I prices . . .

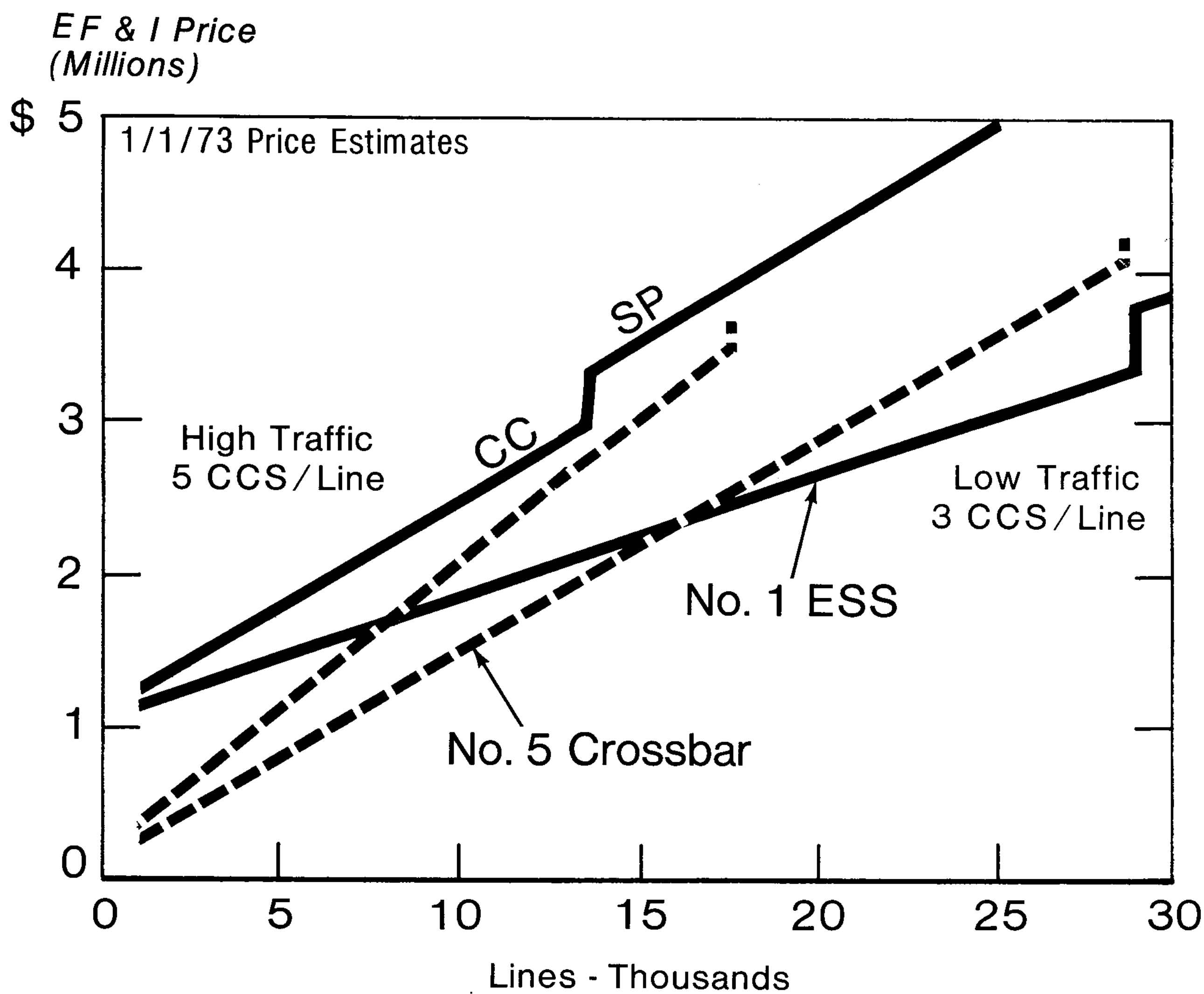


Figure 14

Total price comparison . . .

No. 1 ESS and No. 5 Crossbar (Includes E F & I plus Telco Expenses and Building Space)

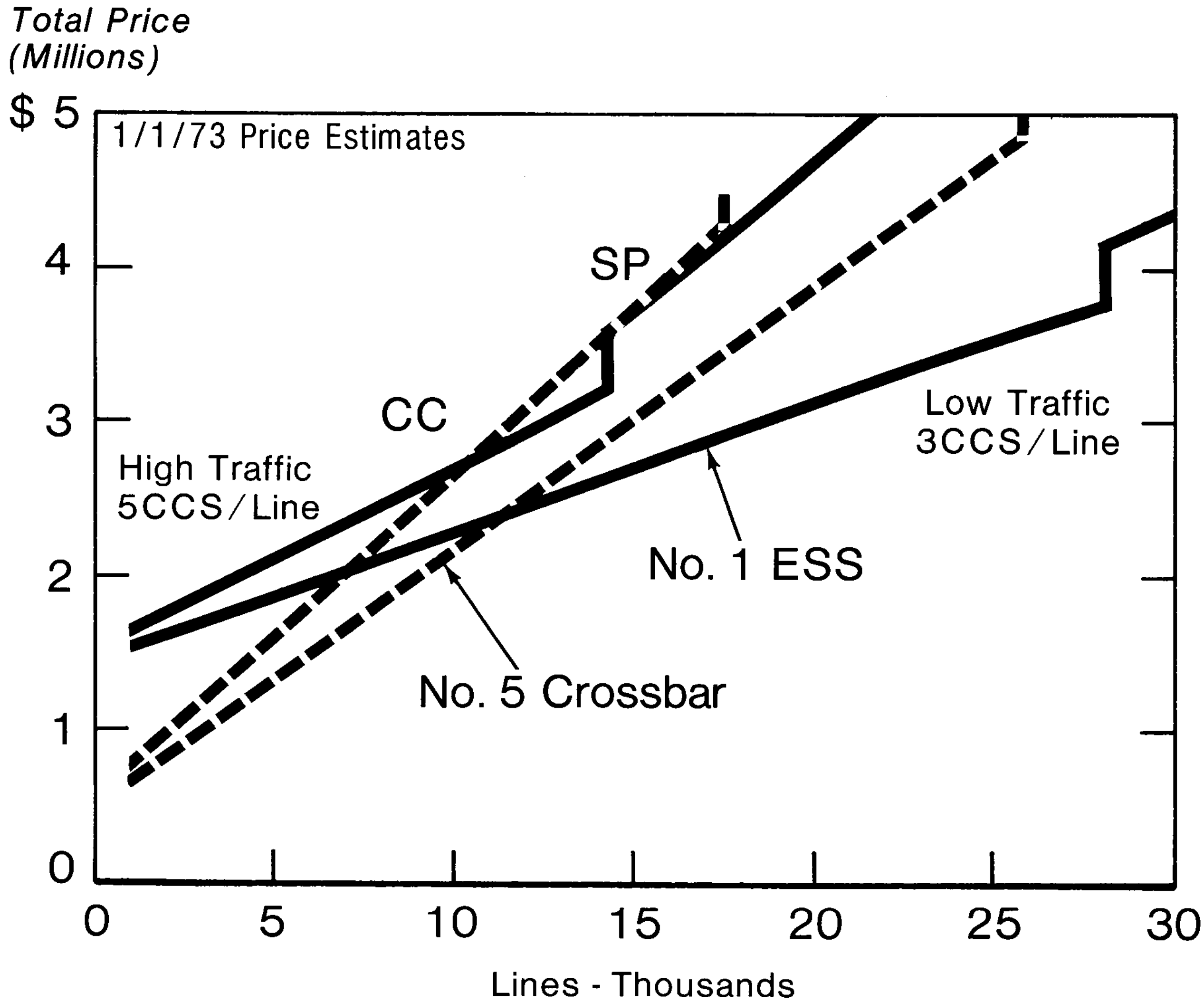


Figure 15

Quantified Features

Universal Features	ESS Credit (Installed Cost)	
	Service Anticipated	**Service Not Anticipated**
TSPS	$2K/Office + $90/TSPS Trk	$25K/Office + $90/TSPS Trk
AIS	$12K/Office	$12K/Office
Dir. Assis. Charging	$3K/Office	$4.5K/Office
Usage Sens. Rates	$5/Line	$10/Line
Traf. Meas.	$23K/Office	$23K/Office
ESS Credit for 15,000 Line Office	$115,000	$214,000

Table 2

Quantified Features

Selected Features	ESS Credit (Installed Cost)	
	Service Anticipated	Service Not Anticipated
AIOD & DID	$27K/Office	$27K/Office
CTX-CO	$45/CTX-CO Line	$500K
Call Waiting	$50/Equip M Line	$60/Equip Line
Coin DTF	— $3K/Office	$20K/Office
Perm. Sig. Treat.	$15/Equip Line	$15/Equip. Line
ESS Credit for 15K Line Office		
Residential	$110K	$150K
High Business	$320K	$730K

Table 3

No. 1 ESS 32K Call Store

Comparison of Equipment

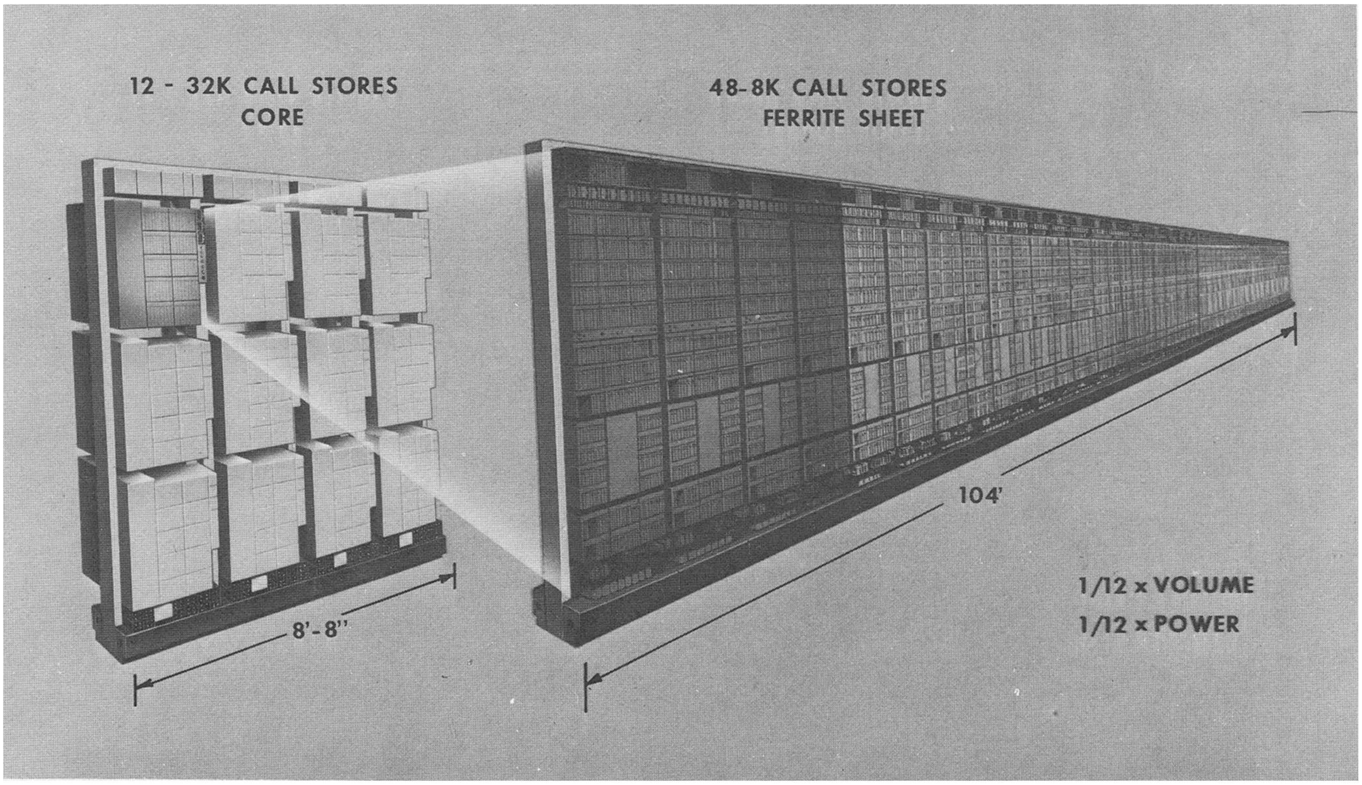
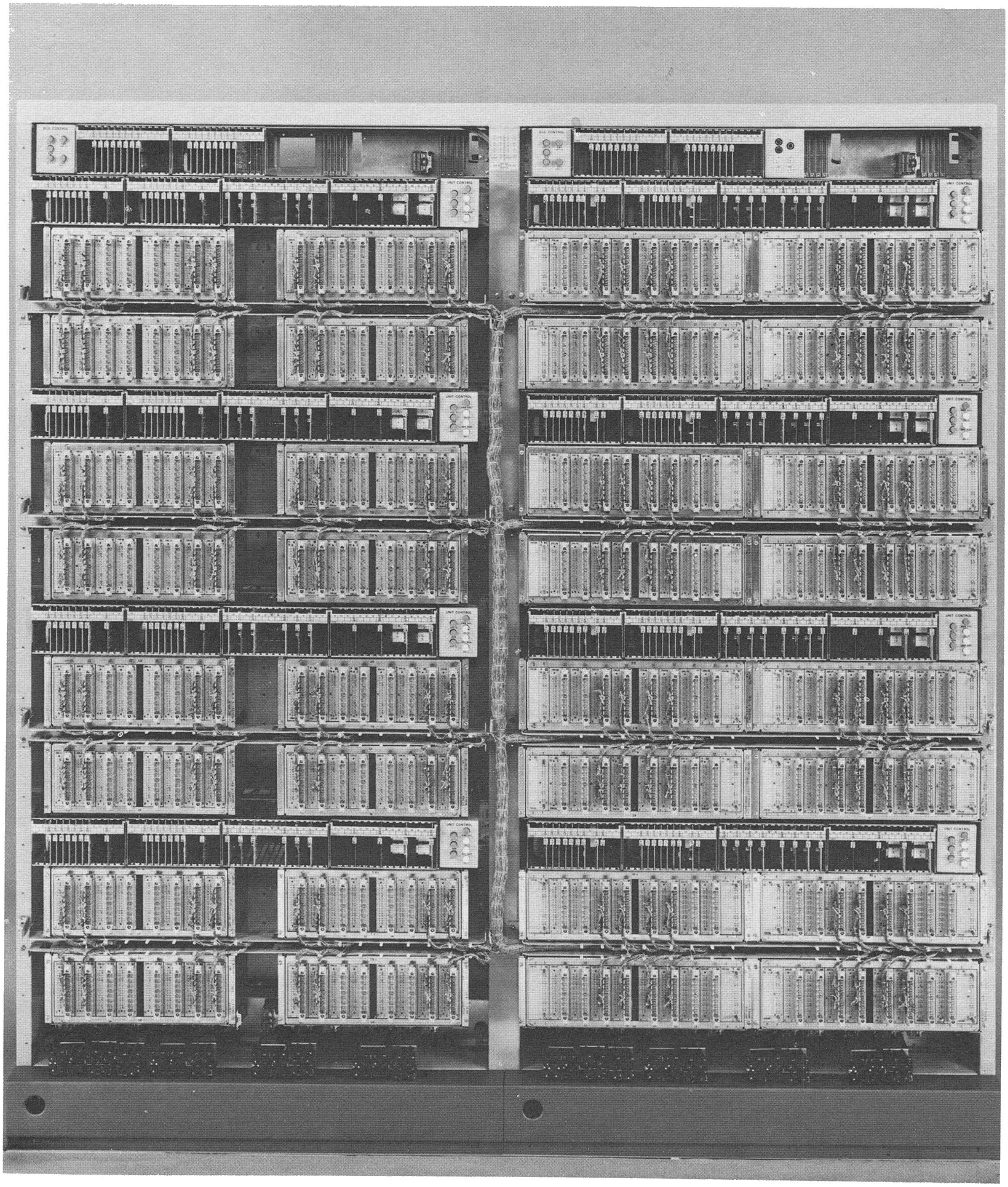


Figure 16

Remreed Trunk Link Network



6' 6"

