THE BELL SYSTEM TECHNICAL JOURNAL
Vol. 62, No. 7, September 1983
Printed in U.S.A.

Total Network Data System:

System Plan

By M. S. HALL, JR.,* J. A. KOHUT,* G. W. RIESZ,* and J. W. STEIFLE†

(Manuscript received July 23, 1982)

The Total Network Data System (TNDS) is a coordinated family of operations systems that work together to mechanize telephone traffic data gathering and reporting. This paper describes the component parts of the TNDS, their functions, their interactions, and their inputs and outputs. The paper also presents the managerial view of TNDS: its product, its size, the number of people involved, how the overall project is organized and coordinated, and how the system evolves to meet the needs of a continually changing environment.

I. INTRODUCTION

The planning effort for traffic data collection and processing for what was to become the Total Network Data System (TNDS) began in the mid-1960s. This plan gradually evolved as the initial steps were taken to mechanize portions of the traffic data collection and data processing functions for the Bell Operating Companies and AT&T Long Lines.

This paper is divided into two parts. The first part, Sections II and III, presents an architectural view of the Total Network Data System.

* Bell Laboratories. † American Bell.

The second part of the paper (Section IV) is written from a managerial point of view.

The first part begins (in Section II) with an overview of the current configuration of the TNDS, and the decisions that led to the current architecture; it concludes with brief descriptions of the functions of the individual subsystems and summaries of their interactions. (Subsequent papers in this volume describe the subsystems and their internal operations in detail.) Section III describes TNDS operations from a different point of view, i.e., by following the flow of a representative data item through the system and describing the database update process.

The second part, which begins with Section IV, describes the product delivered to the end users, including software, documentation, and user support, as well as the organization of the development and maintenance effort, and the planning, requirements, development, test, and delivery cycle. Section IV also examines the need to enhance and update TNDS subsystems to meet changing needs, using the integration of the 5 *ESS** switching system as an example. This article ends with a brief look at possible future directions.

II. CURRENT CONFIGURATION

This section introduces the architecture of the Total Network Data System and briefly describes the individual component systems and their interactions. Subsequent articles in this issue of the *Journal* describe the elements of TNDS in greater detail.

TNDS is now widely deployed throughout the Bell System. All or a portion of TNDS is now in use in every Bell operating company. Of the almost 10,000 switching entities, TNDS collects and processes data for more than 7000. Since the switching entities not now connected are primarily the small electromechanical Community Dial Offices (CDOs), TNDS actually handles more than 90 percent of all Bell System traffic information.

TNDS is a coordinated family of operations systems, which work together to mechanize the data gathering and reporting process. It consists of manual procedures and computer systems that enable operating company managers, network administrators, and network designers to analyze traffic data in a variety of ways.

The development of TNDS has been under way since the mid-1960s. It was the Bell System's first set of integrated operations systems, and has required the planning, development, testing, modification, and introduction of a number of new features and generic programs. This

* Trademark of Western Electric.

systems planning served as the forerunner of the main operations planning activities that have since characterized several plans, including the Total Network Operations Plan (TNOP).

TNDS has now evolved into a system that encompasses 13 major component systems. They are:

- EADAS—Engineering and Administrative Data Acquisition System
- EADAS/NM—Engineering and Administrative Data Acquisition System/Network Management
- TDAS—Traffic Data Administration System
- LBS—Load Balance System
- 5XB COER—No. 5 Crossbar Central Office Equipment Reports
- SPCS COER—Stored Program Control Systems Central Office Equipment Reports
- ICAN—Individual Circuit Analysis
- SONDS—Small Office Network Data System
- CU/EQ—Common Update/Equipment
- TSS—Trunk Servicing System
- TFS—Trunk Forecasting System
- CU/TK—Common Update/Trunking
- CSAR—Centralized Systems for Analysis and Reporting.

Figure 1 shows the overall TNDS architecture.

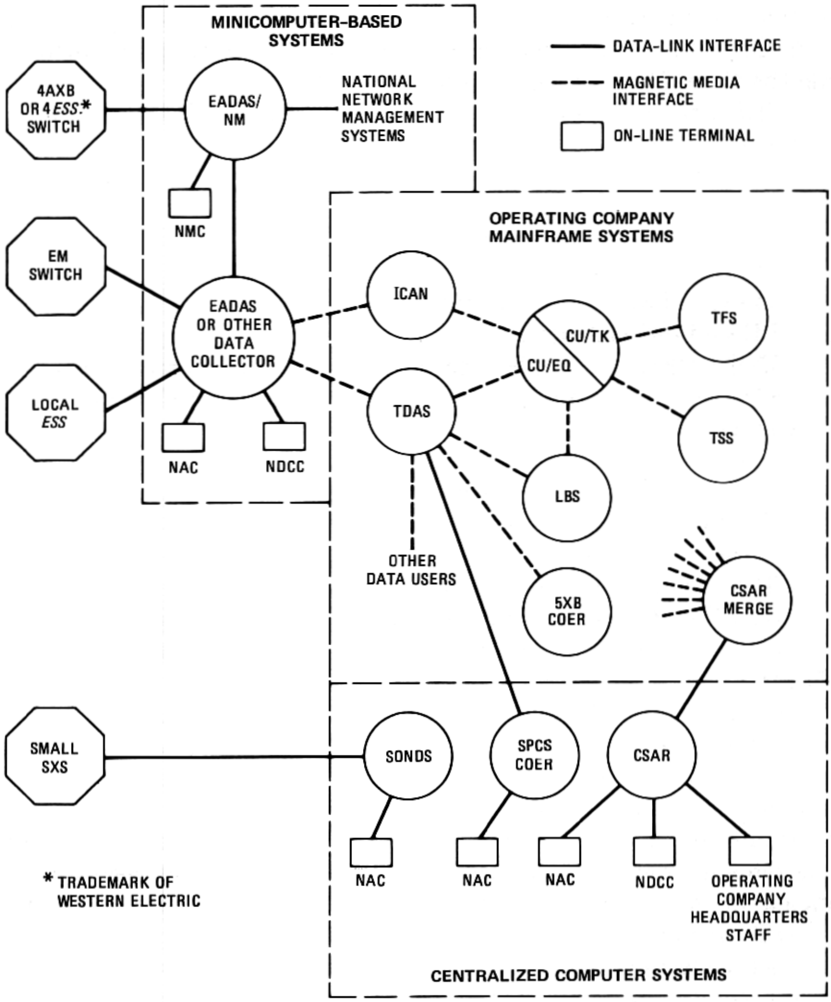
The elements of TNDS are operated in distributed locations. The switching systems, each serving thousands of customers, are generally based in a community's central office. The data collection systems typically employ dedicated minicomputers and gather traffic information from anywhere between 20 and 80 switching systems. Most of the remaining engineering and administrative reporting systems run on either general-purpose operating company computers, or at the AT&T computer center.