Figure 17

Remreed Trunk Link Network

1024 2-Wire

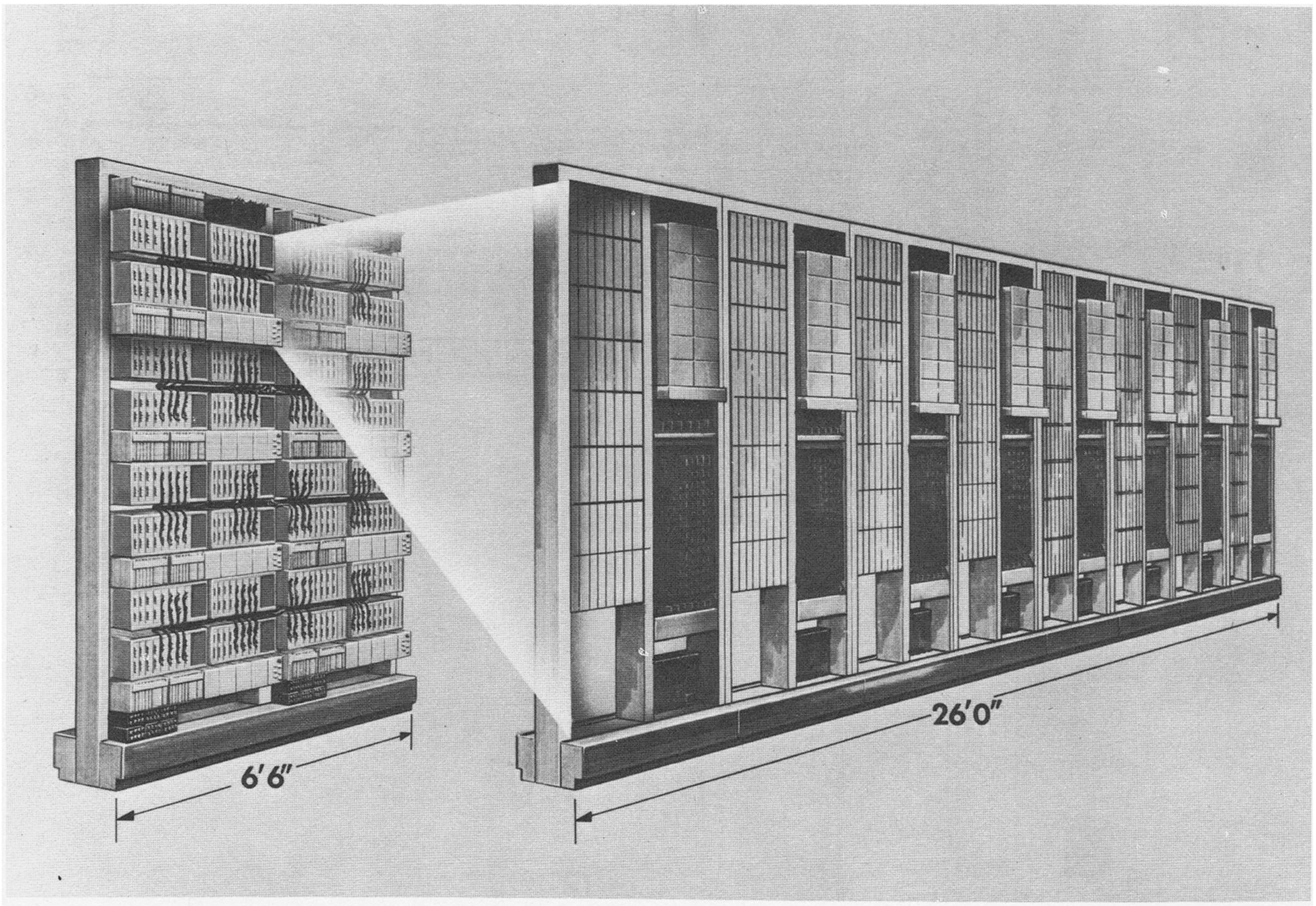


Figure 18

Proposed 1A Processor Floor Plan

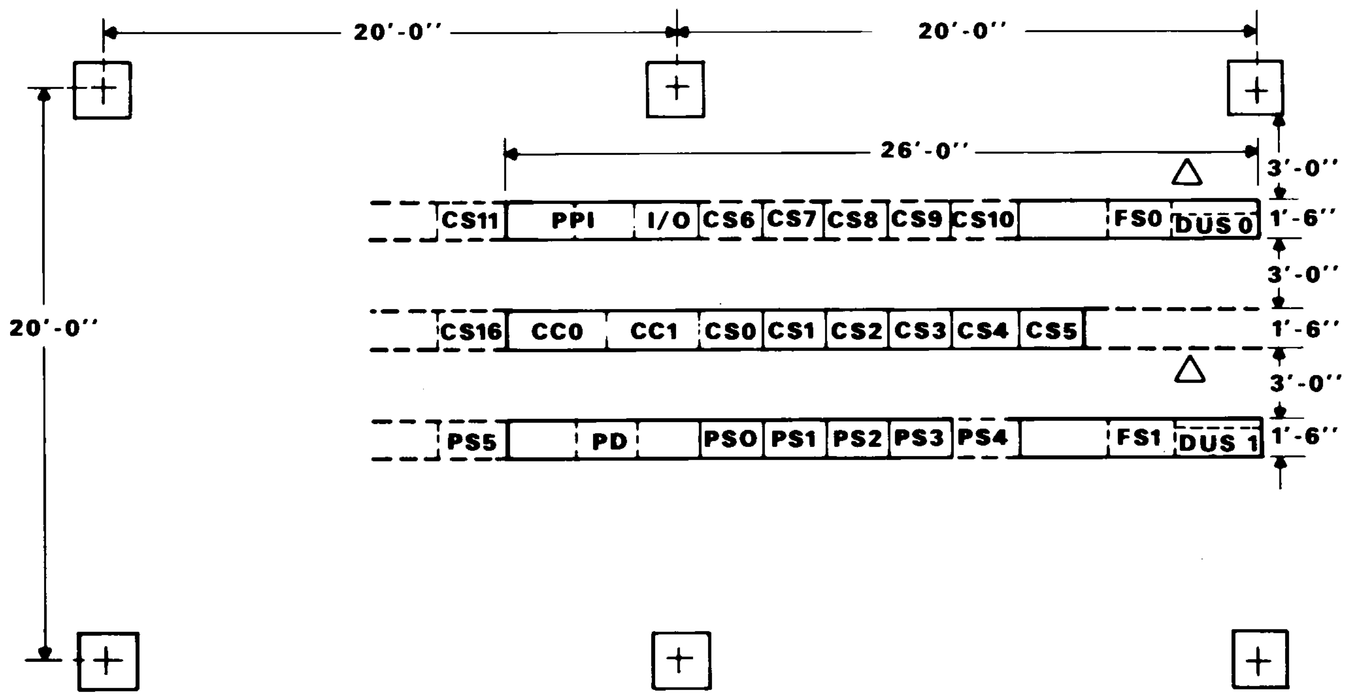


Figure 19

Small Trunk Frame

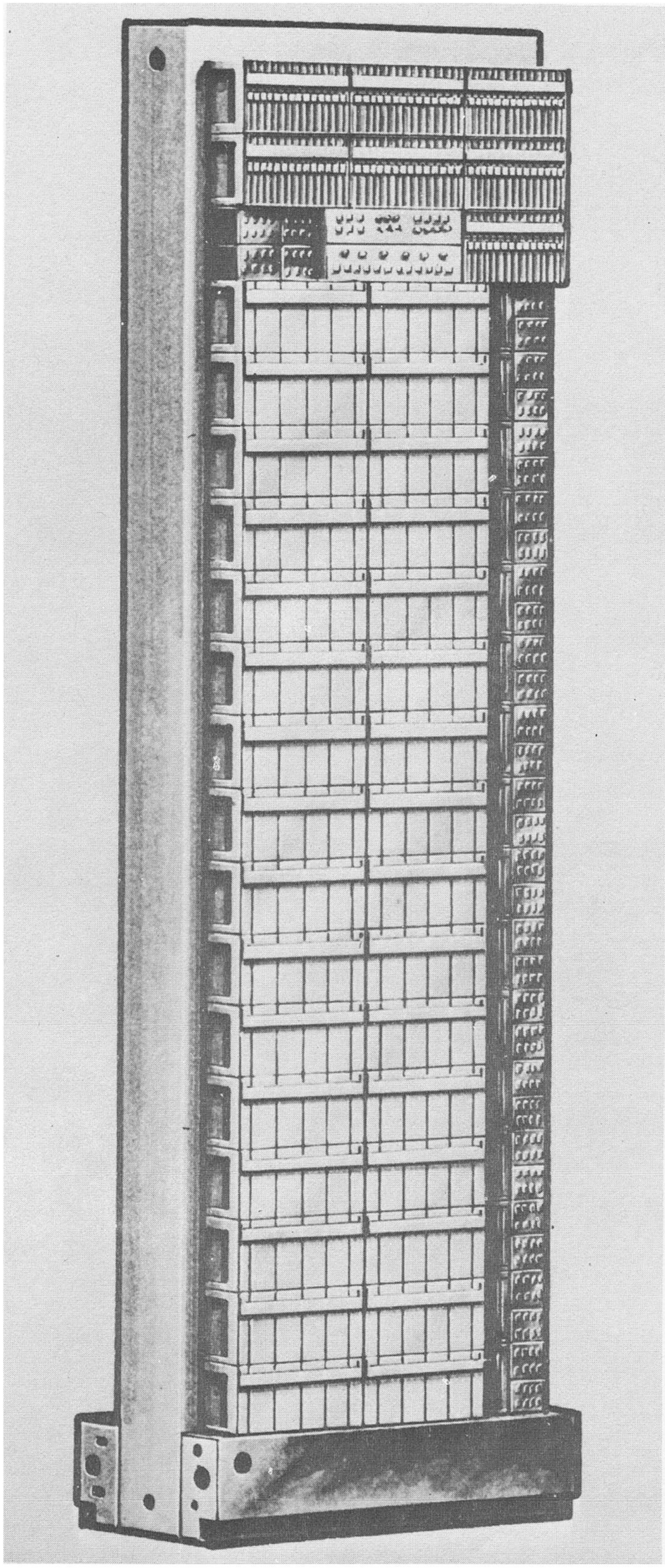


Figure 20

IX - GROWTH CAPABILITIES

1. INTRODUCTION

The No. 1 ESS has been designed to serve a wide range of telephone central offices sizes. In order to conserve Bell System capital, the No. 1 ESS must be able to grow from a small system into a large system in relatively small increments as required to meet service demands. Growth, however, must be accomplished without disrupting the continuous telephone switching mission of the system. Also, the cost of growth and the growth installation interval should be minimized.

2. STATUS OF GROWTH PROCEDURES

At the time that No. 1 ESS was first introduced in 1965, the ability to increase the size of the office through the addition of frames did not exist. Growth procedures for a few frame types were officially published in 1968 although a limited number of frames were added earlier for special cases with direct support by Bell Laboratories.

Between 1968 and 1972 procedures were written, field tested, and published for the addition of all No. 1 ESS frame types (Table A). In addition to this, procedures have been published to permit the conversion from a CC type office to an SP office while maintaining all call processing. Many of the techniques developed for additions have been utilized in initial installations where they have provided substantial reduction in cost and interval.

By mid-1974, procedures will be available to change the concentration ratio of an existing line or trunk link network. These procedures have become especially important since several of the originally allowed concentration ratios were rated A&M, and the new remreed networks are currently only being produced in the standard ratios. As new equipment designs, such as the 32K Call Store or the remreed network, are released, growth procedures are developed at the time the first frames are being shipped; hence, from this point on, any "growable" frame should be able to be added to any in-service No. 1 ESS.

3. GROWTH TEST FACILITIES

During growth, a unit being added is subjected to tests residing in the generic program and/or to tests specifically prepared for the growth environment. Both types of growth tests are discussed in the next two sections.

3.1 Application of Generic Program Tests During Growth

In general, growth units are tested using the diagnostic and fault recognition test programs residing in the standard generic program before the growth units are placed into service. Existence of the large, powerful set of generic test programs has simplified the growth development project substantially.

However, before a growth unit can be tested with the generic program tests, it must be placed in a "transitional" state so that the test programs can access the unit while the operational system remains oblivious to the existence of the unit. To accomplish this and permit an orderly introduction of new equipment into the system the "Transitional Parameter" module was developed. Transitional parameters are defined as a set or sets of parameter modules used for operating the office during the addition of specified equipment. The "Transitional Parameter Processing System" (TPPS) modifies the parameter data assembler to allow for growth by backing off certain parameter constants for the growth units. This backed off information is introduced into the system in accordance with a specific sequence provided in the growth procedures. Growth recent change (GRC) forms are provided by the Regional engineer and filled in by the Telephone Company with the parameter and translation changes necessary for the introduction of new equipment into the system.

Growth Procedure Availability

Frame Type	Date Available
Master Scanner	8-15-1968
Universal Trunk	8-15-1968
Power Distribution	6-27-1969
Miscellaneous	6-27-1969
Program Store 3-5	6-27-1969
CC — Call Store 8K	6-27-1969
Miscellaneous Trunk	6-27-1969
Misc. Trk. E/W Suppl. Sig. Dist.	6-27-1969
Junctor	6-27-1969
Full Trunk Link Network	6-27-1969
Full Line Link Network (Regular Traffic)	7-01-1969
Full Line Link Network (Heavy Traffic)	9-01-1969
Central Pulse Distributor	3-13-1970
Misc. Trk. E/W TTY	3-13-1970
Supplementary Trunk Test	3-13-1970
Misc.Trk. E/W TTY & TR Unit	9-25-1970
Misc. Trk. E/W SxS Incoming Bylink	9-25-1970
SP Call Store 8K	11-13-1970
Recorded Announcement	11-20-1970
Program Store 6-11	4-15-1971
CC — Call Store 32K	5-14-1971
Centrex Data Link	5-14-1971
Misc. Trk. E/W Data Link Circuit	6-11-1971
Partial Line Link Network	6-11-1971
Partial Trunk Link Network	6-11-1971
CC to SP Conversion	11-15-1971
AIOD	5-01-1972
Change Network Concentration Ratio	2Q74

Table A

3.2 Auxiliary Program Growth Test

During the development of growth procedures, it became apparent that certain frame types (e.g., program stores) would require more than system diagnostics to prepare the growth frame for integration into service. To fill this need, the auxiliary program concept was introduced into the system. The auxiliary program system allows the introduction of special purpose programs into the system on a temporary basis by replacing one copy of the central control diagnostic program. Hence, access is provided to programs, as needed, without requiring the cost of twistor memory space for each program. This technique not only provides for a wide range of tests to be performed on growth frames, but has evolved into a versatile tool for use in all ESS offices. Auxiliary Programs are now capable of performing functions such as translation building, parameter-translation data verification, translation search, translation dump via AMA tape and Data-Link transmission.

4. GROWTH IMPROVEMENTS

With the completion of procedures for any frame type, the emphasis in the growth area has shifted from development of procedures to reduction of installation interval and reduction of cost. Much has been accomplished in these areas with reason to be optimistic toward further significant reductions.

An addition is significantly different from an initial installation in that all equipment must be integrated and tested in an in-service environment. This condition limits the techniques that can be applied and causes intervals for additions to be somewhat longer than those required for the initial installation of comparable amounts of equipment. The hours for transition work on additions are usually limited to the low traffic periods of the office. Procedures are available to defer the automatic midnight maintenance routines to prevent the loss of one to two hours per day of WE installation time. This extends the usable hours for transition work an average of 20 percent.

4.1 Projected Intervals

Engineering and manufacturing intervals for No. 1 ESS additions were changed from 37 weeks to 22 weeks in 1973 through utilization of a two-shipment plan, with a supplementary shipment occurring six weeks after the initial shipment (See Figure 1) Installation Intervals were also reduced for 1973 and 1974 (Table B). Original intervals for additions were established for orders shipping in the 1969 to 1971 period. Prior to 1971, Western Electric had difficulty meeting the established intervals. However, during 1971 the trend changed and now Western Electric has been able to reduce the published interval guidelines. It is expected that even greater improvements in performance will occur in future years.

TABLE B

INTERVAL WEEKS FOR EACH PERIOD

Frames	69-71	72	73	74
10-15	20	18	16	14
16-26	25	22	20	18
27-40	30	27	24	22
41-56	35	32	28	25
57-76	40	36	32	28
77-98	45	41	35	30
99-120	50	45	38	32
121-140	55	50	40	33
141-160	58	54	42	34
161-180	—	57	44	35

4.2 Tabs

Many changes have been introduced in growth techniques. One of the major changes recently introduced is "Trunk Additions using Borrowed (Junctor) Subgroups" (TABS). TABS is expected to reduce the growth interval by effectively overlapping growth functions. Prior to TABS the method of adding trunk link networks required 1) testing of the network frames, 2) a junctor redistribution and 3) testing of all trunks assigned to the new network. The three-stage operation was dictated by the fact that the new trunks required access to test circuits in the existing system. The early junctor redistribution temporarily reduced the number of available switch paths until such time as the trunks were tested and placed into service. TABS effectively eliminates the need for post-junctor redistribution testing of trunks by arranging to have the required test circuits placed in one existing network (reference network) and doing a junctor redistribution of only one subgroup to that network. This provides the necessary access to the test circuits and permits overlap testing of networks and trunks, thus permitting parallel work operations. Among the benefits of this technique is the elimination of duplicate testing of trunks by the installer and telephone company craft. Since the number of junctor redistributions is minimized, the engineering effort required to plan and sequence growth operations is reduced. The cost is also reduced by virtue of the fact that networks and their associated trunks can be added simultaneously thereby eliminating the need for an additional parameter run.

4.3 Merge

Growth recent change forms (GRCs) provide the specific recent change messages required to introduce new equipment into the system. Until the development of MERGE (Mechanical Regional Growth Entries) all these forms were manually prepared and typed into the No. 1 ESS. While MERGE only deals with the addition of trunks, the number of GRC forms required for trunks is large. MERGE constitutes the first step toward complete mechanization of all translation input data for growth.

The MERGE system produces punched paper tapes containing all necessary recent change messages required to build trunk translations along with a listing of these messages and their content. The paper tape produced is marked in a way such that small groups of trunks are identifiable and can be inserted into the systems via the service order TTY as required. Error checking mechanisms are built into the system

4.4 Multimod Testing

Western Electric is experimenting with multitask auxiliary programs which will allow the parallel test team approach to be used on additions. This technique has been successfully introduced on initial installations. The use of multimod testing on additions has limitations predicated by the lack of the temporary memory needed by the multimod test programs for scratch registers.

4.5 Equipment Improvements and Their Effect on Growth

One of the most dramatic changes in equipment packaging is the change from 8K call stores to 32K call stores. Introduction of the 32K call store has reduced the growth installation interval from 8 weeks to one-half week for equivalent call store memory additions. The fact that only two 32K call store frames are ever required and are always installed initially, eliminates the need for adding framework during growth. All buses are connectorized throughout the frames, and signal leads are cabled to future unit positions. Only the mounting of the new unit, software changes and unit testing are required for an addition. The 32K call store system diagnostic is more sophisticated; it is expected that 32K call store growth trouble-shooting will require considerably less time than is required for 8K call store growth.

The future of No. 1 ESS holds considerable promise in the areas of network growth and connectorization. The development of the remreed network is expected to produce results similar to those afforded by the 32K call store. Connectorization of the remreed network will save several days of wiring effort in the area of bus connections. In addition, the extensive testing performed on the remreed network before it is shipped (often as a single frame per network) will reduce the field testing effort.

In addition to the above, the miniaturization of universal trunks will affect the cost of additions, while the redesign of miscellaneous trunks will not only reduce cost, but greatly reduce the installation interval. See Section X — EF&I Intervals for a more detailed explanation of the effects of the redesign of trunks.

4.6 Special Additions

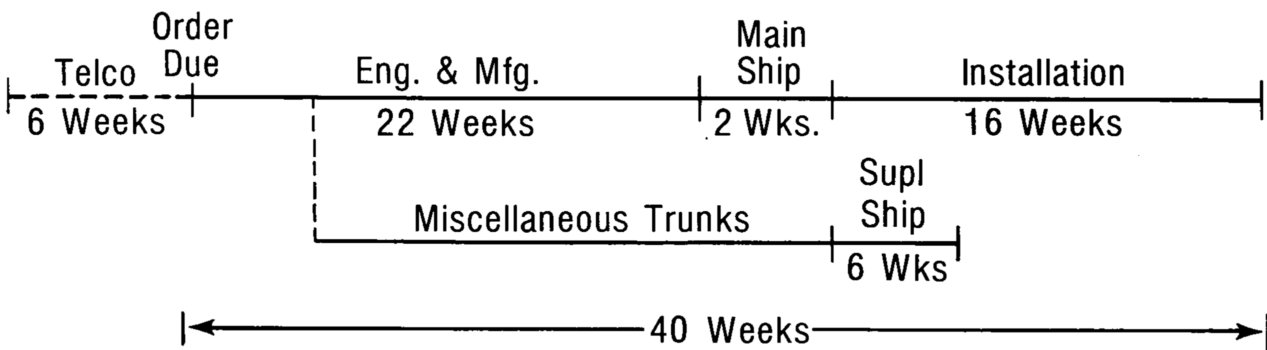
Western Electric is presently investigating the provision of special short service addition intervals for business customers. Because of the difficulty in accurately forecasting business customer needs and because of the need to remain flexible in the business customer market, procedures are required to allow an Operating Company to meet an unexpected service request in an interval much shorter than a standard growth interval. By standardizing frames of selected Miscellaneous Trunks and stockpiling these and other frames as necessary, it appears that EF&I additions intervals in the range of 15 to 20 weeks can be achieved.

At this time, procedures to implement the short service intervals have not been established, however, Figures 2 and 3 show the goals for 15 frames or less of a specific variety. The success of the proposed short order service will determine the extent to which the service will be expanded. If the trials for the proposed plan prove successful, an expansion of the allowable frame types for special service can be expected. While it is anticipated that normal planning and standard ordering techniques will prevail, it is hoped that larger numbers of frames which include the majority of No. 1 ESS frame types can be provided as a special basis.