Once collected and stored, a number of different systems of the TNDS may process the same items of traffic data to produce a variety of reports.

Despite these distributed operations, the TNDS for any operating company can be thought of as a single, integrated entity designed to provide managers with comprehensive, timely, and accurate information about the network.

2.1 Architectural overview

The Total Network System did not, like Athena from Zeus, spring full blown from the head of a grand planner. Instead it evolved, like most things, from a combination of several individual system developments. R. L. Martin has observed[1] that the architecture of a system



5XB COER – NO. 5 CROSSBAR CENTRAL OFFICE EQUIPMENT REPORTS
CSAR – CENTRALIZED SYSTEMS FOR ANALYSIS AND REPORTING
CU/EQ – COMMON UPDATE/EQUIPMENT
CU/TK – COMMON UPDATE/TRUNKING
EADAS/NM – ENGINEERING AND ADMINISTRATIVE DATA AQUISITION SYSTEM/NETWORK MANAGEMENT
ICAN – INDIVIDUAL CIRCUIT ANALYSIS
LBS – LOAD BALANCE SYSTEM
NAC – NETWORK ADMINISTRATION CENTER
NDCC – NETWORK DATA COLLECTION CENTER
NMC – NETWORK MANAGEMENT CENTER
SONDS – SMALL OFFICE NETWORK DATA SYSTEM
SPCS COER – STORED PROGRAM CONTROL SYSTEMS CENTRAL OFFICE EQUIPMENT REPORTS
SXS – STEP BY STEP
TDAS – TRAFFIC DATA ADMINISTRATION SYSTEM
TFS – TRUNK FORECASTING SYSTEM
TSS – TRUNK SERVICING SYSTEM

Fig. 1—TNDS architecture.

is the product of the history of the organization that builds it, the present and near-present technology, and the intended application. This observation is certainly true for TNDS. Its roots reach back into the 1960s. Its components originated in a number of organizations at

Bell Laboratories and the operating companies. The uses of its output within the operating companies are widespread and diverse. It is, therefore, not surprising that the TNDS architecture (shown in Fig. 1) is not uniform or highly integrated. It is perhaps amazing that it fits together as well as it does.

2.1.1 The primal components

One of the earliest threads leading to TNDS began in 1966. A group of planning department representatives from eight associated companies, along with Long Lines and AT&T, met in New York City and recommended a Bell System effort to centralize the development of a computerized trunk facilities system. Among the components recommended for development were a Traffic Trunk Estimating Subsystem and a Traffic Trunk Servicing System. Development of these two components began shortly thereafter in the Business Information Systems (BIS) area of Bell Laboratories as the Trunk Forecasting System (TFS) and the Trunk Servicing System (TSS). A third program, designed to acquire data from a variety of manual and mechanized sources and to distribute it to client programs, was also included in the planning. This program, called Identify and Edit, later became TDAS.

Identify and Edit served as a data "warehouse." It labeled traffic measurements, stored them, and distributed batches of data to downstream users as they were needed. It and the downstream systems it fed were designed to serve entire operating companies, and in some cases the entire Bell System. These downstream systems were placed on large mainframe computers to take maximum advantage of economies of scale in processing, and to reduce the administrative problems of operating multiple systems. Another factor that led to these systems being company-wide in scope was the need for TFS to design company-wide trunk networks. This capability required a centralized database for trunk traffic measurements. It led to the centralization of the downstream systems with that database. The database, to which was added data for central office equipment, later became the CU/EQ and CU/TK components.

During this early period, the place later taken by EADAS (see Fig. 1) was occupied in planning by the Traffic Data Recording System (TDRS). TDRS was a special-purpose system that collected traffic data from electromechanical switching offices. Also during this period, AT&T planners expected to meet central office equipment data needs by standardizing programs developed by various telephone companies for individual switch types. The programs would receive data from Identify and Edit. Chief among these "Central Office Equipment" programs was one developed by New Jersey Bell for No. 5 Crossbar offices (it was running in 1968). Later standardized by AT&T and still later revised by Bell Laboratories, this program became the present-day 5XB COER component of TNDS.

The basic allocation of processing functions among these early systems has prevailed until now. TDRS was responsible for the real-time collection of traffic measurements for about 40 electromechanical switching offices. This number of offices was selected to balance the cost of switch-to-TDRS data links with the economics of scale available with centralized processing functions. This basic configuration and size have continued with little change even though the role of TDRS has been taken over by EADAS.

The early downstream systems (TSS, TFS, Identify and Edit, and 5XB COER) were designed for batch processing on mainframe computers. This approach was the prevalent technology for large software systems in that era. It provided an economical way to meet user needs with minimal technical risks. Quick turnaround was not a requirement on the reports produced by these systems. These early systems have evolved and been enhanced over the last fifteen years. LBS and ICAN have been added. However, the fundamental architecture established in the late 1960s for this set of operating company, mainframe-based systems has changed little. Only now are on-line, real-time features being added.

The arrangement of Central Office Equipment Reports (COER) systems within the TNDS architecture was driven by different factors than the other downstream systems. Each type of switching equipment has unique traffic data processing requirements. The switch architectures and service features strongly influence these requirements. This characteristic led to separate COER developments for each switch type. Only recently has the technology needed for a generic COER been pursued.[2] Several approaches were taken by the various organizations that developed the COER modules. As discussed above, 5XB COER is implemented on a mainframe system, and SPCS COER (which is a collection of COER modules) is implemented on a centralized, time-shared system (as is SONDS). The selection of time sharing for these systems is discussed below.