1973 EF&I Interval

No. 1 ESS Standard Addition

15 Frames



9 Frames

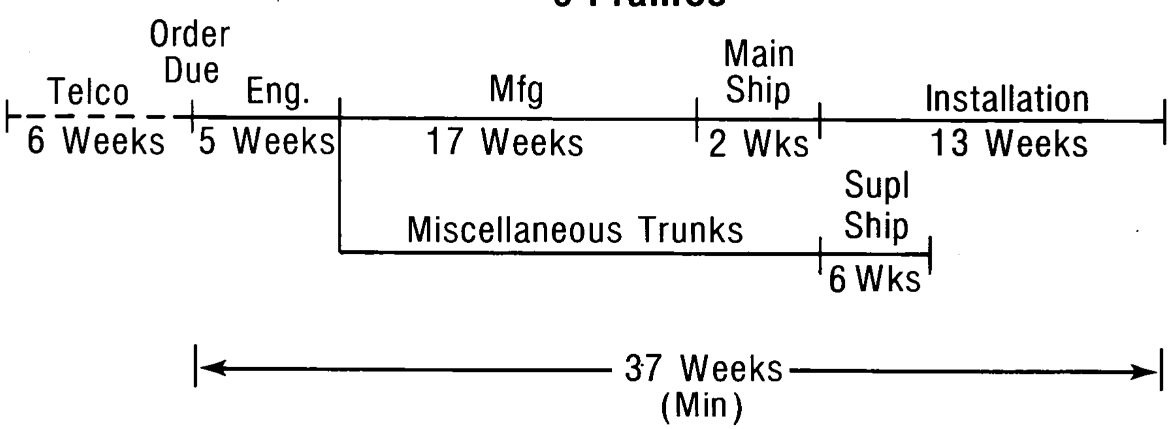


Figure 1

Short order service

No. 1 ESS Additions

Service Offerings:

- PBX -CO.
- Centrex Customer Service

Allowable Equipment List:

- Misc. Trunk Frames (Made to Order)
  Equipped with any of the following:

AIOD	FX Trunk
SSD	6-Port Conf
3-Port Conf	2-Way Trunks
Att. Loop	Tie-Line Trunks
Att. Trunk	

- Master Scanner

Figure 2

No. 1 ESS Short Order Service

Proposed Interval

- 15 or Less Frames

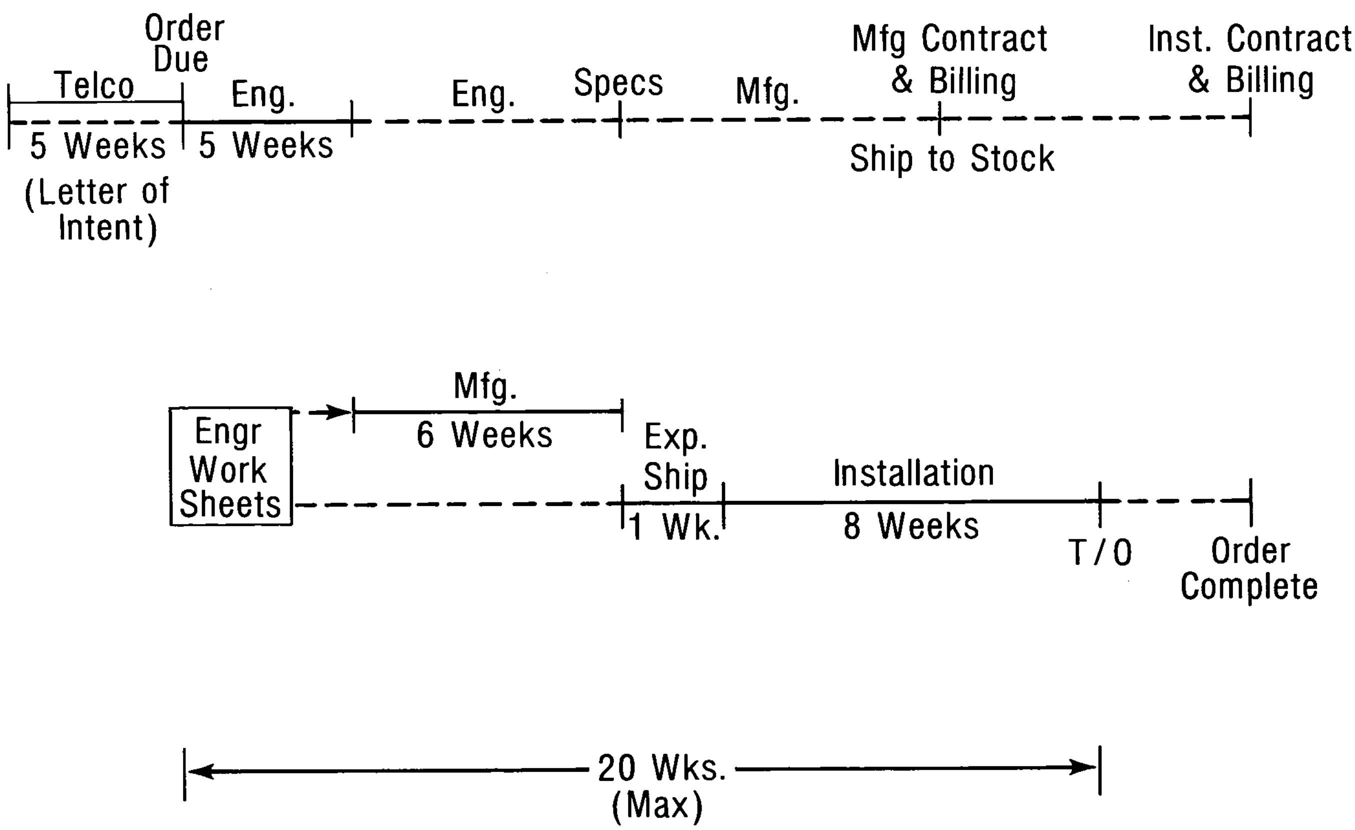


Figure 3

X - ENGINEER, FURNISH, AND INSTALL INTERVALS

1. INTRODUCTION

The period of time from the placing of an order to the actual use of equipment has historically been one under constant scrutiny in most businesses and of particular interest in the telephone industry. Until such time as customers utilize the equipment, no revenue is realized; and with the large capital investment required for telephone equipment, there is a never ending search for ways of reducing this interval.

The No. 1 Electronic Switching System was based on a completely different concept of telephone switching and was launched before cadres of trained technicians could become available to all the organizations that service a new product of Western Electric. Telephone Companies had similar problems. Consequently, much of the original ordering, engineering, and installing was accomplished with direct support from the Bell Laboratories and Western Electric Product Engineering Control Center (PECC). With such a large training task and continuing development of the new system resulting in numerous changes, it followed that intervals were quite lengthy.

1.1 Overall Intervals

With little applicable experience upon which to base the initial estimates of the required interval, many estimates were overly optimistic and a number of schedule slips occurred in early No. 1 ESS orders. As the training program took hold, it was possible to more accurately predict and maintain schedules. It became apparent that the schedules were too lengthy and ways had to be devised to make them competitive with existing systems. In 1966, the EF&I schedule for a 235-frame office was 128 weeks. 1972, this interval had been reduced to 84 weeks. The effect of training, organizational improvements and better manufacturing techniques can be readily seen; but the results fell far short of what was expected. Considerable effort had been expended to minimize the time required but usually by individual organizations. These efforts had no far reaching effects and the need for more effective overall changes in the system became apparent.

1.2 Installation Intervals

Installation Intervals estimated for 1966 through 1968 were based on Bell Laboratories Design Data and Western Electric Installation Testing Data that at the time was in the early planning stage. Subsequent to this, several significant developments were completed in the ESS program. The Signal Processors and Centrex, each of which required development of a separate generic program, are the major examples. At the time the intervals were established, it was believed that the "shakedown" period would end by early 1966 and later installations would begin to normalize. However, because of the above developments it turned out that the "shakedown" period existed through 1968.

When it became apparent that the intervals were inadequate, a reevaluation of ESS installations was undertaken. The upward evaluation for 1968 which resulted (for CC offices) is shown on Chart A. As a further result of this study, it was revealed that the use of a 2-shift 5-day schedule provided the most equitable return in terms of interval and efficiency. For example, a 100-frame CC office requiring a 40-week interval with a 2-shift 5-day schedule would require 75 weeks if performed on a single shift basis. On the other hand, that same installation, if performed on a 3-shift 5-day basis, would only be reduced to 30 weeks. A further reduction of approximately 18 percent is achievable by a 6-day 2-shift schedule but cost will increase due to premium pay for the 6th day. Chart A is compiled on a 2-shift 5-day basis.

With the experience gained through 1968 providing a more stable platform, Chart A shows the continuing trend of interval reduction through 1973.

The factors responsible for the reductions in interval for the years 1969 and 1970 and in part responsible for 1971 through 1973 are quality of product improvements, streamlining of time consuming tests, and elimination of supplementary tests which were no longer required as a result of the product improvement. The supplementary tests are being retained only as trouble-shooting aids if the need arises. Along with the above is the "learning curve" factor as applied to installation personnel.

Other factors responsible for the remaining interval reductions indicated in Chart A are multiauxiliary Program Testing, use of Growth Test Programs and techniques, and the introduction of new equipment types such as the 32K Call Store.

2. TASK FORCE CONCEPT

In order to obtain a major overall reduction in the EF&I interval, a task force was formed in 1970 to review all aspects of the interval from Operating Company order preparation to cutover. Representatives of Western Electric and AT&T worked together for almost two years to arrive at and implement some of the basic changes in the new plan for interval reduction.

2.1 Basic Plan

The EF&I interval in effect at the start of this major effort on interval reduction was about 84 weeks; the plan which evolved from the task force program resulted in an interval of 58 weeks, a 30 percent reduction, for the same office. (See Figure 1.) The basic elements of the interval reduction plan were:

1. A meeting by the sixth week prior to ESS Order Due Date to assure subsequent development of effective input for the Power and ESS equipment orders. This meeting is intended to provide complete and correct information to the WE Regional Engineering at week minus 2 for Power Order and week 0 ("Order Due Date") for the ESS order.
2. Increased use of parallel operations within WE Engineering and Manufacturing with the establishment of main and supplementary material shipments for both the Power and ESS order.
3. Central Processor Complex testing to being in the fifth week of installation and increased use of parallel testing operations.
4. Telephone Company access to the ESS machine on a third shift basis by approximately 75 percent of the installation interval: a specified percent of trunks available to the Telephone Company for testing at that time.

2.2 New Intervals

The breakdown of the resulting intervals for a 235-frame Signal Processor office is as follows: (These intervals with their overlaps are also shown in Figure 1.)

Telco/Regional Eng. Overlap	6 weeks
Power Order (Main)	21 weeks
ESS Order (Main Ship)	24 weeks
Central Processor Complex Power Installation	9 weeks
ESS Installation	32 weeks
Telco/Installation Overlap	9 weeks
Telco-Turnover to Cutover (typical)	4 weeks

3. NEW TESTING TECHNIQUES

Multiauxiliary (or Multimod) Program Testing techniques consist of the use of growth program modules run in parallel on two separate network frames permitting direct comparison of a known good pulse from any location in a controller with a pulse from the same location of a controller under test. Previously, only past experience and considerable knowledge permitted a proper analysis of a pulse and limited network testing to only the most capable of installers. The comparison technique afforded by the use of Multimod testing has reduced by more than fifty percent the time required to troubleshoot these areas; an added benefit is the reduction in installer training to perform the same tests. Another advantage of Multimod testing is that it can provide for up to five different test programs to be run simultaneously permitting a like number of test teams to operate on different problems at the same time. This increased use of parallel testing effort holds promise for still further installation interval reduction.

Among the Growth Programs and Techniques used in initial installations is the Universal Network Growth (UNIGRO) package. UNIGRO is one of the test programs in the

Auxiliary Program Library and is designed to test, exercise and aid troubleshooting of new and partial line and trunk link networks in a growth office. The new network portions of the UNIGRO program along with a test set and a revised set of procedures are used to test the network frames and fabric in a new office installation.

4. TELCO-INSTALLATION OVERLAP

Telephone Company personnel will be on the job site for at least one shift beginning at the 75 percent point of the installation interval (nine weeks prior to turnover in a typical job) to run trunk and call-through tests as outside facilities become available. They will also perform line verification tests. This overlap of testing between the installer and the Telephone Company craft is intended to reduce the interval between turnover and cutover and has the added benefit of eliminating redundant testing by WE and the Telephone Company craft.

5. NEW EQUIPMENT TYPES

The introduction of 32K call store as a new equipment type to replace the 8K call store carries with it considerable impact on installation interval. The maximum number of 32K call store frames required is two per office. These two frames are provided in the initial installation and thereby have a two-fold effect on intervals. The reduction in frame count and the connectorization of buses to the call store resulted in a 75 percent reduction in cabling, wiring, and test effort over that which was expended on 8K call stores. The other benefit is in floor plan stabilization. Floor plan stabilization has far reaching effects on the overall engineer, furnish, and install interval. Stabilization of the floor space provided by 32K call store is of particular value since experience has shown that call store requirements have been among the most variable in No. 1 ESS. Stabilization of floor plans also permits greater automation of cable running, cable rack layouts, lighting, power, and alarms. The reduction of interval afforded by 32K was partially realizable in mid-1972 with full realization taking place in 1973 (see Chart A).

Remreed networks presently under development are expected to provide similar reductions in interval due to the reduction in frame count, method of connection to the system, improved factory test, and shipment as a single unit.

Presently under development is a redesign of virtually all No. 1 ESS trunks; this will have considerable impact on overall intervals and cost. Universal trunks will require about one-third the floor space presently used; reduced costs to the customer are also expected.

Miscellaneous trunks (MTs) are presently completely wired-in and extensively tested by the installer. Regional engineering effort (writing specifications) is lengthy due to the fact that present miscellaneous trunks do not lend themselves to automated techniques and, therefore, must be done manually. Scan points and signal distributor points must be connected to external frames; this results in a need for making assignments, keeping records and running cable for each trunk. The redesign of the miscellaneous trunks includes a considerable reduction in size and a plan to make the MTs plug-in. New framework design will provide the required scanner and signal distributor points on a predetermined basis; this eliminates switchboard cable and the previously mentioned record keeping. Also the new design will permit the use of computer specification forms which greatly reduces regional engineering cost and interval on both additions and initial installations.

Manufacturing organizations benefit from the redesign since more complete shop tests are possible. The load on the frame shops will be reduced as a result of a two-thirds reduction in the space required by the new trunks. With a reduction in frame count and cabling and with the eventual elimination of installer trunk testing, the reduction in installation interval and cost becomes obvious. Figures 2 and 3 show the interval savings expected as a result of the trunk redesign.

6. CONCLUSION

It can be seen that much fruitful effort has been expended to reduce all phases of the EF&I interval. From 1966 when the EF&I interval was 128 weeks to the 58 weeks achieved in 1973 represents a reduction of approximately 55 percent. Similar reductions in growth interval have been achieved and are discussed in detail in Section IX. Further significant reductions can be expected with the introduction of new equipment types such as remreed networks and new testing techniques in both manufacturing and installation. Further reductions in overall EF&I interval will come with the No. 1A ESS in the late 1970s. Projections and plans already worked out call for a total EF&I interval of 34 to 44 weeks depending on office size. Effort will continue toward full realization of all potential reductions with confidence that No. 1 ESS will be competitive with any other system.

Installation Interval No. 1 ESS 2 Wire*

INTERVAL IN WEEKS

NO OF FRAMES	1965	1966	1967	1968	1969	1970	1971	1972 (8K CS)	1972½ (32K CS)	1973 (32K CS)	1974
CC		74	61	70							
300		73	53	70							
		72	59	69							
		71	59	69							
		70	57	68							
		69	55	68							
250		68	55	67							
		67	54	67	47	44					
		66	53	65	47	44					
		64	52	65	45	43					
		63	51	63	45	42					
200		61	50	63	45	42					
		59	49	62	43	41	34	32	29	28	
		57	47	61	43	41	34	32	29	28	
		55	45	60	42	40	33	31	28	27	
		53	44	59	42	39	33	31	28	27	
150		51	42	58	42	39	33	31	28	27	
		49	41	57	40	37	32	30	27	26	
		47	39	55	40	37	32	30	27	25	
		45	37	53	39	36	31	29	26	25	
		43	36	51	39	35	31	29	26	25	
100		40	34	43		35	31	29	26	25	
		39	33	47	38	33	30	28	25	24	
		37	31	45	38	33	30	28	25	24	
		35	29								
		32	27								
		31	26								
0											

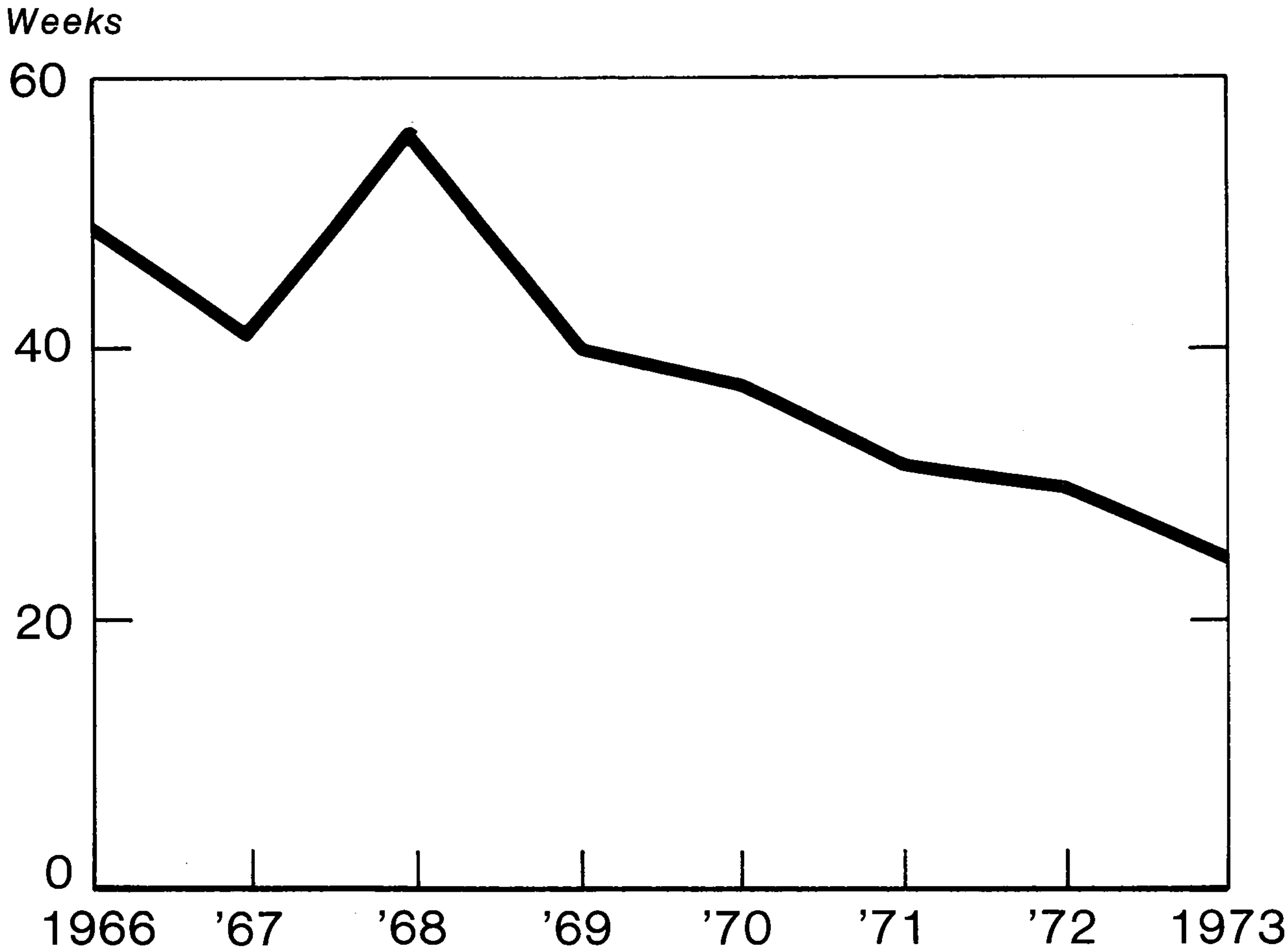
NO OF FRAMES	1965	1966	1967	1968	1969	1970	1971	1972	1972½	1973	1974
SP 500					71	65	56	50	47	40	
					71	65	56	50	47	40	
					71	66	55	50	47	40	
					71	66	55	50	47	40	
450					71	66	55	50	47	40	
					68	64	53	47	45	39	
					68	64	53	47	45	39	
					58	64	53	47	44	38	
				83	63	64	53	47	44	38	
400				83	53	64	53	47	44	38	
				82	65	62	51	45	43	38	
				82	65	62	51	45	43	38	
				81	63	61	50	45	42	37	
				81	63	60	50	45	42	37	
350				80	63	40	50	45	42	37	
				80	61	49	43	44	41	36	
				79	61	49	49	44	41	36	
				79	59	48	48	44	41	35	
				77	59	57	48	44	41	35	
300				77	59	57	48	44	41	35	
				76	58	56	47	43	40	34	
				76	58	56	47	43	40	34	
				75	55	55	45	42	39	33	
				75	56	54	45	42	39	33	
250				74	56	54	46	42	39	33	
				74	54	52	45	41	38	32	
				72	54	52	45	41	38	32	
				72	52	51	44	40	37	32	
				70	52	50	44	40	37	32	
200				70	52	50	44	40	37	32	
				69	50	49	43	39	36	31	
				68	50	49	43	39	36	31	
				67	49	48	42	39	36	31	
				65	49	47	42	39	35	31	
150				65	48	47	42	39	35	31	
				64	47	46	41	38	35	30	
				62	47	46	41	38	35	30	
				60	46	46	41	38	35	30	
				58	46	46					
100				56	46	46					
				54							
				52							
0											

*BASED ON FIVE DAY TWO SHIFT WORK WEEK.
NOTE 1. APPROXIMATELY 18% REDUCTION IS ACHIEVED WITH A TWO SHIFT SIX DAY WORK WEEK

Chart A1

Installation interval No. 1 ESS 2 wire*. . .

Typical CC Office = 150 Frames

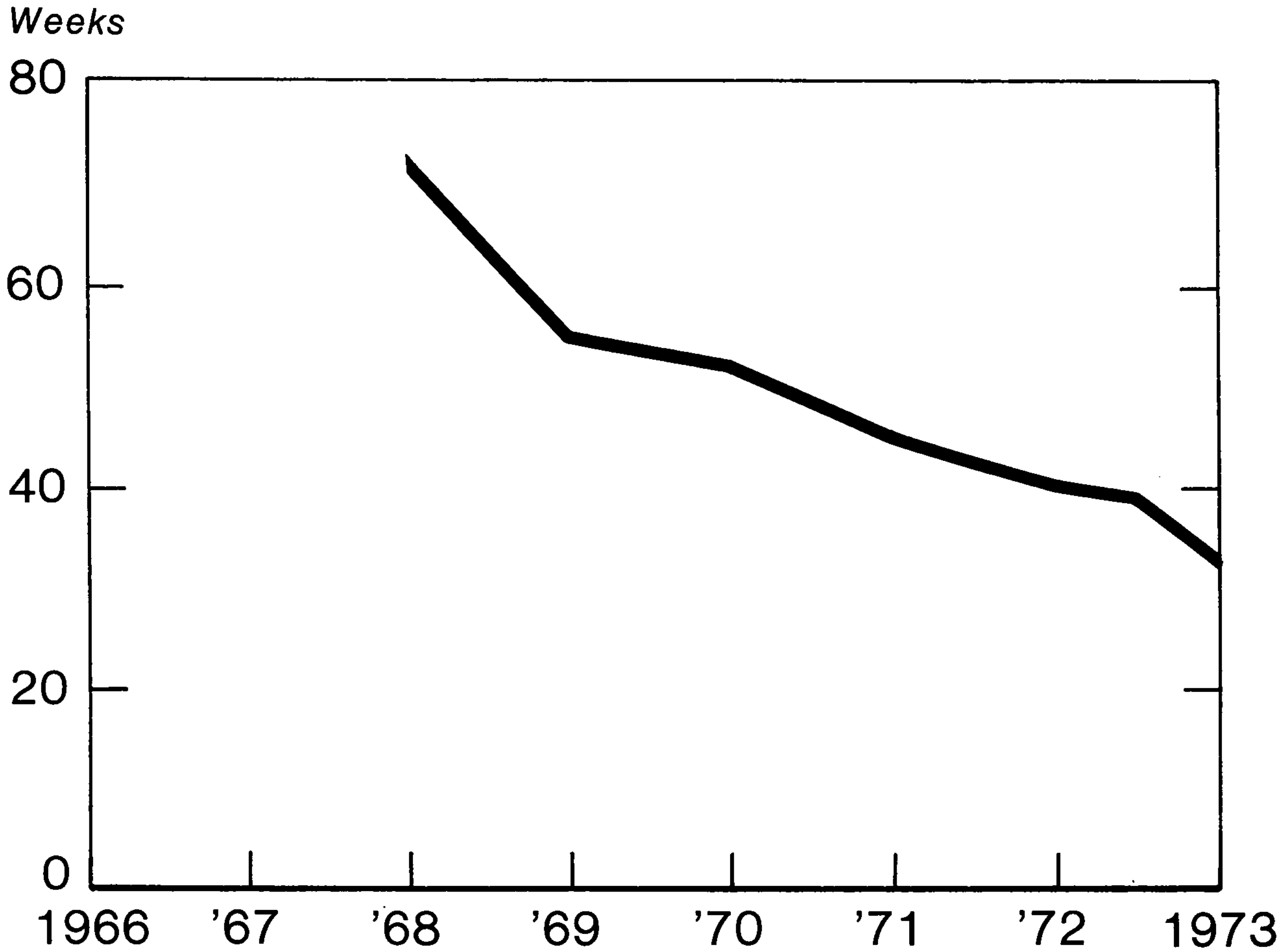


*Based on five day two shift work week.

Note Approximately 18% reduction is achieved with a two shift six day work week.

Installation interval No. 1 ESS 2 wire*. . .

Typical SP Office=235 Frames

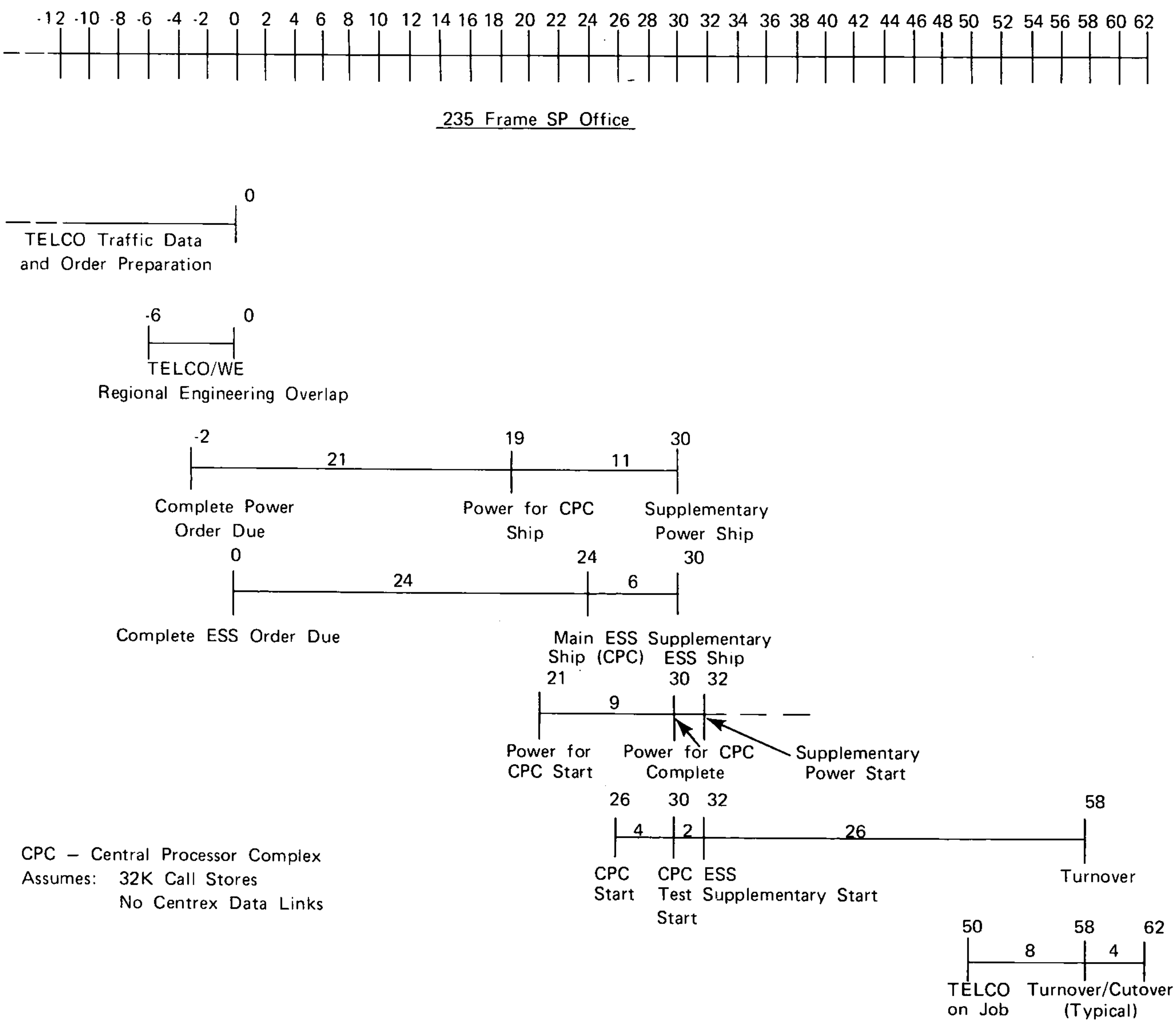


*Based on five day two shift work week.

Note Approximately 18% reduction is achieved with a two shift six day work week

Chart A3

No. 1 ESS Intervals For Initial Installations



CPC – Central Processor Complex
Assumes: 32K Call Stores
No Centrex Data Links

Figure 1

Present No. 1 ESS Intervals

Typical Intervals
235 Frame SP Office

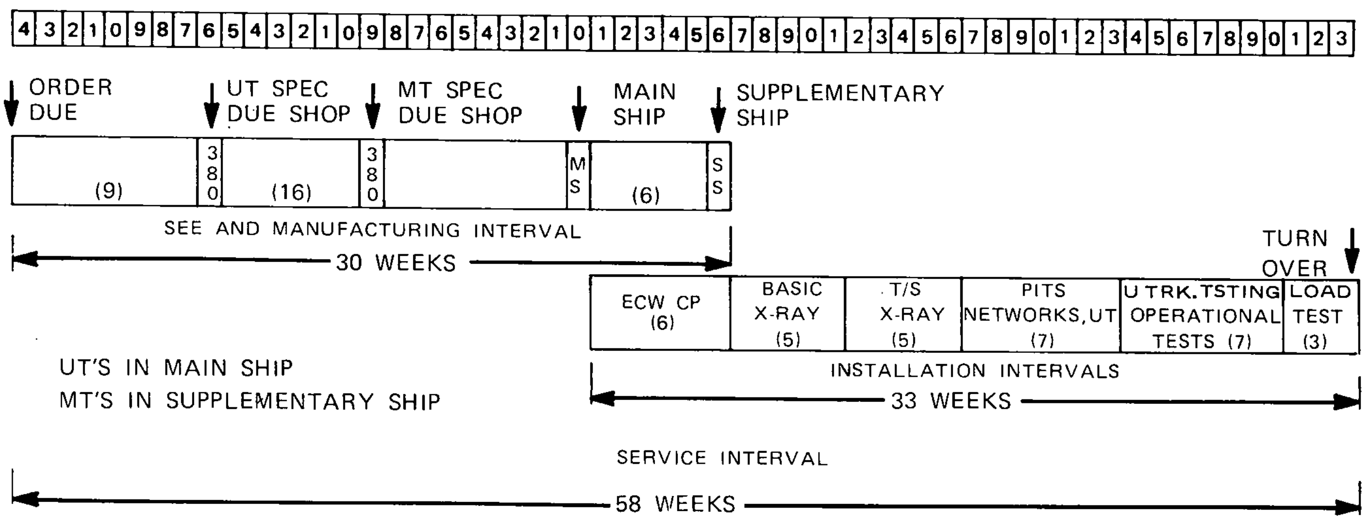
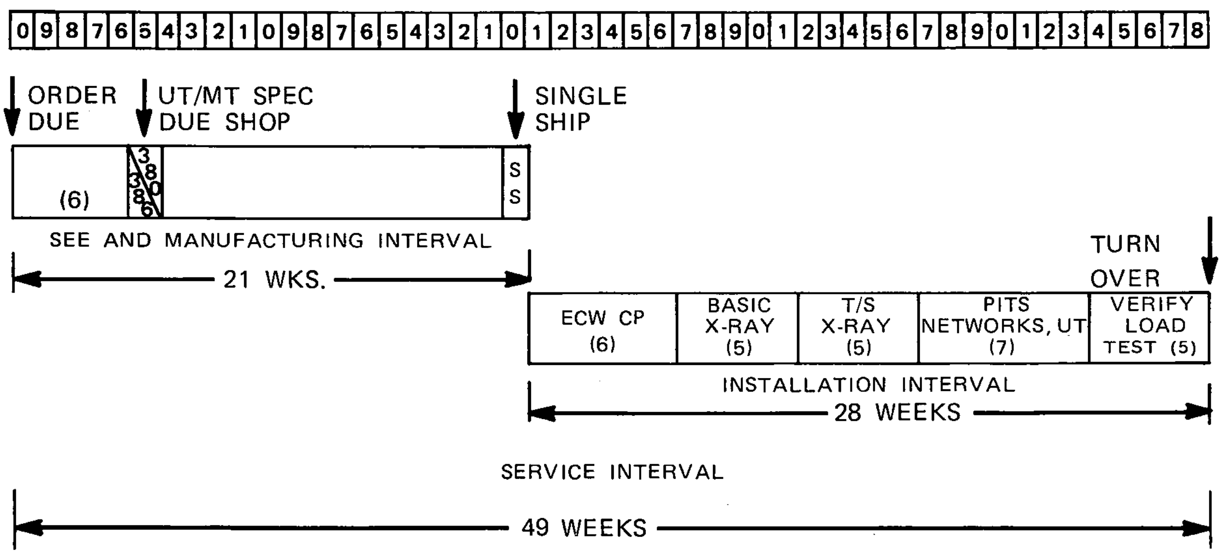


Figure 2

Proposed No. 1 ESS Intervals with Miniaturized Trunks



SERVICE INTERVAL
SAVINGS – 9 WEEKS
INSTALLATION INTERVAL
SAVINGS – 5 WEEKS

Figure 3

XI - CURRENT AND NEAR FUTURE DEVELOPMENTS

This section describes those No. 1 ESS developments which are expected to be available within the next 1 to 3 years. Most of these are expected to be included in either the CTX-7 or CTX-8 generic programs.

It should be noted that many of these developments are for toll switching applications. The CTX-7 program provides initial combined 2-wire local/toll switching features as a Class 4 office. Operation as a high-volume toll or toll/tandem 2-wire trunk-only switcher is also available with the CTX-7 development. In addition, several business customer features are added to provide more complete hotel/motel and hospital service packages.

Major 2-wire toll or toll/tandem features included in the CTX-7 development are as follows:

1. Network Management Controls to generate dynamic overload signals to subtending offices and to provide displays, data and other controls useful in reducing tandem and toll network congestion.
2. 2048 Terminal Trunk Link Network for toll or tandem offices only in a 1:1 concentration ratio provides a maximum trunk capacity of 30,000 trunks. Offices equipped with this network configuration cannot serve lines in the initial phase of this development.
3. Combined Operator-Office Trunks are used for Class 4 operation with connecting CDOs. Calls from the CDO are connected to the toll switchboard through these trunks. Switchboard pulse conversion is accomplished through other operator trunks connecting the switchboard to the No. 1 ESS which are tandem switched to the combined operator-office trunks.
4. Compatibility with Residual Operator Traffic from TSPS is required for Class 4 operation. Certain operator assisted calls require switchboard handling and are passed to a toll operator by the TSPS operator. Special signaling required in this situation is provided.
5. Operator Signaling to and from the Toll Network provides ability to receive and transmit operator control signals such as rering when acting as a Class 4 office.
6. Receiver Attachment Delay Test is comparable to the Sender Attachment Delay Recorder (SADR) in electromechanical offices. Software-generated incoming test calls will record the number of failures to connect to a receiver within a fixed length of time.
7. Maintenance of Tandem and Toll Trunks provides augmented TLTP and STTP transmission testing of toll connecting and intertoll trunks.
8. 103 Test Line is used for signaling tests on intertoll trunks.
9. 104 Test Line provides for one-man testing of noise and 2-way loss measurements.
10. 108 Test Line provides for in service testing of suppressors on intertoll trunks.
11. Improved Call-Carrying Capacity will increase both tandem and local call capacity.

Major local call features included in the CTX-7 development are:

1. Reduction of Charge Delay Timing on coin and certain other calls is made from 2 to 4 seconds to 0.6 to 0.8 seconds. Also provides 0.6 to 0.8 second timing on all outgoing calls and eliminates flash timing on outgoing calls.
2. Automatic Door Answering Service provides the ability to remotely control a door lock from a subscriber's telephone.
3. INWATS Billing provides an AMA record at the terminating office for each INWATS call. Simulated facilities are provided to restrict INWATS traffic and provide overflow counts.

4. "Hot Line" Service allows a line to automatically place a call to one predesignated destination by simply going off hook.

5. Compatibility with No. 1A Line Concentrator and with MJ Radio provides reorder tone to calling customers when all concentrator trunks or radio channels are busy.

6. Customer Changeable Speed Calling permits a customer to change his speed calling list by dialing a special code followed by the new speed calling list entry. Also, eliminates need for prefix 11 or * when using speed calling feature.

7. International Direct Distance Dialing (TSPS Version) routes all IDDD calls to TSPS. Route selection to gateway office and AMA records will be made at the TSPS. Also, provides for special toll IDDD calls and access to overseas operators.

8. Remote Call Forwarding provides limited multiple call forwarding of calls from directory numbers with this service. AMA record of the forwarded portion of the call will be made on chargeable calls.

9. CO-Centrex, Directed Call Pickup permits a user to dial a code from any centrex station and pick up a call which as been answered or is ringing at his own station

10. CO-Centrex, Improved Hotel/Motel Message Registers provides improved message register operation via a simple data link using MF pulsing to customers served as a CO-Centrex or PBX.

11. CO-Centrex, Single Digit Dialing for Hotel/Motel Service permits business customers served as a CO-Centrex or PBX to use single digit dialing for reaching various internal services.

12. CO-Centrex, Terminating Line Make-Busy for Hospital Slumber Service under key control, terminating traffic to patient rooms can be routed to busy, announcement, or attendant.

13. Co-Centrex, Toll Diversion to Attendant routes intercepted toll calls to the attendant instead of the reorder or announcement.

14. CO-Centrex, Dial Transfer to Tandem Tie Lines provides a centrex station with the ability to transfer a call to a tandem tie line.

15. CO-Centrex, Customer Dialed Account Recording on AMA permits the originating centrex station to dial a billing number to be included with the normal AMA recording information.

16. CO-Centrex, Station Billing on Attendant-Handled Calls provides for AMA recording of the originating station as billing number on calls handled by an attendant.

17. Multiple 50A Consoles — provides ability to serve up to 16 50A Consoles.

Improved maintenance and administration features included in the CTX-7 development are:

1. Operation with Remote Maintenance Center provides the interface with the controls and displays of the common systems remote maintenance center.

2. Improved tri-level office alarm system for operation with the remote maintenance center.

3. Additional Traffic Measurements will transmit selected traffic data on a 15-minute basis, provide parity on the traffic TTY output, provide tape perforator activation character, permit a second TTY to be used for traffic data, provide the ability to alter traffic registers, and provide counts on first failure to match on incoming calls.

4. Prevention of unauthorized use of TOUCH-TONE equipment on dial pulse stations.

5. Monitoring of the Recent Change Area provides new TTY messages to report the status and composition of the recent change area.

6. Delayed Activation of Recent Change Messages provides the ability to activate recent changes, which were previously inputted via teletypewriter on a delayed basis, by either another recent change message or by a specially designated telephone.

A firm list of features for the CTX-8 development is not yet available. The following list of features are those which are expected to be developed following CTX-7.