2.1.2 Evolution and integration

In the early 1970s economical new minicomputer systems with greater flexibility and versatility replaced the specialized TDRS hardware being used for data collection. Some locally developed and vendor-supplied systems were installed for this purpose. The predominant system in use, however, is EADAS, which is a product designed by Bell Laboratories. Being real-time systems, these minicomputer systems could easily provide the short-term traffic reporting functions that were also required.

Another major evolutionary step was the addition of network management functions in 1975. Network management requires near-real-time data processing and requires an overview of a larger number of switching offices than can be served by one EADAS. However, the EADAS system provided a convenient and economic concentration point for the real-time, local office, traffic measurements needed for network management. Therefore, a decision was made to create a hierarchical architecture with up to six EADAS data collection minicomputers concentrated on an EADAS/NM minicomputer. For 4A Crossbar and 4 *ESS* toll switching offices, however, a direct switch-to-EADAS/NM connection was chosen because the number of these toll offices is relatively small and the data volumes interchanged with them are relatively high. It also provided a higher level of reliability for the communications with these critical switching entities.

Three systems—SPCS COER, SONDS, and CSAR—were implemented on Bell System national-based time sharing systems. All three systems began as experiments conducted at Bell Laboratories to investigate improved traffic data management methods. For SPCS COER and CSAR, centralized time sharing was a means to deploy required on-line processing functions without the need for operating companies to buy additional hardware, or to support software in a number of geographically dispersed sites. These are attractive attributes for an experimental prototype.

SPCS COER and CSAR were standardized on centralized time sharing because it was easier and more economical to evolve the prototype software than it would have been to rewrite it for another computer system and perhaps purchase new hardware. The decision to deploy SONDS on centralized time sharing was more difficult, however.

The SONDS prototype was implemented on a minicomputer system at Bell Laboratories. It was determined that a single computer installation could economically support all the Bell System's small step-by-step offices expected to utilize SONDS. These electromechanical switching offices were expected to be gradually replaced by electronic offices (served by EADAS) over a fifteen- to twenty-year period. The decision therefore was between: (1) standardizing the minicomputer prototype and supporting a centralized, dedicated minicomputer for 15 to 20 years of declining switch population; or (2) rewriting all the prototype software for a general-purpose, time-sharing system. It was decided that users could get better support if the system was on a general-purpose computer. So SONDS joined CSAR and SPCS COER on the AT&T time-shared computer facility.

Integration of TNDS occurred as a series of steps. An early step was linking data collection to downstream processing. Minicomputer-based data collection systems like EADAS wrote traffic measurements on magnetic tapes that could be used as direct input to TDAS. The tape formats used for this link have been changed to improve processing efficiency, but the basic arrangement is still used. Integration of SPCS COER was another major step. Initially SPCS COER received data from punched paper tape via dial-up connections. In 1975, EADAS was upgraded to collect 1 *ESS* traffic data and pass it to TDAS via magnetic tapes. Data transmission from TDAS to SPCS COER was then used to complete the link. Other key integration steps were the automatic input to TFS of trunk group base load data from TSS, and linking the standard CSAR system by means of the downstream CSAR merge program. As part of their initial development, EADAS/NM, ICAN, and LBS were all integrated. TNDS was officially recognized as an integrated system for planning purposes in 1974. This was accomplished by an internal Bell Laboratories memorandum which, in fact, declared it an integrated system and documented its architecture.

The slow pace of evolution from the early architectural choices attests to their workability, but also is evidence of how difficult it is to change established architectures. As discussed at the end of this article, more changes are occurring. They are driven by the needs of users for new processing functions and technological advances that can be effectively incorporated into TNDS. Recently, developers have explored: (1) the use of on-line functions in mainframe systems for database management, report distribution and documentation delivery; and (2) the migration of some functions on centralized time sharing to on-line mainframe systems.

The remainder of this section describes, in more detail, the existing component systems and their current roles within the TNDS architecture.

2.2 Component system functions

To understand the interrelationship of TNDS systems and how they collect and use traffic data, let's look at the four primary functions of TNDS in their general order of occurrence—data acquisition and management, central office equipment reporting, trunk network reporting, and system performance measurement—and at the systems responsible for each function.

2.2.1 Data acquisition collection and management

Managers need data on network performance and traffic loads carried by trunk groups and switching systems to assess the quality of service and to plan for network growth.

This network information begins as bits of data collected in switching offices. For example, in electromechanical offices a specialized data collection device, called a Traffic Usage Recorder, scans the trunks and other components periodically (typically every 100 seconds) and counts how many are busy. Other traffic data such as peg count and overflow are also collected. In *ESS* offices, a similar process is used, but there is no need for specialized equipment, since traffic data are collected by the switching system's central processor.

2.2.1.1 EADAS. Traffic data are transmitted to the first of the 13 systems of TNDS—the Engineering and Administrative Data Acquisition System (EADAS). EADAS runs on dedicated minicomputers located at an operating company's Network Data Collection Centers. As its name suggests, it is the major data-collecting TNDS system. However, a few operating companies use locally developed or non-Bell vendor-supplied systems instead of or in addition to EADAS for this first step in the TNDS process. In addition, the large toll machines, 4 *ESS* and No. 4 Crossbar [with its associated computer, the Peripheral Bus Computer (PBC)] collect their own data and do not connect to EADAS.

Each EADAS serves up to 80 switching offices and, upon receiving traffic data, performs three basic functions.

1. It processes some data in near-real time (shortly after they are received) to provide hourly and half-hourly reports and a short-term database for network administrators.
2. It collects and summarizes data for processing by remaining "downstream" TNDS systems.
3. It performs on-line surveillance and reporting functions.

EADAS also links other TNDS systems by forwarding traffic data to them via a data link or magnetic tape. Three systems receive these data directly from EADAS.