1. Traffic counts used for determining division of toll traffic revenue.
2. Standard interface with EADAS
3. AMA recording of Directory Assistance calls.
4. Co-Centrex selected traffic data to the customer.
5. ACD-CO Service (Phase 1)
6. Fraud prevention on terminating calls (Black Box Fraud).
7. Periodic printout of inactive coin lines
8. CCSA customer identity on AMA records
9. CTX-CU flexible route selection
10. Dial control to restrict inward and/or outward calling to/from hotel-motel rooms.
11. Standard billing number in AMA record for WATS lines.
12. Optional loading of program features to save program store space.

XII - SUMMARY AND FUTURE DIRECTIONS

It is difficult to briefly summarize all the improvements made in No. 1 ESS in the nine years or so since Succasunna. There are, however, a few worthy of special mention.

Progress on No. 1 ESS has been speeded up immeasurably by the cooperation of Operating Companies in prompt reporting of troubles via the Operational Trouble Report (OTR) route. For example, from 1970 to 1973, a total of 2970 OTRs have been received. Of these WE PECC referred 858 to BTL for fixes and of these, 842 have been resolved. WE PECC at Indian Hill issues a status report on the OTRs, a copy of which is sent to all Operating Company Technical Assistance Centers. BTL is making a strong effort to solve these OTRs promptly since about one third of the manpower assigned to No. 1 ESS is used on the solution of these and other No. 1 ESS field problems.

Most of the Bell Laboratories development work on growth programs for No. 1 ESS has been completed. There are additional field trials that have to be made on particular concentration ratio changes but that is all. The point that should be stressed here is that the procedures for changing a CC to an SP office have been completed and have been used very successfully by WE on a standard basis. It is, therefore, no longer necessary for an Operating Company to install an SP office where a CC office could carry the load for the engineering interval. An Operating Company should look at this option very carefully because of the first cost incurred when an SP office is installed instead of a CC office.

No. 1 ESS has also made several important cost reductions in the last few years. The development and successful application of the 32K Call Store has substantially reduced the cost, space, and power required in No. 1 ESS call store memories. In addition, the remreed trunk link network has been developed and is now being installed. The remreed trunk link network, in addition to being considerably smaller than the ferreed trunk link network, is designed to be program compatible with the ferreed trunk link network and hence can be installed as a growth unit in existing ferreed offices.

On the other hand, the size of the generic program continues to increase. The original SP-1 program required 24 unduplicated program modules. The program has grown (in the SP-CTX-7 program) to 38 unduplicated mods. The size increase is due to the large number of features, detailed in earlier chapters, that have been added to the program. The size would be considerably greater than even the 38 mods if particular attention had not been paid to revising and condensing the existing code in the process of adding the new features.

Little more needs to be said about real time improvement. There will be some small across the board improvements in call carrying capacity beyond those issued in CTX-7. The real time improvements that have been made in No. 1 ESS to date have been made in spite of the real time used up by the addition of new features. It it not expected that dramatic real time improvements will be made in No. 1 ESS in the future; however real time improvements will continue to be investigated and implemented with the hope that these small gains will offset the real time cost of adding new features.

ESS development personnel have been monitoring the field performance of No. 1 ESS very closely in the nine years since Succasunna was placed into service. In addition to providing customer features in response to Operating Company needs, a fairly comprehensive group of auxiliary programs (Mod 5) has been developed. These auxiliary programs cover a wide range of diagnostic features from bus testing to data mapping and board-to-board testing. The last of these auxiliary programs, the board-to-board testing program, permits Operating Companies to utilize the No. 1 ESS machine to check their lines before cutover. This program has been successfully used in a number of offices, and has produced both large Plant labor savings and a cleaner cutover.

The future of No. 1 ESS lies in the 1A Processor. The speed of the new processor eliminates the worry about real time capacity to the extent that

No. 1A ESS (2-wire) will handle about 240,000 calls per hour (peak); this capacity, as with the No. 1 ESS, will be dependent upon call mix and equipment arrangements. Thus, for the first time, ESS will be network limited. Plans are being made to increase the size of the network to achieve this system capacity. The first No. 1A ESS office, which will also have an all remreed line link and trunk link network, will be put into service in the early 1977 time frame. This will be followed by the first retrofit of the 1A Processor approximately one year later and the completed development of a larger network. General availability of the large network and of retrofit procedures for the 1A Processor will be in the 1978 time frame.

In looking towards the future, the No. 1 ESS generic program has not been ignored. Bell Laboratories is looking at ways of supplying programs to the offices in feature packages to reduce the number of program stores needed. This is not to say that an office would be able to order only the features that they require but they would be able to order smaller packages which contain the features they require. This will still save capital investment in new program stores. This work is being pursued vigorously by Bell Laboratories; it is planned that initial packages will be available in the CTX-8 time frame.

In summary then, No. 1 ESS has achieved essentially of its design objectives. Major improvements have been achieved in the past five years in terms of real time capacity, reliability, feature capability and cost as well as other areas. More improvements lie ahead, but the real task of the near future is to fully integate the No. 1 ESS into daily routines. No. 1 ESS is already widely available and its use is growing rapidly. It is time to document fully the existing capabilities of No. 1 ESS, and to use these capabilities to the utmost — for improvements in administration of the ESS and for improvements in offering of new customer services. For only by vigorously pursuing the capabilities of a system like No. 1 ESS can we realize its true value. And only if we learn to derive full value from a No. 1 ESS will we be able to profit fully from the greatly expanded capabilities of the next generation of electronic systems, like No. 1A ESS.

XIII - SYSTEMS IN SERVICE

Following is a list of No. 1 ESS (two-wire) installations, arranged by Operating Telephone Company, as of May 1, 1974. Some schedules are tentative and some are based upon Advanced Notification Orders (ANOs).

Each installation is shown, along with the generic program and the number of equipped lines. The cutover date or proposed service date is also shown.

Page XIII-13 summarizes, by generic program, the No. 1 ESS installations in service, as of May 1, 1974. It also lists the systems and lines in service for each year from 1965 to the present.

ESS INSTALLATIONS BY COMPANY

NEW ENGLAND TELEPHONE AND TELEGRAPH COMPANY

INSTALLATION	GENERIC PROGRAM	EQUIP. LNS(K)	CUTOVER DATE
Boston Back Bay #1	SP-CTX5	16.9	6/03/73
Boston Back Bay #2	SP-CTX5	21.5	6/03/73
Boston Bowdoin Sq #1	SP-CTX5	30.7	8/25/73
Boston Harrison #1	SP-CTX5	19.5	7/04/63
Boston Harrison #2	SP-CTX3	18.4	11/21/70
Boston Harrison #3	SP-CTX5	20.5	2/10/73
Brighton Stadium	SP-CTX5	31.7	11/23/63
Cambridge	SP-CTX3	41.0	5/20/70
Cambridge Kendall Sq	SP-CTX5	21.5	8/12/72
Cambridge Ware St.	SP-CTX4	12.3	2/25/72
Malden	SP-CTX3	15.4	7/17/71
Nashua	SP-CTX5	30.7	5/20/73
Provid. Green St. #1	SP-CTX3	32.8	11/18/67
Provid. Green St. #2	SP-CTX1	16.4	12/13/69
Quincy	SP-CTX5	12.3	9/02/72
Waltham	SP-CTX4	12.3	10/30/71

NEW YORK TELEPHONE COMPANY

INSTALLATION	GENERIC PROGRAM	EQUIP. LNS(K)	CUTOVER DATE
Albany State St.	SP-CTX6	12.3	12/13/70
Amherst	SP-CTX4	16.4	12/20/70
Bklyn. Ave R	SP-CTX5	12.3	1/27/73
Bklyn. Ave U	CC-CTX2	17.4	3/28/73
Bklyn. Ave Y	SP-CTX3	30.2	10/09/71
Bklyn. Bridge St. #1	CC-CTX1	14.3	6/29/63
Bklyn. Bridge St. #2	SP-CTX4	28.7	2/10/73
Bklyn. Bushwick	SP-CTX5	35.8	4/28/73
Bklyn. Clinton Ave	SP-CTX6	41.0	8/08/70
Bklyn. Liberty	SP-CTX5	25.6	8/11/73
Bklyn. Rockaway	SP-CTX4	41.0	12/11/71
Bklyn. 14th St.	SP-CTX4	35.8	5/06/72

NEW YORK TELEPHONE COMPANY (CONTD.)

INSTALLATION	GENERIC PROGRAM	EQUIP. LNS (K)	CUTOVER DATE
Bronx Edson	CC-CTX4	35.8	5/20/72
Bronx Tiebout Ave	SP-CTX4	49.1	5/20/72
Bronx Tratman	SP-CTX5	41.0	7/21/73
Buffalo Franklin	SP-CTX5	12.3	5/05/73
Buffalo-Baily	SP-CTX6	25.6	11/27/73
Guilderland	SP-CTX4	8.2	4/23/72
Huntington Station	CC-CTX2	10.2	10/25/70
Latham	SP-CTX5	16.4	12/10/72
Lindenhurst	CC-CTX4	20.5	6/07/70
Liverpool	CC-CTX6	15.3	10/13/73
NYC Convent Ave	SP-CTX5	30.7	12/13/70
NYC E. 30th St.	SP-CTX5	18.4	5/23/70
NYC E. 38th St. #1	SP-CTX5	18.4	4/16/72
NYC E. 38th St. #2	SP-CTX5	24.6	6/16/73
NYC E. 56th St. #1	SP-CTX5	21.5	10/28/67
NYC E. 56th St. #2	SP-CTX5	25.1	2/06/71
NYC E. 56th St. #3	SP-CTX5	20.5	10/27/73
NYC E. 79th St. #1	SP-CTX3	25.6	6/27/70
NYC E. 97th St.	SP-CTX5	36.9	5/19/73
NYC Manhattan Ave.	SP-CTX5	35.8	9/15/73
NYC Varick St.	SP-CTX5	21.5	8/07/71
NYC WTC Tower A #1	SP-CTX5	16.4	2/16/74
NYC W. 18th St.	SP-CTX5	35.8	5/27/72
NYC W. 36th St. #E	SP-CTX5	17.9	6/27/71
NYC W. 36th St. #F	SP-CTX6	18.8	12/07/73
NYC W. 36th St. #1	SP1	10.8	3/02/63
NYC 104 Broad St. Ent F	SP-CTX5	16.8	3/30/74
NYC 104 Broad St. #1	SP-CTX5	17.4	6/25/71
NYC 104 Broad St. #2	SP-CTX5	14.3	3/30/73
NYC 1095 Ave America #1	SP-CTX5	21.5	7/07/73
NYC 1095 Ave America #2	SP-CTX6	21.5	1/12/74
NYC 140 West Ent L	SP-CTX5	16.4	8/26/72
NYC 140 West Ent M	SP-CTX5	16.4	7/21/73
NYC 140 West Ent N	SP-CTX5	17.9	3/30/74
NYC 140 WEST ST #1	SP-CTX5	18.4	6/22/69
Patchogue	CC-CTX4	10.2	7/01/72
Queens Forest Hills	SP-CTX5	8.2	10/26/73
Queens JFK Airpt	SP-CTX5	7.2	10/21/72
Queens Newtown	SP-CTX5	53,2	9/08/73
Queens Ravenswood	SP-CTX5	30.7	9/29/73
Queens Whitestone	SP-CTX5	28.7	2/24/73
Queens 115th Ave	SP-CTX5	24.6	5/19/73
Schenectady Franklin	SP-CTX4	16.4	6/27/71
Suffolk Deer Park	CC-CTX4	10.2	7/19/73
Syracuse Fairmount	SP-CTX5	8.2	4/06/72
Syracuse State GR2	SP-CTX5	32.8	7/29/73
West Seneca	CC-CTX6	11.3	10/06/73

NEW JERSEY BELL TELEPHONE COMPANY

INSTALLATION	GENERIC PROGRAM	EQUIP. LNS(K)	CUTOVER DATE
Atlantic City	SP-CTX3	29.7	3/07/71
Bayonne	CC-CTX6	4.1	11/11/73
Boonton	CC-CTX4	5.1	11/28/71
Camden	SP-CTX3	18.4	11/28/70
Dumont	CC-CTX6	2.0	12/02/73
East Orange	SP-CTX5	26.6	12/07/69
Elizabeth	SP-CTX5	32.8	5/24/70
Englewood	SP-CTX5	7.2	8/27/72
Freehold	CC-CTX6	8.2	12/02/73
Herbertsville	CC-CTX6	6.1	4/07/74
Irvington Essex	CC-CTX2	15.4	7/30/67
Jsy. City Journal Sq	SP-CTX4	13.3	12/05/71
Linden	CC-CTX4	8.2	11/12/72
Metuchen	CC-CTX4	8.2	12/05/71
Morristown	SP-CTX6	18.4	4/23/67
New Brunswick	SP-CTX5	24.6	12/06/70
Newark Humboldt	SP-CTX5	21.5	10/01/72
Newark Ironbound	SP-CTX3	18.4	10/11/70
Newark Market	CC-CTX4	12.3	10/13/68
Newark Waverly	CC-CTX6	13.2	12/30/73
Nutley	CC-CTX4	8.2	11/26/72
Passaic	CC-CTX6	10.2	9/30/73
Paterson Sherwood	SP-CTX4	25.6	1/26/69
Somerville	CC-CTX4	8.2	12/19/71
South Orange	CC3	17.4	8/04/68
Succasunna	CC-CTX4	9.2	5/30/65
Trenton State St.	SP-CTX5	47.1	12/08/63
Union City	SP-CTX4	16.4	12/19/71
Vineland	CC-CTX6	8.2	11/11/73
Wildwood	CC-CTX4	12.3	3/15/70
Williamstown	CC-CTX4	12.3	5/20/73

THE BELL TELEPHONE COMPANY OF PENNSYLVANIA

INSTALLATION	GENERIC PROGRAM	EQUIP. LNS(K)	CUTOVER DATE
Allentown	SP-CTX5	16.4	7/29/72
Bethlehem	SP-CTX4	24.6	1/26/69
Eastwick	CC-CTX4	6.1	8/06/72
Phila. Baldwin #1	SP-CTX5	20.5	11/23/69
Phila. Baldwin #2	SP-CTX6	15.4	1/27/74
Phila. Dewey	SP-CTX5	28.7	7/20/69
Phila. Germantown	SP-CTX5	32.8	6/25/67
Phila. Jefferson	SP-CTX5	19.5	11/07/70
Phila. Locust #1	SP-CTX5	20.5	1/14/68
Phila. Locust #2	SP-CTX5	20.5	5/14/72
Phila. Locust #3	SP-CTX6	15.4	4/28/74

THE BELL TELEPHONE COMPANY OF PENNSYLVANIA (CONTD.)

INSTALLATION	GENERIC PROGRAM	EQUIP. LNS (K)	CUTOVER DATE
Phila. Market #1	SP-CTX5	17.9	10/03/71
Phila. Market #2	SP-CTX6	12.8	7/29/73
Phila. Mayfair	SP-CTX5	20.5	12/06/70
Phila. Orchard	CC-CTX4	4.1	11/19/72
Phila. Pennypacker	SP-CTX5	22.5	12/14/69
Phila. Poplar	SP-CTX5	14.3	7/09/72
Phila. Regent	SP-CTX5	28.7	10/15/72
Phila. Sherwood	SP-CTX5	24.6	11/07/71
Phila. Trinity	SP-CTX5	18.4	11/02/69
Phila. Waverly	SP-CTX5	24.6	9/12/71
Ptsbg. Crafton	SP-CTX6	17.9	8/26/73
Ptsbg. Downtown #1	SP-CTX4	23.0	10/26/68
Ptsbg. Downtown #2	SP-CTX5	15.4	5/01/71
Ptsbg. Oakland	SP-CTX5	28.7	1/30/72
Ptsbg. Sharpsburg	SP-CTX4	16.4	12/19/71
Ptsbg. Squirrel Hill	SP-CTX5	20.5	1/25/70
Ptsbg. Homestead	SP-CTX6	19.4	10/28/73
Scranton	SP-CTX6	16.4	5/20/73
Wilmington #1	SP-CTX6	41.0	7/15/73

THE CHESAPEAKE AND POTOMAC TELEPHONE COMPANY

INSTALLATION	GENERIC PROGRAM	EQUIP. LNS(K)	CUTOVER DATE
Arlington Barcroft	CC-CTX4	6.1	3/26/73
Arlington Irving	SP-CTX5	12.8	12/17/72
Arlington Pentagon	SP-CTX5	30.7	12/19/69
College Park Berwyn	CC-CTX4	4.6	6/10/72
Germantown, Md.	CC-CTX4	4.6	6/25/72
Rockville Center	CC-CTX4	4.1	11/20/71
Silver Springs	CC-CTX4	6.1	9/16/72
Wash. Brookland	SP-CTX3	10.8	3/28/71
Wash. Congress Hgts.	CC-CTX4	4.1	6/24/72
Wash. Downtown Me 8	SP-CTX3	18.4	6/15/68
Wash. Downtown Na 8	SP-CTX3	16.4	8/15/70
Wash. Dupont Ctr	SP-CTX5	31.7	8/20/72
Wash. Georgia Center	SP-CTX5	30.2	11/28/71
Wash. Midtown	SP-CTX4	21.5	9/05/71
Wash. Republic	SP-CTX5	14.3	2/25/73
Wash. Southeast Ctr	SP-CTX4	21.0	1/09/72
Wash. Southwest Ctr	SP-CTX5	15.4	5/10/72

THE CHESAPEAKE AND POTOMAC TELEPHONE COMPANY OF MARYLAND

INSTALLATION	GENERIC PROGRAM	EQUIP. LNS(K)	CUTOVER DATE
Balto. Charles St.	SP-CTX4	10.2	6/04/72
Balto. Chase	CC3	6.1	1/16/66
Balto. Edmonson	SP-CTX5	7.2	11/05/72
Balto. Hamilton	SP-CTX6	16.8	12/30/73
Balto. Liberty	SP-CTX5	17.9	8/21/71
Balto. University	SP-CTX4	26.1	8/03/69
Balto. Wolfe Ctr	SP-CTX5	10.8	11/04/72
Bethesda	CC-CTX6	3.6	12/21/73
Columbia City	CC3	14.3	11/24/68
Gaithersburg	CC-CTX6	8.7	12/14/73
Hyattsville	CC-CTX6	7.1	1/20/74

THE CHESAPEAKE AND POTOMAC TELEPHONE COMPANY OF VIRGINIA

INSTALLATION	GENERIC PROGRAM	EQUIP. LNS(K)	CUTOVER DATE
Newport News-Harpers.	CC-CTX4	2.0	9/16/73
Newport News-Jeff.	CC-CTX4	7.2	4/29/73
Norfolk Bute St.	SP-CTX4	26.6	8/18/68
Sandston	CC-CTX6	8.2	10/28/73
Virginia Beach Gt. Nk.	CC-CTX4	7.2	5/13/73

SOUTH CENTRAL BELL TELEPHONE COMPANY

INSTALLATION	GENERIC PROGRAM	EQUIP. LNS(K)	CUTOVER DATE
Birmingham	SP-CTX4	27.6	6/18/72
Jackson Pearl St.	CC-CTX4	12.3	8/18/68
Memphis Main #0	SP-CTX5	16.9	8/30/70
Memphis Main #1	SP-CTX6	23.0	12/15/73
Memphis Midtown	SP-CTX5	10.8	7/19/70
Nashville Main	SP-CTX5	6.1	11/17/68
Nashville Vanderbilt	SP-CTX5	20.5	4/19/70
New Orleans Main	SP-CTX4	18.4	4/30/70
Shreveport	SP-CTX6	25.6	8/25/73

SOUTHERN BELL TELEPHONE AND TELEGRAPH COMPANY

INSTALLATION	GENERIC PROGRAM	EQUIP. LNS(K)	CUTOVER DATE
Atl. Buckhead	SP-CTX3	0.5	10/16/70
Atl. Courtland #0	SP-CTX5	34.8	11/29/70
Atl. Courtland #1	SP-CTX6	6.6	12/07/73
Atl. Smyrna	CC-CTX6	5.1	12/02/73
Atl. East Point	SP-CTX4	6.7	12/06/71
Atl. Hollywood Rd	SP-CTX6	5.1	12/17/73
Atl. Peachtree #1	SP-CTX5	6.7	11/19/67
Atl. Peachtree #2	SP-CTX4	12.8	11/06/71

SOUTHERN BELL TELEPHONE AND TELEGRAPH COMPANY (CONT.)

INSTALLATION	GENERIC PROGRAM	EQUIP. LNS(K)	CUTOVER DATE
Atl. Toco Hills	SP-CTX4	8.2	4/13/72
Charlotte Caldwell	SP-CTX3	10.2	7/17/70
Clarkston Indian Crk	SP-CTX3	21.5	11/29/70
Florence	SP-CTX4	24.6	4/16/72
Ft. Lauderdale	SP-CTX5	39.9	5/02/71
Gainesville, Fla. Main	SP-CTX6	24.5	12/15/73
Hollywood Main	SP-CTX3	24.6	8/16/70
Jacksonville Clay St.	SP-CTX5	14.3	7/19/70
Miami Beach 672	SP-CTX5	17.9	11/15/70
Miami Metro #1	SP-CTX5	17.9	9/15/73
Miami Metro #2	SP-CTX6	10.2	4/20/74
Miami 378	CC3	8.2	11/05/67
Orlando Colonial	SP-CTX4	12.3	12/05/71
Rome	CC-CTX6	4.1	12/29/73
Winst.-Salem 5th St.	SP-CTX3	15.4	6/20/71

THE OHIO BELL TELEPHONE COMPANY

INSTALLATION	GENERIC PROGRAM	EQUIP. LNS(K)	CUTOVER DATE
Akron Blackstone	SP-CTX6	18.9	2/02/74
Canal Winchester	CC-CTX4	10.2	4/22/72
Cleveland Clearwater	CC-CTX4	4.1	9/15/73
Cleveland Main 621	SP-CTX4	20.5	10/07/67
Cleveland Main 687	SP-CTX5	12.8	7/18/70
Cleveland Main 771	SP-CTX6	18.4	7/14/73
Columbus Capitol	SP-CTX5	50.6	11/09/68
Columbus 231	SP-CTX4	8.2	10/02/71
Columbus 274	SP-CTX4	8.2	1/08/72
Dayton 222, 223	SP-CTX5	24.6	8/30/70
Dayton 293	SP-CTX4	8.2	10/16/71
Euclid Redwood	CC-CTX4	6.1	10/04/71
Maple Hts—Montrose	CC-CTX4	4.1	12/03/72
Shaker Heights	SP-CTX4	18.4	9/17/72
Toledo 382	CC-CTX6	11.3	1/26/74
Toledo 476	SP-CTX5	17.4	9/29/73
Toledo 536	SP-CTX5	7.2	5/30/72
Willoughby Whitehall	CC-CTX2	6.1	11/11/70

MICHIGAN BELL TELEPHONE COMPANY

INSTALLATION	GENERIC PROGRAM	EQUIP. LNS(K)	CUTOVER DATE
Ann Arbor	CC-CTX6	8.2	3/01/74
Detroit Fairborn	CC-CTX4	6.1	11/12/72
Detroit Lakeview	CC-CTX4	17.4	9/09/72
Detroit Trinity #1	SP-CTX5	17.9	12/01/68

MICHIGAN BELL TELEPHONE COMPANY (CONTD.)

INSTALLATION	GENERIC PROGRAM	EQUIP. LNS (K)	CUTOVER DATE
Detroit Trinity #2	SP-CTX5	27.6	9/03/72
Detroit Tuxedo	CC-CTX4	20.5	11/11/72
Detroit University	SP-CTX6	28.7	1/20/74
Detroit Valley	SP-CTX1	28.7	6/22/69
Detroit Vermont	CC-CTX6	17.4	9/30/73
Detroit Webster	SP-CTX5	20.5	11/10/68
Detroit Woodward #1	SP-CTX3	20.5	10/27/68
Detroit Woodward #2	SP-CTX3	20.5	8/16/70
Detroit Woodward #3	SP-CTX5	25.6	7/08/72
Detroit Woodward #4	SP-CTX5	8.2	6/23/73
Grand Rapids Monroe	SP-CTX4	16.4	1/16/72
Highland Pk. Townsend	SP-CTX5	27.6	4/14/68
Lansing	SP-CTX6	14.3	3/02/74
Pontiac Main	SP-CTX5	15.4	4/01/73
Southfield	SP-CTX3	16.4	4/04/71
Sterling Hts Warren	CC-CTX6	6.1	6/23/73
Troy Somerset	SP-CTX5	20.5	11/22/71
Warren Techline	SP-CTX5	23.0	3/16/69

INDIANA BELL TELEPHONE COMPANY, INCORPORATED

INSTALLATION	GENERIC PROGRAM	EQUIP. LNS(K)	CUTOVER DATE
Bloomington	SP-CTX5	33.8	12/03/72
Indianapolis 262	SP-CTX4	9.2	8/27/72
Indianapolis 632	SP-CTX4	21.5	9/26/71
Muncie	SP-CTX5	43.0	5/21/72

WISCONSIN TELEPHONE COMPANY

INSTALLATION	GENERIC PROGRAM	EQUIP. LNS(K)	CUTOVER DATE
Green Bay East	CC-CTX4	10.2	8/21/71
Madison Main	SP-CTX4	15.4	8/22/70
Milw. Aetna Court	SP-CTX5	33.8	3/01/69
Milw. Broadway #1	SP-CTX5	28.7	7/12/69
Milw. Broadway #2	SP-CTX5	16.4	12/02/72
Milw. No. 26th St.	SP-CTX5	13.3	6/02/73
Milw. No. 41st St.	CC-CTX4	15.4	5/15/71
Milw. So. Logan	CC-CTX4	20.5	4/22/72
Milw. So. 26th St.	CC-CTX4	18.4	10/30/71
Milw. Wright	CC-CTX4	10.2	5/20/72
Somers Parkside	CC-CTX4	9.2	7/10/71

ILLINOIS BELL TELEPHONE COMPANY

INSTALLATION	GENERIC PROGRAM	EQUIP. LNS(K)	CUTOVER DATE
Alton College St.	SP-CTX4	18.4	4/04/71
Arlington Heights	CC-CTX4	8.2	12/23/71
Aurora Main	SP-CTX3	24.6	9/20/70
Bellwood	CC-CTX4	10.2	6/24/73
Calumet City	CC-CTX4	6.1	5/14/71
Champaign Main	SP1	28.7	7/04/69
Champaign University	CC-CTX2	15.4	11/27/69
Chicago Beverly	SP-CTX5	14.8	12/03/72
Chicago Calumet	SP-CTX5	36.9	4/12/70
Chicago Canal	SP-CTX6	17.9	2/24/73
Chicago Franklin #1	SP-CTX5	25.6	5/24/69
Chicago Franklin #2	SP-CTX6	16.4	5/28/72
Chicago Monroe	SP-CTX6	30.7	2/15/70
Chicago Portsmouth	CC-CTX4	7.2	11/28/71
Chicago Pullman	SP-CTX6	20.5	6/11/72
Chicago Superior #1	SP-CTX5	26.6	11/10/68
Chicago Superior #2	SP-CTX6	15.4	1/22/72
Chicago Wabash #1	SP-CTX5	16.4	5/27/73
Chicago Wabash #2	SP-CTX5	17.9	5/27/73
Decatur	SP-CTX4	36.9	10/31/71
Elk Grove	CC-CTX4	8.7	12/06/70
Gary North	SP-CTX5	11.3	7/22/73
Chicago Lake Shore	SP-CTX6	15.3	12/15/73
Hinsdale	CC-CTX6	14.3	11/02/69
Hoffman Willow Crest	SP-CTX5	25.6	4/08/73
Kankakee	SP-CTX4	27.6	8/29/71
Lombard	CC-CTX6	6.1	9/30/73
Moline	SP-CTX5	22.5	1/09/72
Peoria Jefferson	SP-CTX3	36.9	8/04/68
Rockford	SP-CTX6	41.0	3/07/71
Summit	CC-CTX6	7.2	2/21/71

NORTHWESTERN BELL TELEPHONE COMPANY

INSTALLATION	GENERIC PROGRAM	EQUIP. LNS(K)	CUTOVER DATE
Council Bluffs	SP-CTX4	25.6	7/10/71
Des Moines Ashworth	CC-CTX4	6.1	11/20/71
Des Moines Downtn	SP-CTX6	12.0	12/07/73
Minneapolis Cedar St.	SP-CTX5	14.3	8/11/72
Minneapolis Crystal	SP-CTX5	28.7	3/08/70
Minneapolis Dwntn #1	SP-CTX3	21.5	10/09/70
Minneapolis Dwntn #2	SP-CTX5	17.4	4/15/73
Minneapolis Franklin	SP-CTX6	16.4	2/16/74
Minneapolis Hopkins	SP-CTX5	28.7	2/24/73
Minneapolis Normandl	SP-CTX5	14.3	10/08/72
Minneapolis South	SP-CTX6	28.7	5/21/71

NORTHWESTERN BELL TELEPHONE COMPANY (CONT.)

INSTALLATION	GENERIC PROGRAM	EQUIP. LNS(K)	CUTOVER DATE
Minneapolis. Orchard	SP-CTX6	23.5	12/22/73
Omaha Douglas	SP-CTX5	24.6	9/05/70
Omaha Izard	SP-CTX5	20.5	3/03/73
Omaha 78th St.	SP-CTX4	16.4	5/16/71
Rapid City, Sd.	CC-CTX6	19.7	11/24/73
Rochester	SP-CTX4	14.3	2/26/67
Sioux Falls Downtown	SP-CTX5	41.0	3/25/73
St. Paul Cottage Gr.	CC3	10.2	10/15/67
St. Paul Market	SP-CTX5	16.9	2/18/72
St. Paul Park Row	CC-CTX6	16.4	2/16/74

SOUTHWESTERN BELL TELEPHONE COMPANY

INSTALLATION	GENERIC PROGRAM	EQUIP. LNS(K)	CUTOVER DATE
Austin, Greenwood	SP-CTX6	32.2	10/27/73
Ballwin Manchester	SP-CTX3	12.8	2/22/71
Dallas Addison 239	SP-CTX5	20.5	7/29/72
Dallas Emerson #1	SP-CTX5	28.7	4/30/70
Dallas Emerson #2	SP-CTX5	24.6	2/17/73
Dallas Farm. Branch	SP-CTX5	24.6	12/09/72
Dallas Riverside #1	SP-CTX5	20.5	1/29/72
Dallas Riverside #2	SP-CTX5	18.4	10/28/72
Dallas Whitehall	SP-CTX5	24.6	4/22/72
Ft. Worth Arlington	SP-CTX5	12.3	3/05/73
Ft. Worth Edison	SP-CTX5	20.5	5/19/73
Hazelwood	SP-CTX5	20.5	3/26/72
Houston Capitol #1	SP-CTX5	16.4	6/28/69
Houston Capitol #2	SP-CTX5	27.6	8/18/73
Houston Fairbanks	SP-CTX5	20.5	10/21/72
Houston Homestead	SP-CTX3	25.6	8/28/71
Houston Mohawk #1	SP-CTX5	24.6	1/27/73
Houston Mohawk #2	SP-CTX5	28.7	9/22/73
Houston Republic	SP-CTX5	23.0	9/29/73
Kansas City Drexel	SP-CTX3	24.6	5/29/71
Kansas City Hiland	SP-CTX5	28.7	4/08/73
Kansas City Wabash	SP-CTX3	25.1	5/23/71
Kirkwood, Mo.	SP-CTX6	.5	11/18/73
Little Rock Franklin	SP-CTX6	9.2	1/19/74
Oklahoma City Jacks.	SP-CTX5	21.5	8/31/73
St. Louis Chestnut #1	SP1	26.1	11/01/69
St. Louis Chestnut #2	SP-CTX4	15.4	2/12/72
St. Louis Evergreen	SP1	26.1	2/02/69
St. Louis Flanders	SP-CTX4	20.5	10/17/71

SOUTHWESTERN BELL TELEPHONE COMPANY (CONTD.)

INSTALLATION	GENERIC PROGRAM	EQUIP. LNS (K)	CUTOVER DATE
St. Louis Forest	SP-CTX5	13.3	8/05/72
St. Louis Jefferson	SP-CTX5	21.5	6/17/72
St. Louis Mission	SP-CTX4	16.4	3/19/72
St. Louis Parkview	SP-CTX5	35.3	12/16/72
Tulsa Elgin	SP-CTX6	18.7	7/01/73

THE MOUNTAIN STATES TELEPHONE AND TELEGRAPH COMPANY

INSTALLATION	GENERIC PROGRAM	EQUIP. LNS(K)	CUTOVER DATE
Boulder Table Mesa	SP-CTX4	18.4	11/07/71
Broomfield Northglen	SP-CTX4	16.4	4/16/72
Colo. Spgs. Pikeview	SP-CTX3	10.2	12/13/70
Denver East	SP-CTX5	10.2	4/29/72
Denver Lakewood	SP-CTX5	20.5	7/17/71
Denver Littleton	SP-CTX5	26.1	1/17/71
Denver Main #1	SP-CTX6	29.2	2/26/69
Denver Main #2	SP-CTX4	24.6	10/31/71
Denver Main #3	SP-CTX5	18.4	6/02/73
Denver North	SP-CTX4	13.3	3/05/72
Denver South	SP-CTX5	12.3	8/20/72
Denver Southeast	SP-CTX5	12.3	9/20/69
Denver Westminster	SP-CTX4	8.2	6/06/70
El Paso Southeast	SP-CTX4	4.1	10/24/71
Los Alamos Main	CC-CTX1	8.2	2/14/70
Phoenix Main	SP-CTX6	10.8	4/28/73
Phoenix Maryvale	CC-CTX2	15.4	1/31/71
Phoenix McClintock	CC-CTX4	12.3	2/06/72
Phoenix Mesa	CC-CTX4	15.4	9/01/71
Phoenix North	SP-CTX6	25.1	8/17/69
Phoenix Northwest	SP-CTX4	10.2	2/06/72
Salt Lake City East	SP-CTX4	10.8	6/28/71
Salt Lake City Main	SP-CTX5	10.8	5/07/73
Tucson Craycroft	CC-CTX4	12.3	7/15/73

PACIFIC NORTHWEST BELL TELEPHONE COMPANY

INSTALLATION	GENERIC PROGRAM	EQUIP. LNS(K)	CUTOVER DATE
Bellevue Glencourt	SP-CTX5	16.4	7/02/67
Eugene 10th Ave	SP-CTX5	16.4	8/22/70
Olympia Evergreen	CC-CTX4	4.1	7/14/73
Olympia Whitehall	SP-CTX4	14.3	11/05/71
Portland Belmont	SP-CTX6	15.4	8/18/73

THE MOUNTAIN STATES TELEPHONE AND TELEGRAPH COMPANT (CONT.)

INSTALLATION	GENERIC PROGRAM	EQUIP. LNS(K)	CUTOVER DATE
Portland Capitol #1	SP-CTX6	17.9	12/03/71
Portland Capitol #2	SP-CTX5	14.3	12/02/72
Portland Capitol #3	SP-CTX6	14.3	8/18/73
Salem	SP-CTX5	8.2	12/09/72
Seattle Campus	SP-CTX5	12.3	5/28/72
Seattle Cherry	CC-CTX6	4.1	3/17/73
Seattle Main #1	SP-CTX6	10.2	1/29/71
Seattle Main #2	SP-CTX5	15.4	12/26/72
Seattle West	CC3	10.2	11/23/69
Springfield N.E. 10th	SP-CTX5	25.6	4/22/72
Tacoma Skyline	SP-CTX6	18.4	8/12/73

THE PACIFIC TELEPHONE AND TELEGRAPH COMPANY

INSTALLATION	GENERIC PROGRAM	EQUIP. LNS(K)	CUTOVER DATE
Alhambra 1st St.	SP-CTX4	12.3	10/04/69
Anaheim	CC-CTX4	6.1	10/17/72
Brea	CC-CTX6	12.3	3/23/74
Burlingame	SP-CTX3	10.2	1/09/71
Compton	CC-CTX6	7.2	4/27/74
Danville	CC-CTX6	12.3	1/07/74
El Cajon	CC-CTX4	5.1	6/18/72
Escondido	CC-CTX4	5.1	11/14/72
Hawthorne	SP-CTX4	15.4	9/25/71
Hayward	SP-CTX5	9.2	11/14/70
L.A. Daley	SP-CTX6	16.4	3/08/74
L.A. So. Vermont	SP-CTX4	8.2	12/18/71
L.A. West Adams	CC-CTX4	8.2	6/29/69
L.A. Whittier	SP-CTX4	7.2	4/17/71
L.A. 420 So. Grand #0	SP-CTX4	22.5	5/29/70
L.A. 420 So. Grand #1	SP-CTX5	20.5	3/17/72
L.A. 420 So. Grand #2	SP-CTX6	20.5	3/30/73
L.A. 420 So. Grand #3	SP-CTX6	20.5	2/08/74
Monterey	SP-CTX6	2.0	2/15/74
Northridge	SP-CTX3	10.2	1/23/71
Oakland Franklin #1	SP-CTX4	21.5	2/26/71
Oakland Franklin #2	SP-CTX5	28.7	2/17/73
Oakland Franklin #3	SP-CTX5	12.3	2/17/73
Oakland Holly	SP-CTX4	24.6	7/15/72
Palo Alto	SP-CTX4	8.2	2/12/72
Pasadena	CC-CTX6	6.1	7/21/73
Rosemead	SP-CTX4	8.2	7/01/71
S.F. McCoppin St.	SP-CTX4	20.5	9/19/70
S.F. 2nd & Folsom	SP-CTX6	20.5	5/25/73
S.F. 2345 Pine St. #1	SP-CTX5	8.2	10/24/70

THE PACIFIC TELEPHONE AND TELEGRAPH COMPANY (CONT.)

INSTALLATION	GENERIC PROGRAM	EQUIP. LNS(K)	CUTOVER DATE
S.F. 2345 Pine St. #2	SP-CTX4	23.6	2/04/72
S.F. 555 Pine St. #1	SP-CTX5	26.1	4/16/71
S.F. 555 Pine St. #2	SP-CTX4	20.5	1/21/72
S.F. 555 Pine St. #3	SP-CTX5	20.5	8/04/72
S.F. 9th Ave	SP-CTX4	8.2	12/04/71
S.J. Almaden Valley	SP-CTX4	10.2	1/29/72
S.J. So. White Road	CC-CTX4	12.3	1/22/72
Sacramento Wabash	CC-CTX4	4.1	4/08/72
San Bruno SF Airpt	SP-CTX5	10.2	6/03/72
San Diego Lindavista	CC-CTX4	10.2	8/26/72
San Diego 9th Ave	SP-CTX5	17.9	3/12/71
San Jose Main	SP-CTX4	16.4	1/28/72
San Juan Capistrano	CC-CTX4	12.3	12/18/71
San Mateo	SP-CTX5	20.5	11/08/69
Santa Ana-5th St.	SP-CTX4	13.8	9/02/67
Santa Ana, Irvine	CC-CTX6	12.3	9/23/73
Stockton Main	CC-CTX4	8.2	4/03/71
Van Nuys Cedros	SP-CTX6	4.1	1/09/72
W.L.A. Bev. Hills #1	CC-CTX6	11.3	1/08/67
W.L.A. Bev. Hills #2	SP-CTX4	22.5	9/06/70

CINCINNATI BELL INC.