2.2.1.2 EADAS/NM. Two of three direct recipients of traffic data from EADAS are the Individual Circuit Analysis (ICAN) Program and the Engineering and Administrative Data Acquisition System/Network Management (EADAS/NM). They are the only systems that use data collected and processed by EADAS without first having it formatted by TDAS. ICAN is not a data acquisition system, but rather one of the central office engineering and administrative reporting systems, and is described in that section. TDAS is the third direct recipient.

EADAS/NM is located at operating company Network Management Centers, and uses data received from EADAS or directly from some types of switching systems (e.g., 4A and 4E). It watches switching systems and trunk groups designated by network managers, and reports existing or anticipated congestion on a display board at the center. EADAS/NM also provides information to AT&T Long Lines'

Network Operations Center at Bedminster, N.J. This center is supported by an operations system, the Network Operations Center System (NOCS), which performs functions similar to EADAS/NM, but on a national scale.

2.2.1.3 TDAS. The Traffic Data Administration System (TDAS) formats traffic data for use, in turn, by a number of the other "downstream" systems.

But unlike EADAS and EADAS/NM—both of which employ dedicated minicomputers—TDAS runs in an operating company computer center supporting the Network Data Collection Centers. If TNDS were to be pictured as a series of distinct steps, then TDAS can be thought of as the second data acquisition step. Each week it accepts millions of pieces of data from EADAS (or the equivalent of locally developed or vendor-supplied systems) or directly from the large toll machines. In response to requests from downstream systems users, TDAS sorts, labels, stores, and, at the appropriate time, provides the data in the proper format to the engineering and administrative reporting systems. In effect, TDAS acts primarily as a warehouse and distribution facility for traffic data.

TDAS treats its data acquisition job as a basic order/inventory problem. Orders, or Traffic Measurement Requests, for data are manually prepared and sent to TDAS by operating company personnel. These orders are stored in a master database.

As traffic data are received by TDAS, they are matched against the orders held in Common Update. When the data necessary to fill an order have been received, a weekly data summary—either printed or on magnetic tape—is sent to the system that requests it to use in preparing an engineering or administrative report.

Once TDAS has received, formatted, and sent data to the appropriate downstream reporting system, the data acquisition function is complete. At this point, traffic data have moved from the switching system to EADAS and then directly to TDAS and the requesting engineering and administrative reporting system. The next step is to look at how managers employ the TNDS systems to analyze the data that have been gathered.

2.2.1.4 CU/EQ. In addition to the above systems, a common record base is used. TDAS and several of the downstream engineering and administrative systems need much of the same record-base reference information. Those data are maintained in a common system, called Common Update/Equipment (CU/EQ), rather than duplicated in each system. The information for each central office includes the configuration of switching equipment as well as specifications of traffic registers. This database is updated as changes occur in the physical arrangements of central offices.

2.2.2 Central office equipment reporting

There are five downstream TNDS engineering and administrative systems that send reports about central office switching equipment to operating company personnel. These systems, which run on either operating company computers or at the AT&T computer center, are the:

1. Load Balance System (LBS)
2. No. 5 Crossbar Central Office Equipment Reports (5XB COER)
3. Stored Program Control Systems Central Office Equipment Reports (SPCS COER)
4. Individual Circuit Analysis (ICAN) Program
5. Small Office Network Data System (SONDS).

The first three receive traffic data from TDAS. ICAN receives data directly from EADAS, but also uses Common Update for some of its reference information. SONDS collects its own data directly from small step-by-step offices.

2.2.2.1 LBS. The Load Balance System, LBS, which is run on the operating company computer, helps assure that the customer traffic load is uniformly distributed over each switching system. Customer lines are connected to the switching system "concentrators," which allow customers to share switching equipment. LBS analyzes traffic data coming to it from TDAS to establish the traffic load on each line group of each switching system. Then, personnel in the Network Administration Center use LBS reports to determine "lightly loaded" line groups to which new subscriber lines can be assigned. This minimizes congestion on a given concentrator. In addition, LBS calculates "load balance indices" for the entire operating company, indicating how effectively each central office has avoided congestion by efficiently distributing traffic.

2.2.2.2 5XB COER, SPCS COER. Two other central office equipment reporting systems—5XB COER for No. 5 Crossbar offices, and SPCS COER for 1, 2, 3, and 5 *ESS* offices—also use traffic data collected by EADAS and formatted by TDAS to support the Network Administration Center. While 5XB COER runs on operating company computers and SPCS COER at the AT&T computer center, the two systems perform similar functions. Both analyze traffic data to indicate the overall load carried and the service provided by the switching systems, and to determine how much of the switching system's capacity is being used. This information helps planners decide when new equipment is needed and answers many other important administrative questions.

2.2.2.3 ICAN. The two remaining central office equipment reporting systems, ICAN and SONDS, do not use TDAS to format their data. ICAN, which receives data directly from EADAS for certain electromechanical offices equipped with an EADAS option called Individual Circuit Usage Recording (ICUR), detects switching system equipment faults by identifying abnormal load patterns on individual circuits. ICAN then produces a series of reports used at the Network Administration Center to analyze individual circuit usage and verify circuit grouping.

2.2.2.4 SONDS. SONDS—the fifth downstream central office equipment reporting system—is the only TNDS system that performs a full range of data manipulation functions. It economically provides a number of TNDS features for the smaller electromechanical step-by-step offices.

To do that, SONDS—which runs at the AT&T computer center—collects traffic data directly from offices measured, processes them, and automatically distributes weekly, monthly, exception, and on-demand reports to managers at the Network Administration Center via dial-up terminals.

2.2.3 Trunk network reporting

Three TNDS systems—all run on operating company computers—support trunk servicing and forecasting at the Circuit Administration Center:

1. Trunk Servicing System (TSS)
2. Trunk Forecasting System (TFS)
3. Common Update/Trunking (CU/TK).

Together these three systems are sometimes referred to as Total Network Data System/Trunking (TNDS/TK). TSS helps trunk administrators develop short-term plans to relieve unacceptable blocking on final trunk groups. It processes traffic data supplied by TDAS, and computes the "offered load" for each trunk group. TSS calculates the number of trunks theoretically required to handle that traffic load at a designated grade of service—an objective expressed in terms of percent of blocking. TSS produces weekly reports showing which trunk groups are underutilized and which trunk groups are performing below the grade-of-service objective.