INSTALLATION	GENERIC PROGRAM	EQUIP. LNS(K)	CUTOVER DATE
Avondale	SP-CTX5	8.7	7/15/73
Cincy. East	CC-CTX4	9.2	1/10/71
Cincy. Groesbeck	CC-CTX4	4.1	6/04/72
Cincy. Valley	CC-CTX4	12.3	5/07/72
Cincy. W. 7th St. #1	SP-CTX5	27.6	10/26/68
Cincy. W. 7th St. #2	SP-CTX5	18.4	6/14/70
Covington	SP-CTX4	16.4	8/01/71
Hamilton	SP-CTX3	27.7	11/02/69
Norwood	SP-CTX5	22.5	4/16/72

THE SOUTHERN NEW ENGLAND TELEPHONE COMPANY

INSTALLATION	GENERIC PROGRAM	EQUIP. LNS(K)	CUTOVER DATE
Bridgeport	SP-CTX6	32.8	1/26/74
Bristol	CC-CTX4	6.1	4/21/68
Hartford	SP-CTX6	17.5	12/31/73
Manchester	CC-CTX4	7.7	8/26/67
Meriden	CC-CTX4	3.1	1/18/70
New Haven Hamden	CC-CTX2	3.1	12/06/70
New Haven Westville	CC-CTX4	3.1	5/31/70
Norwalk	CC-CTX4	8.7	10/21/67
Stamford	CC-CTX6	6.1	2/25/73
Stratford	CC-CTX4	5.6	12/17/67

No. 1 ESS Offices in Service as of May 1, 1974

CC-3	6
SP-1	4
CC-CTX-1	2
CC-CTX-2	7
CC-CTX-4	66
CC-CTX-6	32
SP-CTX-1	2
SP-CTX-3	31
SP-CTX-4	72
SP-CTX-5	174
SP-CTX-6	55
	451

Bell of Canada

SP-CTX-1	11

No. 1 ESS (2-wire) Systems and Lines in Service

	1965	1966	1967	1968	1969	1970	1971	1972	1973
Systems	1	2	18	41	70	127	208	315	427
Working Lines (Millions)	.004	.008	.076	.339	.642	1.233	2.107	3.585	5.347

XIV - MAJOR DOCUMENTATION AND REFERENCES.

Note: the following list of documentation may contain several letters, etc. relating to the same topic. As a routine matter, the reader should always consult the latest correspondence on a given subject.

1. BOOKS, MANUALS, ETC.

Traffic Engineering Guide (TEG) No. 1 ESS (2-Wire)	Sections 1 — 10
Translation Guide (TG-1A) No. 1 ESS	Volume I — IV
Traffic Facilities Notes and Practices (TFN&P)	Division D, Section 10
No. 1 Electronic Switching System Trunk and Service Circuit Engineering Specifications, (J1A063A-1)	
Floor Plan Data Sheets	Section 12
Program Specification (PD)	PD-1A001 to PD-1A200
Program Listing (PR)	PR-1A004 to PR-1A200
Program Flowchart (PF)	PF-1A004 to PF-1A200
Output Manual (OM)	OM-1A001
Input Manual (IM)	IM-1A001
Schematic Drawings (SD)	SD-1A100 to SD-1A330
Engineered Order Manual	
Broad Gauge Price Estimating Guide	
No. 1 ESS 2-Wire Parameter	PA-591001 Volume I,II
No. 1 ESS 2-Wire Translation Output Configuration	PA-591003
No. 1 ESS 2-Wire Reproducible Forms for Growth Recent Change	PA-591099
Program Map	PK-1A002
COMPOOL Record	PK-1A003
Raw Data Documents	PK-1A016 to PK-1A121
Trouble Locating Manuals (TLM)	TLM-1A100 to TLM-1A301
Western Electric Installation Handbook 275	
E-8056 and E-8056A No. 1 ESS Equipment Questionnaire and Equipment Notes	
E-1896 Power Questionnaire	
E-8070 Questionnaire for Junctor Assignment in No. 1 ESS	
Bell System Technical Journal "No. 1 Electronic Switching System"	Vol. 43, September, 1964
PA-591099 Reproducible Copy of all GRC Forms	
Bell System Practices	Sections 231, 820, 966

PBX-CENTREX SYSTEMS Information Package	
ESS News	Number 1 to 10
SPCS News	Number 11 to 12
ELECTRONIC SWITCHING SYSTEMS — Plant Training Administration Guidelines	
M-284 Customer Records and Billing — Definitions and Specifications	
BELL LABORATORIES RECORD	

Article	Issue
Electronic Switching Control Techniques	April 1962
Electronic Switching Introduction	June 1965
The Evolution of Telephone Switching	June 1965
From Morris to Succasunna	June 1965
Features and Service	June 1965
The Stored Program	June 1965
The Control Unit	June 1965
Memory Devices	June 1965
The Switching Network	June 1965
Mechanical Design	June 1965
Power System and Ringing and Tone Plants	June 1965
A New Approach to System Maintenance	June 1965
Some Magnetic Materials	June 1965
Semiconductor Devices	June 1965
Testing the System	June 1965
Cut-Over at Succasunna	June 1965
A Computer Program for No. 1 ESS Junctor Assignments	June 1965
AMA for No. 1 ESS	September 1966
Translations and Recent Change Information in No. 1 ESS	March 1967
Trunk and Line Testing for No. 1 ESS	December 1967
New Connectors Plug in ESS Frames for Fast Installation and Easy Growth	October 1968
Centrex Service In No. 1 ESS	November 1968
The No. 1 ESS Signal Processor	April 1969
A Decade of ESS	December 1970
What's New in No. 1 ESS	June/July 1971
Service Link Network Simplified No. 1 ESS Call Handling	June/July 1971
Streamlined Programs and Expanded Use of Memories Boost No. 1 ESS Capacity	June/July 1971
Emergency Action for No. 1 ESS	June/July 1971
New Memory Reduces No. 1 ESS Cost and Size	April 1971
Major Trends in Switching	October 1972
Patrol Surveys Traffic for No. 1 ESS Offices	March 1973

2. ENGINEERING AND PLANT LETTERS AND MEMORANDA

Date	Number	Title
12/18/62	P.E.L. 7100	No. 1 ESS — Brochure
12/28/62	P.E.M. 8191	ESS — BSP Number Assignment
12/16/63	P.E.L. 7257	No. 1 ESS — Equipment Questionnaire and Trunk Coding Table
12/17/63	P.E.M. 8625	No. 1 ESS — Changes in Equipment Frames
2/26/64	P.E.M. 8727	No. 1 ESS — 723A Tool-Circuit Pack Extractor
3/18/64	P.E.M. 8758	ESS — Documentation
4/30/64	P.E.M. 8814	No. 1 ESS — Floor Plan Information
8/14/64	P.E.M. 8929	No. 1 ESS Equipment Frames
1/14/65	P.E.M. 9145	No. 1 ESS Main Distributing Frame Loudspeakers
1/15/65	P.E.M. 9150	ESS — Documentation
1/15/65	P.E.M. 9151	Engineering Drawings — Latest List of Subdivisions for SD, T, ED, J Drawings and Circuit Discrepancies
1/25/65	P.E.M. 9158	No. 1 ESS — MDF Arrangements
4/26/65	P.E.M. 9293	T1 Carrier — 7 Foot High Bays for No. 1 ESS Offices
7/13/65	P.E.M. 9419	No. 1 ESS — Magnetic Latching Relay Timing Set
8/18/65	P.E.M. 9463	Floor Plan Information
9/17/65	P.E.L. 7473	No. 1 ESS — Supplementary Trunk Testing Positions
12/16/65	P.E.M. 9616	Program Documents for Stored Program Control Systems
1/13/66	P.E.M. 9659	Crossbar Tandem — TSP and other CAMA Trunks for Operation with No. 1 ESS
3/25/66	P.E.L. 7522	No. 1 and No. 101 ESS — Pressure Cleaning
5/02/66	P.E.L. 7509	No. 1 ESS — Line and Trunk Assignments for Testing
6/06/66	P.E.M. 9793	No. 1 ESS — Equipment Prices
6/24/66	P.E.M. 9907	No. 1 ESS, 2- and 4-Wire New Magnetometer Probe
7/01/66	P.E.M 9910	No. 1 ESS 2-Wire — Portable Maintenance Equipments, Apparatus, Cords and Materials
7/14/66	P.E.M. 9931	No. 1 ESS — Tool and Gauges for use on 1A Card Writer Unit and 1A Card Loader
9/16/66	P.E.M. 9787	No. 1 ESS — Magnetic Tape Requirements for AMA Recording
9/19/66	E.M. 0031	No. 1 ESS, TSPS No. 1, No. 2 ESS — Considerations Grounding for Planning Purposes
9/21/66	E.M. 0037	No. 1 ESS (2-Wire and 4-Wire) — Return and Repair of Circuit Packages
9/28/66	P.E.L. 7532	No. 1 ESS — Equipment Engineering Procedures for Ordering Junctor Assignment Service and for Furnishing Line and Trunk Assignments to WECO
10/13/66	E.M. 0061	No. 1 ESS — Change in Teletypewriter Circuitry to Include Provision for an Even Parity Bit
12/02/66	E.M. 0133	No. 1 ESS (Two-Wire) — Trunk Circuits Required with the MCC and STT Test Panels
12/14/66	P.E.L. 7567	No. 1 ESS — Nine Track AMA Recording

Date	Number	Title
12/15/66	E.M. 0170	Program Documents for Stored Program Control Systems
12/16/66	E.M. 0171	No. 1 ESS (Two-Wire) — Availability of Trunk and Service Circuit Engineering Specification
2/01/67	E.M. 0227	T1 Carrier — Carrier Group Alarm for No. 1 ESS Office
2/24/67	E.M. 0258	No. 1 ESS — Power Systems — Information Concerning Power Plant Requirements
3/10/67	E.M. 0291	Toll Systems — Requirements for E and M Lead Signaling Applique for Use with No. 1 ESS (Two-Wire)
3/28/67	E.M. 0311	Program Documents — ESS — Advise of Change
4/18/67	E.M. 0342	No. 1 ESS — Redesign of Junctor Frame, Line Switching Frame and Universal Trunk Frame
5/22/67	E.M. 0371	No. 1 ESS — Service Observing on AMA Outgoing Traffic
7/07/67	E.M. 0384	No. 1 ESS (2-Wire) — Cutover Program
7/07/67	E.M. 0462	No. 1 ESS — New EA-4
8/03/67	E.M. 0499	Power Systems — Multiple Paired 111A Power Plants for No. 1 ESS Applications
8/15/67	E.M. 0548	No. 1 ESS 2-Wire and 4-Wire — A3 Switchboard Lamps
8/21/67	E.M. 0497	714E2 Tool for Wiring 66G and 66H Connecting Blocks in No. 1 ESS
8/30/67	P.L. 1567-3A	Reports of Service Problems in No. 1 ESS Central Offices
9/11/67	E.M. 0548	No. 1 ESS 2-Wire and 4-Wire — Procedures and Flow of Information for In-Service Offices
10/17/67	E.M. 0532	No. 1 ESS Portable Maintenance Equipment, Apparatus, Cards and Materials
2/09/68	E.M. 0785	No. 1 ESS — 3A Memory Card
3/15/68	E.M. 0798	BUILDINGS: Heat Release for No. 1 ESS and TSPS No. 1
3/25/68	E.M. 0837	No. 1 ESS — Test Tape for Accounting Center AMA Programs
4/18/68	E.M. 0867	Crossbar Tandem — 100A Traffic Service Position and Traffic Service Position Systems No. 1 — Trunking from No. 1 ESS
5/10/68	E.M. 0892	ESS — 105 Type Transmission Test Line
5/10/68	E.M. 0896	No. 1 ESS — Modification of #A Code Call Circuit for Operation with No. 1 ESS CENTREX
6/17/68	E.M. 0939	No. 1 ESS 2- and 4-Wire Additional Maintenance Items
9/19/68	E.M. 1082	No. 1 ESS (2-Wire) — Availability of Trunk and Service Circuit Software Engineering Specifications
10/22/68	E.M. 1054	Program Documents — ESS — Program Application Specifications
10/22/68	E.M. 1116	Bell System Practices — Standing Orders for No. 1 ESS CENTREX and No. 101 ESS Practices Rated AT&TCo. SPCS
11/22/68	E.M. 1162	ESS — 75682 Tool
12/13/68	E.M. 1191	Power Systems — Solid-State Interrupter for use in 806H and 808A Ringing and Tone Plants for No. 1 ESS Offices
3/21/69	E.M. 1314	No. 1 ESS Electromagnetic Compatibility
4/22/69	P.L. 2344-1	No. 1 ESS 2-Wire — Interim Service Results Plan

Date	Number	Title
5/29/69	E.M. 1306	No. 1 ESS — CC-3 Generic Program Features and Improvements
5/02/69	E.M. 1317	No. 1 ESS — Evaluation of Standard Load Test Procedures
6/24/69	E.M. 1343	No. 1 ESS — Reissuance of Junctor Assignment Program Questionnaire E8070
6/24/69	E.M. 1472	No. 1 ESS — Environmental Limits
6/26/69	E.M. 1474	No. 1 ESS — CC-CTX-2 Generic Features and Improvements
8/04/69	E.M. 1547	No. 1 ESS — TOUCH-TONE Calling Detector Circuit
8/06/69	E.M. 1435	Input and Output Message Manuals — ESS — Channel Manuals
8/12/69	E.M. 1533	No. 1 ESS — Improved Cutover Program
8/13/69	E.M. 1545	No. 1 ESS 2- and 4-Wire — Emergency Service Procedures and Flow of Information for In-Service Offices
9/22/69	E.L. 297	Service Link Network (SLN) for No. 1 ESS
11/11/69	E.M. 1679	No. 1 ESS — Line and Trunk Assignments for Testing
12/30/69	E.M. 1707	No. 1 ESS — Permanent Signal, Partial Dial Treatment to Preclude Receiver Off Hook (ROH) Tone for PBX Lines
1/07/70	E.M. 1785	No. 1 ESS — Provision of Limited Plant Measurement
2/13/70	E.M. 1735	No. 1 ESS — Development of Coin Service Improvement Features
3/26/70	E.L. 403	No. 1 ESS — Improved Cutover Programs
3/31/70	E.L. 452	Multilevel Precedence and Preemption Feature in SP-CTX-3
3/31/70	E.L. 483	No. 1 ESS — Equipment Additions to In-Service Offices
5/08/70	E.L. 548	No. 1 ESS — Additional Maintenance Items
5/25/70	E.L. 572	Power System — No. 1 ESS — 812A Solid State Ringing and Tone Power Plant
7/14/70	E.L. 664	No. 1 ESS 2-Wire — Auxiliary Program for ESS Offices
8/08/70	P.L. 2344-2	No. 1 ESS 2-Wire — Service Results Plan
8/10/70	E.L. 718	No. 1 ESS 2-Wire Elimination of E-Digit Blocking on Customer-Dialed 10-Digit Calls
8/24/70	E.L. 766	No. 1 ESS 2-Wire — Portable Test Equipment
9/11/70	E.L. 725	No. 1 ESS — Tandem Tie Line Feature (1XX Cut-Through)
9/16/70	P.L. 1567-3B	Reports of Service Problems in No. 1 ESS
11/09/70	E.L. 911	No. 1 ESS 2-Wire — Auxiliary Programs for ESS Offices
11/19/70	E.L. 792	No. 1 ESS — Translations Area Analysis (TAA) and Translations Retrofit Repack (TRR) System
12/17/70	E.L. 943	No. 1 ESS — Improved Cutover Program
12/21/70	E.L. 942	No. 1 ESS — Automatic Intercept Service Feature
12/31/70	E.L. 1004	Power Sharing by Two or More No. 1 ESS Offices
1/18/71	E.L. 1033	No. 1 ESS — Open Switching Interval Protection Feature
1/25/71	E.L. 1071	No. 1 ESS — 2- and 4-Wire Auxiliary Programs Used During Additions and Retrofit
1/26/71	E.L. 1051	No. 1 ESS — New Maintenance Features

Date	Number	Title
2/19/71	E.L. 1096	No. 1 ESS — Cardwriting Protection Feature
3/10/71	E.L. 1125	No. 1 ESS — International Direct Distance Dialing (IDDD) Feature
3/14/71	E.L. 1252	A-Coded Circuit Packs
4/02/71	E.L. 1173	No. 1 ESS — Combined TOUCH-TONE and Dial Pulsing On Incoming Tie Trunks Feature
4/06/71	E.L. 1174	No. 1 ESS — 32K Call Store J1A072A
5/07/71	E.L. 1151	Systems Planning — No. 1 ESS Combined Local and Toll Operations
6/11/71	E.L. 1305	No. 1 ESS — 4- and 8-Party Features
6/14/71	E.L. 1296	Power Systems — Power Sharing Between TSPS and No. 1 ESS
8/13/71	P.L. 2344-3	No. 1 ESS 2-Wire Service Results Plan
8/18/71	E.L. 1385	Oscilloscopes Uses in Electronic Switching and Traffic Service Systems
8/18/71	E.L. 1418	No. 1 ESS — Recent Change Messages Associated with Junction Redistribution Provision of Punched Paper Tape
9/20/71	E.L. 1458	Guidelines for Terminating More Than One No. 1 ESS Control Group (Entity) on Modular Distributing Frames
9/21/71	E.L. 1450	No. 1 ESS — Economics of Signal Processor Additions
10/14/71	E.L. 1492	No. 1 ESS (2-Wire) — Teletypewriter Control of Line Load Control and Toll Network Protection
10/28/71	E.L. 1508	No. 1 ESS — Planning for Future Retrofits of 1A Processors into No. 1 ESS Offices
11/03/71	E.L. 1510	Emergency Recovery Routine for No. 1 ESS
11/11/71	E.L. 1509	Generic Overwrites in No.1 ESS
11/30/71	E.L. 1560	No. 1 ESS Toll Tandem Capabilities
1/06/72	E.L. 1595	No. 1 ESS — Procedure for Inserting Generic Overwrites
1/19/72	E.L. 1598	No. 1 ESS — Automatic Identified Outward Dialing (AIOD)
1/20/72	E.L. 1631	No. 1 ESS Standardization of Network Options
1/21/72	E.L. 1633	No. 1 ESS — Centrex Attendant Control of Facilities Feature
2/09/72	E.L. 1674	No. 1 ESS — Corrections to Ordering Information for Coin Service Improvement
2/28/72	E.L. 1703	No. 1 ESS 2-Wire Offices — Maintenance of Generic Programs
3/01/72	E.L. 1701	No. 1 ESS — Interchangeable Area and Office Codes
3/13/72	E.L. 1731	No. 1 ESS — CC to SP Conversion
3/28/72	E.L. 1562	No. 1 ESS — 3A Memory Card
4/19/72	E.L. 1654	Environmental Limits — Electronic Systems
4/21/72	E.L. 1815	No. 1 ESS — Three-Way Calling Feature
4/21/72	E.L. 1816	No. 1 ESS — Call Forwarding Features for Centrex CO Customers
5/04/72	E.L. 1837	No. 1 ESS — Modifications to the Code Calling Feature to Allow Attendant and Tie Trunk Access to Code Calling