The traffic load data calculated by TSS also help support the trunk forecasting function performed by TFS. Those data, in conjunction with information on network configuration and forecasting parameters stored in Common Update, are used for long-term construction planning. The Trunk Forecasting System uses that information to forecast message trunk requirements for the next five years. These forecasts are a fundamental input to the planning process, which leads to the provisioning of additional facilities.

CU/TK provides a common record base for TSS/TFS. It contains information describing the configuration of the trunk network. The traffic data are provided from TDAS.

2.2.4 CSAR system performance measurement

Centralized System for Analysis and Reporting (CSAR) is the newest TNDS system. It was designed to monitor and measure how well data are being processed through TNDS from beginning to end. CSAR quantitatively measures the accuracy, timeliness, and completeness of the data flow for operating company personnel at the Network Data Collection Center, Network Administration Center, and the Circuit Administration Center. It also supplies sufficient information to locate trouble so corrective action can be taken. It does not presently analyze data from EADAS/NM, SONDS, or TFS.

CSAR is an on-line, interactive system that puts TNDS performance information at the user's fingertips. At the conclusion of each run of a system in TNDS, data required by CSAR are placed in a special file. Then, at an appropriate time, they are transferred to the AT&T computer that contains the CSAR program. CSAR then performs the proper association and analysis of data.

Operating company managers can access the report information from terminals at their own work locations. The reports can be arranged in a number of formats, and can provide details on overall TNDS performance or individual system effectiveness. Reports can be broken down by traffic unit (trunk group or switching system), district, division, or area to help identify and resolve problems at various operating company organizational levels.

III. HOW IT WORKS

This section will describe the end-to-end data flow of TNDS using two examples. One example will explain the steps necessary to pass *Touch-Tone** dialing originating register data from a No. 5XB office to the 5XB COER system, and the other will focus on the delivery of trunking data from a 1 *ESS* office to TSS. In both cases considerable preparation is necessary in the switching office and in the databases of the affected TNDS subsystems before data flow can begin. This preparatory work will be described first.

3.1 Addition of Touch-Tone *originating registers in a No. 5XB*

Generally, the marketing department would decide that the level of customer demand was sufficient to justify the cost of purchasing and establishing a *Touch-Tone* originating register (OR) group in a No. 5XB office. Following this decision, the Traffic Engineer would engineer the addition using forecasts of usage and would write a traffic order for the new equipment. A copy of the order would be received

* Registered service mark of AT&T.

by Network Administration personnel whose job it is to assign the *Touch-Tone* equipment to measurement devices. After the assignments are made, central office personnel will connect the leads of the Electronic Traffic Data Collection (ETDC) unit to the *Touch-Tone* equipment.

Traffic counts are maintained on a data collection device (DCD). Before data collection was computerized, traffic measurements were accumulated in mechanical registers. The modern equivalent to these registers are the DCDs, which are the software storage locations of the accumulated counts. For our example these storage locations are in the EADAS memory, although many of the subsystems of TNDS use DCD locations to refer to traffic measurements. The DCD is the common thread that links the traffic measurements from the switching office through EADAS and on to other systems.

A typical No. 5XB may require 1500 DCDs. The important measurements collected in DCDs on the *Touch-Tone* group are identified and defined in Table I below. As illustrated in Fig. 2, the next step in the sequence of preparing individual systems is loading the EADAS database (by defining the new DCDs) to accept the new data and to print exception and hourly reports.

The mapping between the ETDC at the switching office and the EADAS is accomplished via the DCDs. Likewise, the DCD is the link between EADAS and TDAS. The user prepares TDAS to receive this new data from EADAS by modifying the CU/EQ database using input transactions. Each TNDS equipment (TNDS/EQ) system except 5XB COER shares some portion of the CU/EQ database; hence, each system is assigned a series of numerically coded transaction commands to allow the database to be changed. As examples, a 750 transaction is used to associate a DCD with a particular measurement type, such as *Touch-Tone* OR peg count, and the days of the week and hours of the day that measurements need to be processed by TDAS are specified on the Traffic Measurement Request (790) transaction.

The CU/EQ database can be modified to enable 5XB COER to begin processing *Touch-Tone* OR data and printing reports. Once this is accomplished, all pieces are in place to permit traffic data to flow

Table I—DCD measurements on the *Touch-Tone* group

Measurement Type	Definition of Measurement
Usage	An estimate of the total amount of time the *Touch-Tone* ORs were busy for any reason.
Peg Count	The total number of attempts made to access the *Touch-Tone* ORs.
All *Touch-Tone* Registers Busy	The number of attempts to seize *Touch-Tone* ORs when the entire group was busy.
Maintenance Usage	The total amount of time the *Touch-Tone* ORs were busy for maintenance reasons.

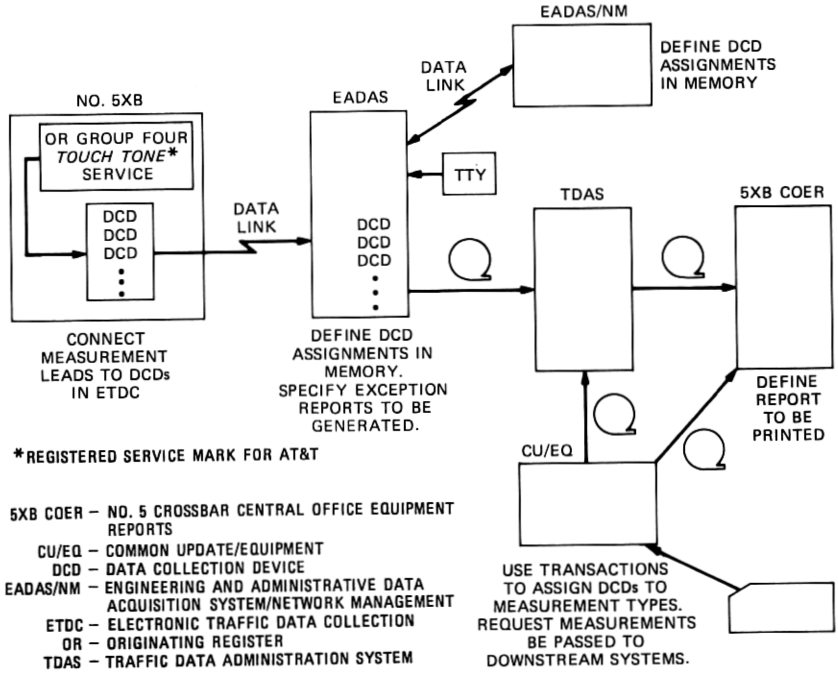


Fig. 2—Database synchronization for *Touch-Tone* originating register data.

from the physical equipment to the Network Administrator and Traffic Engineer. However, two potential users of this data have not yet been included. Those users receive data by an indirect path rather than the main-line path described thus far. Personnel at the network management center receive traffic measurements on critical switching office components in near-real time. To prime EADAS/NM to receive certain of the *Touch-Tone* OR measurements directly from EADAS, the EADAS/NM database is modified by identifying the new measurements (DCDs) that will be available at the EADAS.

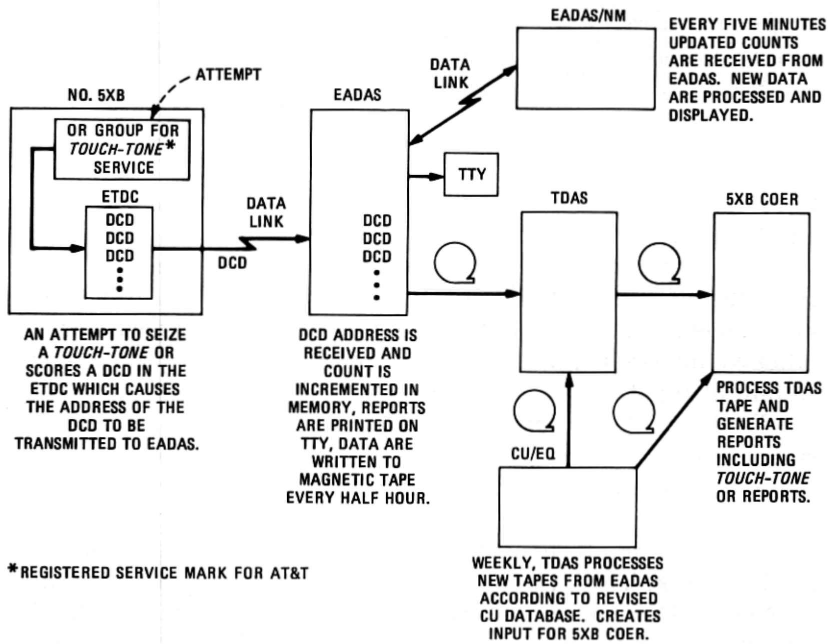
Selected data from each of the 27 EADAS/NM systems are sent to the NOCS computer every five minutes. These data describe the status of toll switching offices and trunk groups, but not the status of the local network. Thus, the new No. 5XB data would not be forwarded to NOCS. Data from toll switching offices are sent to NOCS by identifying it in the EADAS/NM database as being of NOCS interest. An EADAS/NM program automatically notifies NOCS that new data will be sent to it by forwarding a database map to NOCS. This program synchronizes the NOCS database to the EADAS/NM database.

The final system to receive these new measurements is CSAR. However, since CSAR measures overall performance rather than specific items, no database changes are required.

Now that all record base components are ready, the flow of new data can be monitored through each system. Figure 3 graphically illustrates this flow.

Data collection starts with the customers; their *Touch-Tone* calls cause attempts (peg counts), usage, and, during high load periods, an occasional all-busy condition on the *Touch-Tone* ORs. (Maintenance usage is generated by the central office work force when they remove an OR from service to maintain or repair it.) The ETDC is signaled each time an attempt is made to seize a *Touch-Tone* OR. The ETDC, in turn, codes a message, which is sent to EADAS when a seizure is attempted. This coded message is simply the DCD for that measurement. The ETDC, located at the switching office, is connected to the EADAS, which generally is physically remote from the ETDC.

For each switching office served by an ETDC, a block of DCDs in the memory of the EADAS records all the traffic measurements being



5XB COER – NO. 5 CROSSBAR CENTRAL OFFICE EQUIPMENT REPORTS
CU/EQ – COMMON UPDATE/EQUIPMENT
DCD – DATA COLLECTION DEVICE
EADAS/NM – ENGINEERING AND ADMINISTRATIVE DATA ACQUISITION SYSTEM/NETWORK MANAGEMENT
ETDC – ELECTRONIC TRAFFIC DATA COLLECTION
OR – ORIGINATING REGISTER
TDAS – TRAFFIC DATA ADMINISTRATION SYSTEM

Fig. 3—Flow of *Touch-Tone* originating register data through TNDS.

collected. These banks of DCDs are forwarded to EADAS/NM every five minutes when a command is sent from EADAS/NM over a data link. EADAS transmits data from all of the offices requested by EADAS/NM, including the No. 5XB with the new *Touch-Tone* ORs. After receiving data, EADAS/NM performs calculations on that data and displays the results nearly instantaneously to the network manager. If data from the No. 5XB were of national interest, every five minutes they would be forwarded to the NOCS where calculations would be performed and data displayed to national network managers.

Network management requires 5-minute data, whereas traffic engineering requires hourly data. Starting either on the hour or at half past the hour, EADAS writes the current DCD counts to magnetic tape and resets these registers to zero.

One of the major benefits of EADAS is its exception-reporting capability. The network administrator can define an exception condition such as some number of occurrences of all ORs busy in a 30-minute period. If this frequency occurs or is exceeded, a report would be printed at the EADAS teletypewriter (TTY) and the network administrator would take the appropriate action.