Date	Number	Title
5/04/72	E.L. 1838	No. 1 ESS (2-Wire) — Centrex CO Attendant Camp-on Feature
5/15/72	E.L. 1862	No. 1 ESS — Thru Dialing
5/18/72	E.L. 1872	No. 1 ESS Standardization of Network Options
5/25/72	E.L. 1884	No. 1 ESS (2-Wire) — Increased Carrier Group Alarm Capacity
6/05/72	E.L. 1897	No. 1 ESS — Elimination of Centrex Timed Reminder on Tie Trunks and Improvement of the Call Waiting
6/05/72	E.L. 1898	No. 1 ESS (2-Wire) — Centrex CO Call Waiting Service
6/06/72	E.L. 1899	No. 1 ESS (2-Wire) — Centrex CO Attendant Busy — Verification for Lines Feature
6/29/72	E.L. 1956	No. 1 ESS — Belt Line TTY
7/06/72	E.L. 1638	No. 1 ESS (2-Wire) — Improved TOUCH-TONE Testing
7/14/72	E.L. 1929	No. 1 ESS (2-Wire) — APT02 Auxiliary Program Package
7/31/72	E.L. 2026	No. 1 ESS (2-Wire) — Busy verification of Centrex Trunks and Centrex Call Through Tests on Tie Trunks
9/26/72	E.L. 2037	No. 1 ESS (2-Wire) — APT03 Auxiliary Program Package
9/22/72	E.L. 2109	Use of Copy Mode Routine for Installing No. 1 ESS Generic Program Restart Issues
10/26/72	E.L. 2123	No. 1 ESS — Interval Reduction
10/31/72	E.L. 2174	No. 1 ESS — The Cut-Through to Operator after Intercept Announcement Feature
12/06/72	E.L. 2251	No. 1 ESS — Service Link Network
12/14/72	E.L. 2260	No. 1 ESS — AMA Tape Format Changes for the Centrex 6 Generic Program
12/28/72	E.L. 2303	No. 1 ESS — Improved Plant Measurements
1/11/73	E.L. 2319	No. 1 ESS — Standard Call Forwarding for Non-Centrex Service
2/05/73	E.L. 2369	No. 1 ESS — Growth Recent Change (GRC) Forms
2/22/73	E.L. 2411	No. 1 ESS — Use License for Software
3/09/73	E.L. 2435	No. 1 ESS — Announces the Initial Phase of Network Management Controls in the CTX-6 Generic Program
3/23/73	E.L. 2461	No. 1 ESS — Two-Wire Toll Operation with Centrex 7 Generic Program; Engineering Information
4/05/73	E.L. 2493	No. 1 ESS — Development of the Capability to Receive Revertive Pulse Office Brush and Group Selections with the Centrex 6 Generic Program
4/12/73	E.L. 2507	No. 1 ESS Centralized Spare Parts
5/01/73	E.L. 2160	Transmission Aspects of No. 1 ESS Toll
5/02/73	E.L. 2536	No. 1 ESS — Parameter Listings
5/24/73	E.L. 2570	No. 1 ESS — Incoming Trunk Overload Control Feature in CTX-6 Generic Program
6/19/73	E.L. 2688	No. 1 ESS — Switching Control Center
7/10/73	E.L. 2505	No. 1 ESS — 2-Wire — Remote Office Test Line and Processor Controlled Interrogator

Date	Number	Title
9/06/73	E.L. 2787	No. 1 ESS — Development of New Features for Universal Emergency Service Number 911
9/07/73	E.L. 2789	No. 1 ESS — Additions and Improvements of Traffic Measurements in Centrex 6 Generic Programs
9/10/73	E.L. 2792	No. 1 ESS — Network Maintenance Improvements
9/10/73	E.L. 2794	No. 1 ESS — Recent Change Message Interpretation for Centrex 6 and Later Generic Programs
9/21/73	E.L. 2757	No. 1 ESS — Universal Input/Output Circuit — SD-1A147-02
9/26/73	E.L. 2839	No. 1 ESS — The Recorded Announcement Machine Control Program (RAMP)
9/28/73	E.L. 2858	No. 1 ESS — Compatibility with 100-Series Data Sets
10/16/73	E.L. 2869	No. 1 ESS — International Direct Distance Dialing Feature — TSPS Arrangement
10/18/73	E.L. 2876	No. 1 ESS — Toll Center Operation: Operator Tandem Feature
11/19/73	E.L. 3034	No. 1 ESS — Hotel/Motel Service
12/06/73	E.L. 2920	No. 1 ESS — Dead Start Features
12/28/73	E.L. 2949	No. 1 ESS — AMA Tape Format Changes for the Centrex 7 Generic Program
1/03/74	E.L. 2957	No. 1 ESS Centrex Conference Calling
1/07/74	E.L. 2961	No. 1 ESS — Call Pickup Feature
1/21/74	E.L. 2992	No. 1 ESS — 2-Wire ALIT Single Line Demand Test Feature
1/21/74	E.L. 2993	No. 1 ESS — 2W — Additional Maintenance Features for the CTX-6 Generic Program
1/22/74	E.L. 2985	No. 1 ESS — Automatic Positioning of the Beginning of Tape (BOT) Mark and Protection Against Improper Tape Mounting
2/08/74	E.L. 2586	No. 1 ESS — Automatic Board-to-Board Testing
2/15/74	E.L. 3096	No. 1 ESS — Remreed Trunk Link Network
2/19/74	E.L. 3098	No. 1 ESS — Development of Types of Hunting Arrangements and Make-Busy Keys for Multiline Hunt Groups
3/05/74	E.L. 3125	No. 1 ESS — Development of 2048-Junctor Trunk Link Network Feature
3/13/74	E.L. 3138	No. 1 ESS — Flexible Route Selection
3/27/74	E.L. 2994	Comparative Costs of Providing Business Services Using the No. 1 ESS Versus Customer Premises System
3/29/74	E.L. 3177	No. 1 ESS — Trap Register
4/05/74	E.L. 3203	No. 1 ESS — New Queuing for Line Facilities Feature
4/15/74	E.L. 3210	No. 1 ESS — Speed Calling in CTX-7
4/15/74	E.L. 3219	No. 1 ESS — Centralized Automatic Message Accounting Disconnect Feature and Miscellaneous Toll Capabilities Feature

3. UNNUMBERED LETTERS

Date	Title
8/31/62	No. 1 ESS — Planning Information
10/22/62	Brochure — "Looking Ahead with ESS"
10/15/63	Power Systems — No. 1 — Power Plant Engineering Data
1/23/64	No. 1 ESS — General Coordinating Committee Notes
3/03/64	Systems Planning — No. 1 ESS
3/03/64	No. 1 ESS — Traffic Planning Notes
4/07/64	Traffic Engineering Practices — No. 1 ESS
6/01/64	ESS General Coordinating Committee Notes — Issue Two
12/23/64	ESS General Coordinating Committee Notes — Issue Three
1/25/65	No. 1 ESS — General Coordination Committee Notes
2/25/65	No. 1 ESS — Traffic Engineering Practices
3/04/65	No. 1 ESS — Traffic Facilities Practices
3/08/65	No. 1 ESS Training — Utilization
2/21/66	Custom Calling Services — Status of Trial Activity
4/26/66	Systems Planning — No. 1 ESS
7/07/66	No. 1 ESS — Feature List
7/13/66	No. 1 ESS — Program Store Requirements and Central Control Capacity
6/23/66	No. 1 ESS — ESS News
7/18/67	Custom Calling Services — Market Trial Final Report
7/31/67	No. 1 ESS — Increase in Call-Carrying Capacity
8/03/67	Features Desirable in ESS
8/21/67	No. 1 ESS — Evaluation of Call-Carrying Capacities
8/30/67	No. 1 ESS — Central Control Capacity
9/19/67	No. 1 ESS — Growth
10/11/67	Custom Calling Services — Rate Treatment for
10/30/67	No. 1 ESS — Peak Call Processing Capacity
11/15/67	2-Wire No. 1 ESS — Traffic Facilities Practices — Call Stores
3/06/68	Custom Calling Services
3/12/68	2-Wire No. 1 ESS — Program Store Requirements
4/16/68	No. 1 ESS — Costs Study Comparing No. 1 ESS and No. 5 Crossbar Prices
4/18/68	Availability of No. 1 ESS (Two-Wire) Programs and Features
7/18/68	No. 1 ESS Compatibility Chart
10/04/68	No. 1 ESS 2-Wire and 4-Wire — Spare Translation Modules
10/16/68	2-Wire No. 1 ESS — Translation and Assignment Record Forms
12/02/68	ESS Manpower Utilization Study
1/03/69	Step-by-Step — Economical Replacement with ESS No. 1
2/14/69	ESS — Calling Line Identification

Date		Title
2/26/69		Availability of No. 1 ESS (Two-Wire) Programs and Features through 1970
3/20/69		2-Wire No. 1 ESS Traffic Facilities Practices
4/28/69		No. 1 ESS — Replacements Affecting Official PBX Service
4/28/69		No. 1 ESS — Translation Forms Changes
5/07/69		ESS Technical Assistance Centers
5/13/69		Custom Calling Services Planning Information
7/11/69	(GL69-07-009)	No. 1 ESS — Actual Cost, Frames and Equipped Lines for Initial Jobs
7/31/69	(GL69-07-227)	No. 1 ESS Recommended Installation and Ordering Intervals for 1970
8/13/69	(GL69-08-154)	No. 1 ESS — Traffic Engineering Guide
8/21/69	(GL-69-08-180)	No. 1 ESS Maintenance Seminars
9/25/69	(GL69-09-183)	Custom Calling Services and Certain PBX or Centrex Features
10/20/69	(GL69-10-127)	Availability of No. 1 ESS (Two-Wire) Programs and Features
12/16/69	(GL69-12-134)	Planned Compatibility of Announcement Systems with Local ESS Offices
3/20/70	(GL70-03-206)	Electronic Switching Systems
4/13/70	(GL70-04-077)	No.1 ESS — Economic Values of Service Link Network
6/11/70	(GL70-06-059)	No. 1 ESS — Development of the Coin Service Improvement Feature
6/25/70	(GL70-06-199)	2-Wire No. 1 ESS Call Capacity
7/16/70	(GL70-07-133)	Electronic Switching TAC Directory
9/23/70	(GL70-09-207)	No. 1 ESS — Actual Costs; Frames, Equipped Lines and Capacity for Initial Jobs
11/10/70	(GL70-11-025)	Electronic Switching TAC Directory
12/31/70	(GL70-12-241)	Availability of No. 1 ESS (2-Wire) Programs and Features
1/12/71	(GL71-01-059)	No. 1 ESS — 2W Hardware Trouble Summary Survey
2/19/71	(GL71-02-111)	No. 1 ESS — Actual Costs, Frames and Equipped Lines for Initial Jobs Going into Service in 1969 and 1970
2/22/71	(GL71-02-130)	Electronic Switching TAC Directory
3/22/71	(GL71-03-160)	Improved Method for Estimating Peak Day Call Capacity of 2-Wire No. 1 ESS Utilizing a Time-Shared Computer Program
5/19/71	(GL71-05-203)	No. 1 ESS 2-Wire Program — Capacity Improvements
6/07/71	(GL71-07-029)	Custom Calling Services — Planning Information
7/14/71	(GL71-07-073)	No. 1 ESS Traffic Teletypewriter — New Developments
8/03/71	(GL71-08-006)	Custom Calling Services — Illustrative Study of Monthly Capital Costs and Operating Expenses
8/03/71	(GL71-08-007)	Custom Calling Services
8/27/71		Forecast and Development — Custom Calling Services
9/02/71	(GL71-09-001)	No.1 ESS Standard Traffic Data Forms
9/16/71	(GL71-09-103)	Custom Calling Services

Date		Title
10/06/71	(GL71-10-12)	Patrol — A Time Shared Computer Data Management System for No. 1 ESS Traffic Measurement Data
10/08/71	(GL71-10-072)	No. 1 ESS 2-Wire — Equipment Test List
10/13/71	(GL71-10-058)	Procedures for Introducing Custom Calling Services in No. 1 ESS Offices
10/29/71	(GL71-10-144)	No. 1 ESS Recovery from Adjacent Call Store Failure
11/03/71	(GL71-11-015)	Availability of No. 1 ESS (Two-Wire) Programs and Features — Update
12/13/71	(GL71-12-101)	Custom Calling Services — Customer Instruction
2/09/72	(GL72-02-075)	Announces Planned Improvements to the No. 1 ESS PATROL Time-Shared Computer Program
4/04/72	(GL72-04-001)	No. 1 ESS Interval Reduction — Trial Office Procedure
4/18/72	(GL72-04-060)	PBX Series Feature Offering from CO
5/10/72	(GL72-05-063)	Remreed Trunk Link Network for No. 1 ESS
5/23/72	(GL72-05-207)	Increased Call Handling Capacity for No. 1 ESS CTX-6 Program
5/26/72	(GL72-05-198)	No. 1 ESS Price Profile for Initial Jobs
6/05/72	(GL72-06-067)	Announces Planned Improvements to the No. 1 ESS PATROL Shared Time Computer
7/18/72	(GL72-07-144)	No. 1 ESS 2-Wire Traffic Engineering Guide (T.E.G.) Conversion to Traffic Facilities Notes
7/27/72	(GL72-07-189)	Installation Interval Guidelines for New No. 1 ESS Systems Shipping after January 1, 1973
9/25/72	(GL72-09-170)	No. 1 ESS Hands-On Training Evaluation Report
9/26/72	(GL72-09-136)	Electronic Switching TAC Directory
10/20/72	(GL72-10-165)	No. 1 ESS Central Processor Call Capacity Determination Procedures are Now Available in the PATROL System
10/31/72	(GL72-10-195)	No. 1 ESS (2-Wire) Line Load Control
11/08/72	(GL72-11-020)	SYSTEMS PLANNING — No. 1 ESS Two-Wire Toll Operation
11/14/72	(GL72-11-073)	No. 1 ESS COEES Module — Introduced in Two Closed Circuit TV Conferences
1/18/73	(GL73-01-034)	Availability of No. 1 ESS (Two-Wire) Programs and Features — Update
1/24/73	(GL73-01-183)	Operational Reviews — No. 1 ESS Traffic Engineering and Dial Administration
1/25/73	(GL73-01-168)	Dial Central Office Facilities — No. 1 ESS — Trunk Record Update Support Technique (TRUST)
2/09/73	(GL73-02-080)	Plant Training Course No. 539, Module F — No. 1 ESS Systems Operations, Maintenance Procedures
2/12/73	(GL73-02-108)	ESS Training
2/21/73	(GL73-02-178)	Dial Central Office Facilities — No. 1 ESS Traffic Teletypewriter
2/22/73	(GL73-02-145)	Custom Calling Services Development Report
2/22/73	(GL73-02-146)	Installation Interval Guidelines for Additions to No. 1 ESS Offices (Ferreed Network Offices)

Date		Title
2/23/73	(GL73-03-198)	No. 1 ESS — Automatic Board to Board Testing
3/29/73	(GL73-03-233)	Announces the Availability of "No. 1 ESS Maintenance" Videotapes
4/04/73	(GL73-04-013)	No. 1 ESS Call Store Work Sheets
4/26/73	(GL73-04-169)	No. 1 ESS — 2-Wire Service Results Plan
4/26/73	(GL73-04-198)	Operations, Budget and Design Forecasting — Custom Calling Services
5/02/73	(GL73-05-022)	No. 1 ESS Parameter Listings
6/12/73	(GL73-06-058)	Switching Entity Selection – Factors to Use Comparing No. 1 ESS and No. 5 Crossbar
6/18/73	(GL73-06-132)	No. 1 ESS – Program for Administrative Traffic Reports on Line (PATROL)
6/25/73	(GL73-06-177)	No. 1 ESS – Modular Programs
7/11/73	(GL73-07-033)	Automated Switching Control Center Field Experiment in New Brunswick (ASCC)
8/06/73	(GL73-08-014)	No. 1 ESS Documentation
10/26/73	(GL73-10-190)	IDDD Testing in No. 1 ESS
11/06/73	(GL73-11-042)	No. 1 ESS – Availability of Support Computer Programs to Save Program Store Memory
11/12/73	(GL73-11-040)	Feature Documents for Electronic Switching Systems
11/19/73	(GL73-11-095)	Availability of No. 1 ESS (2-Wire) Programs and Features CTX-7
12/27/73	(GL73-12-142)	No. 1A ESS Description and General Planning Information
2/15/74	(GL74-02-074)	No. 1 ESS – Application of the No. 1 ESS as a Toll Office, Class 4 and CSP
2/27/74	(GL74-02-063)	No. 1 ESS – Economic Selection of Line Link Network Concentration Ratio
3/05/74	(GL74-03-010)	Sales Development ESS/ACD
4/10/74	(GL74-04-112)	No. 1 ESS – Capacity May Be Limited by the Signal Processor

4. TRAINING PROGRAMS

PLANT TRAINING PROGRAMS

PTC	TITLE	OBJECTIVE	ENTRY LEVEL REQUIREMENTS	LENGTH OF COURSE
42	Electronic Switching Prerequisites	The trainee will be able to use ESS drawings and apply techniques and precautions in the use of test equipment	None	Foreman 64 hours Craftsmen 80 hours

Selected portions appl.

* Course length under study

PTC	TITLE	OBJECTIVE	ENTRY LEVEL REQUIREMENTS	LENGTH OF COURSE
90	No. 1 ESS (2-wire)	The trainee will be able to describe overall operation of No. 1 ESS, the function, organization and operation of major control call and maintenance programs.	Satisfactory completion PTC 42	680 hours (17 weeks)
90 (Mod.)	No. 1 ESS (2-wire)	To reinforce instructional material for the trainees in the following areas: Parameters, Translations, Programming, Oscilloscope application	Interim — Satisfactory completion PTC 509	560 hours
504	ESS Operations	The trainee will be able to process distributing frame orders, change circuit packs, change AMA tapes and TTY paper, replace fuses, etc.	None	80 hours
507#	Introduction to ESS	The trainee will be able to use the oscilloscope as a pulse measurement tool and be able to locate and replace devices such as ferrods, switches, circuit packs, etc.	Interim: None Future: PTC 504	*
508#	Electronic Systems Peripheral Units	The trainee will be able to use standard references and equipment to locate hardware trouble in ESS peripheral units	Interim and future: PTC 507	*
509#	Central Processor and Program Fundamentals	The trainee will be able to interpret program orders and perform routine hardware oriented maintenance in the memory areas of the processor.	Interim and Future PTC 508	*
534	No. 1 ESS Central Processor Hardware and Programming	The trainee will be able to describe the organization and operation of the central processor hardware	Future: PTC 509	Est. 200 hours
539	No. 1 ESS Theory	The trainee will be able to describe the operation of the No. 1 ESS systems	Future: PTC 534	200 hours
540	No. 1 ESS Hands-On	The trainee will be able to demonstrate his ability to apply efficient maintenance and trouble locating procedures	Present: PTC 90 Interim PTC 90 (Mod) Future: PTC 539	216 hours

\# Selected portions appl.
* Course length under study

Courses offered by
Bell System Center for Technical Education, Lisle, Illinois:

#	TITLE	OBJECTIVE	PREREQUISITE	LENGTH OF COURSE
ESS 1	Electronic Switching System No. 1	To provide first through fourth level Equipment. Maintenance. Plant Extension and Traffic Engineers with a foundation of knowledge of the system's operation.	20 hour prerequisite review	3 weeks
ESS1 DA	Electronic Switching System No. 1 Dial Administration	Upon successful completion of this course, the student will know the fundamentals and methods required to administer a No. 1 ESS and be able to apply them.	BSCTE Traffic Systems Concepts course or equivalent	1 week
ESS1 TOP	Electronic Switching System No. 1 Traffic Order Preparation	Upon successful completion of the course, the student should be able to prepare and analyze a traffic order for an ESS No. 1 installation	Background of Traffic Systems Concepts and general knowledge of basic components of the ESS No. 1	1 week (5½ days)
ESS T1	Electronic Switching System No. 1 Translations – Basic	Upon successful completion of this course, the student will be able to prepare basic translations for lines, trunks, measurements and routing and charging for POTS serving an ESS No. 1 office.	None	1 week
ESS1 T2	Electronic Switching Systems No. 1 Translations – Advanced	Upon successful completion of this course, the student will be able to implement or supervise the preparation of all translations for the No. 1 ESS.	"Basic" Course or actual experience	1 week
ESMP	Electronic Systems Maintenance Program	To provide selected Engineering and Plant management with the basic knowledge, skills and experience needed to assist plant operating forces in maintaining Electronic Switching Systems	Common control switching systems background and No. 1 ESS Systems Functions and Operations Course	26 weeks (modular Structure)
*ESS1 EEC	Electronic Switching Systems No. 1 Equipment Engineering	Upon completion of this course, the student will be able to perform any of the tasks expected of a No. 1 ESS Equipment Engineer	One year's experience as Equipment Engineer or Equipment Engineering Management Course or Equivalent	2-3 weeks

*Pilot session – September 9, 1973