Periodically, the magnetic tape will be forwarded to a data processing center. These tapes will be run through TDAS, which will perform some validations and "warehouse" the data. TDAS will then create new tapes, one for each TNDS downstream system. One tape produced by TDAS would be processed by 5XB COER, which would then perform validation tests and calculations on the data and generate output reports to be used by the network administrator and traffic engineer. These reports would be used to determine if the new equipment was being utilized effectively while providing an acceptable grade of service to the customer. In most companies, the 5XB COER program is run weekly with a TDAS tape containing each day of the week used as input. The key report generated by 5XB COER is the Machine Load Service Summary (MLSS) report, which displays the ten high-day loads and the average busy season load on most switching office components, including the new *Touch-Tone* ORs. The MLSS report is also used by traffic engineers to determine equipment quantities for the next busy season.

At key checkpoints, traffic measurements are monitored by CSAR to ensure that they are received, processed, and are reasonably accurate. If, for example, the DCD associated with *Touch-Tone* OR usage were improperly wired, the occupancy of this equipment could erroneously appear to be greater than 100 percent. CSAR would be notified of these invalid measurements and would include this problem in the calculation of the index. Besides producing the index, CSAR identifies problem areas, thus facilitating their correction.

3.2 Addition of a new trunk group to TSS

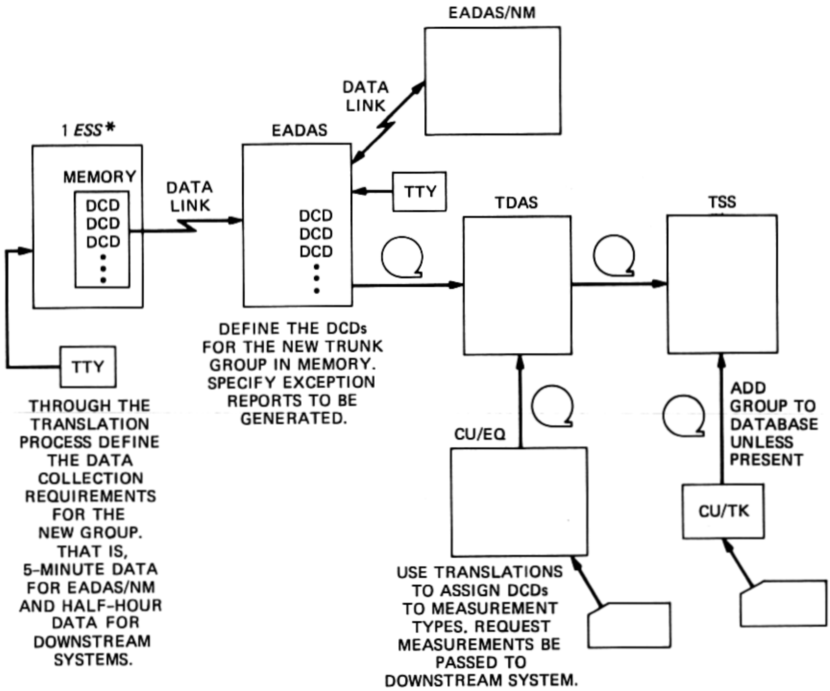
The previous example gave an overview of how TNDS collects and processes equipment data from an electromechanical office. In contrast, the next example describes how trunking data is collected from a 1 *ESS* office and processed by TSS. As before, we will start with a description of the record base process needed to support this data flow. In this case, we will describe the effort needed to add a new trunk group between two 1 *ESS* offices. For this example, measurements will be collected at only one end of the group, hence, data will be needed from only one 1 *ESS* office.

Generally, the recommendation to add a new trunk group would come from TFS as part of the forecasting process. At the time the group need is forecasted, it is added to the CU/TK database. The trunk servicer would write an order to have this new group installed and specify the schedule for data collection. The order would pass through organizations responsible for assigning and installing equipment to make the trunk group operational. One step of this operation would be assigning the group a trunk group serial number (TGSN). The TGSN is similar to the Common Language Location Identifier (CLLI); it is the unique identification for a trunk group in the electronic switching system office. These offices do not require ETDCs; they store counts in their memory and later forward them to the data collection computer.

Figure 4 illustrates the steps necessary to prepare each subsystem to collect and process data from this new trunk group. These steps are similar to those in Fig. 2; the major difference occurs at the switching offices. Traffic measurements are specified in software of the 1 *ESS* switching equipment. This includes the EADAS/NM requirements for five-minute data on the new trunk group and requirements for half-hourly data on the TSS and the other downstream systems. The new trunk group is added to the EADAS and EADAS/NM databases with the TGSN being used to identify the group and the DCDs used to identify individual measurements. If the trunk group is of national interest, it will be marked in the EADAS/NM database to be sent to NOCS.

Record base information for this new group is entered for TDAS and TSS via CU/EQ and CU/TK. As before, transactions are used to define the new measurements, and the time period during which these measurements will be processed, and to specify the new trunk group. Once the record bases have been modified, all subsystems are prepared to process this new group. The next section will trace the data flow from the office to the end users.

Figure 5 shows each step of this data flow. The major difference between this example and the previous one occurs at the front end—



*TRADEMARK OF WESTERN ELECTRIC

CU/EQ – COMMON UPDATE/EQUIPMENT
CU/TK – COMMON UPDATE/TRUNKING
DCD – DATA COLLECTION DEVICE
EADAS/NM – ENGINEERING AND ADMINISTRATIVE DATA ACQUISITION SYSTEM/NETWORK MANAGEMENT
TDAS – TRAFFIC DATA ADMINISTRATION SYSTEM
TSS – TRUNK SERVICING SYSTEM

Fig. 4—Database synchronization for trunk group data.

between the switching office and data collection computer. When an attempt is made to seize the new group, a peg count is stored in a memory location at the 1 *ESS* office. The system passes these data forward upon request from the EADAS. Every five minutes EADAS/NM requests data from the EADAS. In the previous example, data were already in the data collection computer. However, for this example the EADAS must request data from the *ESS* offices that it serves. Raw counts are forwarded to the EADAS, which then subtracts the previous readings and forwards them to EADAS/NM. As before, EADAS/NM processes these data and displays them to the network manager. If this 1*ESS* is a key part of the toll network, data from the new group could be forwarded to NOCS for display.

To satisfy the needs of engineering, much more data are passed from the ESS office to the EADAS on the hour and half hour. These

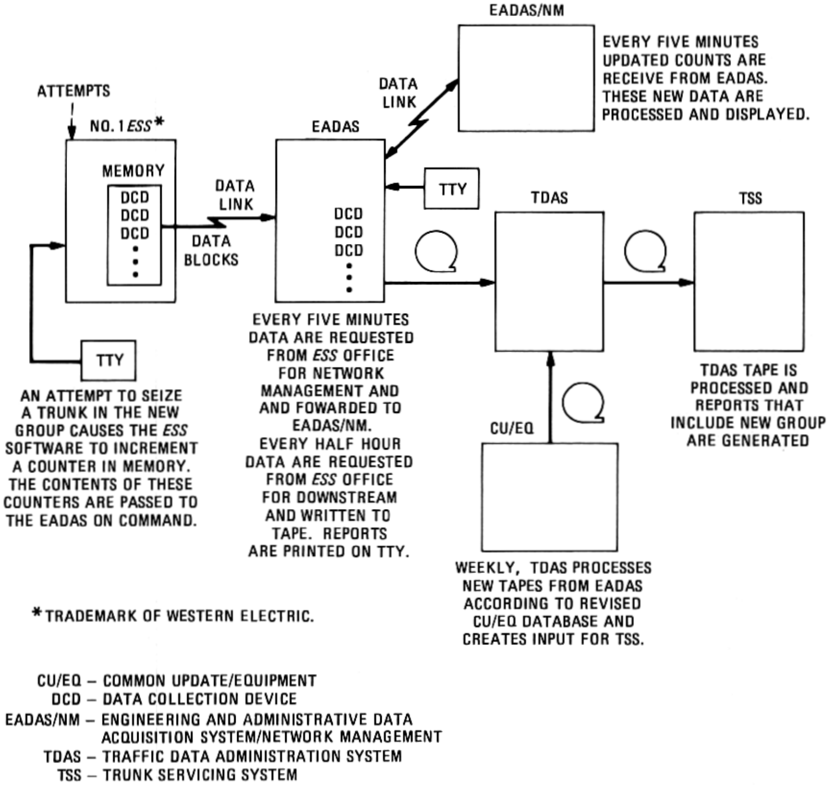


Fig. 5—Flow of trunk group data through TNDS.

data are written to tape and handled identically to the previous example. TDAS generates a separate tape to be processed by TSS and, as frequently as weekly, the TSS subsystem is run to process the data and generate reports. In the case of the new group, the servicer would closely examine its performance to determine if the number of circuits in the group was a good match to the load being offered to the group. If a mismatch occurred, an adjustment in the circuit quantity would be made after a pattern of performance for that group was established by running the TSS program several times with new traffic data.

As was the case for equipment data, CSAR monitors the flow of trunking data, calculates an index on this portion of TNDS, and produces reports that highlight problem areas.

IV. MANAGING SYSTEMS ENGINEERING AND CONTINUING DEVELOPMENT

From the descriptions above, it is clear that from the user viewpoint, TNDS is large and complex. It is even more complex from a software engineering viewpoint. This section describes how the software engineering for this large and complex system is managed.

4.1 End products and services

4.1.1 What is provided

The TNDS organization provides various end products and services to the users. Although the specific details vary among the systems in TNDS, the end products and services can be categorized as follows:

1. Software
2. Documentation
   a. End user
   b. System Operation
3. Training
4. User Support.

The software is in the form of load modules for the specific machine on which the system is run. The load modules for systems run in each operating company are sent by tape or high-speed data transmission and then loaded. System operations personnel install the load modules using the installation guide provided. For centralized systems (e.g., SPCS COER, CSAR, and SONDS), development personnel install the new load modules.

The documentation provided falls into two categories: end user and system operation. End user documentation provides network personnel with information on how to interface with the system. This documentation is usually in paper form, but in the case of SPCS COER and CSAR, it is on-line at the user terminal with the option of printing. Each operating company also receives documentation for system operation from an Electronic Data Processing (EDP) viewpoint for the systems run at that site. This documentation includes information on backup and recovery procedures, resource requirements, etc.

The TNDS/EQ-TNDS/TK training philosophy is to train the trainers—TNDS coordinators and trainers in each operating company—by giving them the information they need to hold similar training courses in their companies. Both user and EDP training is provided. In addition, special release-oriented training usually supplements the basic system training.

User support for each operating company is usually in the form of an assist line (or "hot line") number, which the user can call when questions or problems arise.

4.1.2 Size of the product

Table II shows the relative size of each end product and service for each system in the TNDS. The lines of source code are in various high-level languages (PL/I, COBOL, FORTRAN, and C).

Table II—TNDS software and documentation

	Lines of Code (Thousands)	Pages of Documentation	
		User	EDP
EADAS/NM	900,000	700	800
EADAS	200,000	3500	500
TDAS	75,000	1725	1334
CU (CU/EQ and CU/TK)	119,000	586	2527
ICAN	43,000	1445	318
LBS	42,000	1764	560
5XB COER	128,000	2215	340
SPCS COER	450,000	1000*	20
CSAR	125,000	200*	48
TSS	166,000	1805	641
TFS	80,000	2086	2788
SONDS	178,000	380*	30†
Total (Rounded)	2,328,000	17,000	10,000

* On-line lessons.
† Binders.

4.1.3 TNDS deployment

Another important factor that affects managing the TNDS is its extensive deployment. Table III illustrates the extent of deployment of each component system in TNDS. Looked at another way, some or all of these systems are deployed in all of the operating companies and several are deployed in Bell of Canada.

4.2 Managing change

Although TNDS is a mature system that has been widely deployed and operating in Bell operating companies for some time, the systems are still undergoing extensive development to keep up with the changing operating environment and to furnish improved capabilities. A goal of this continuing development process is to furnish users periodically (usually yearly) with new versions of the systems that incorporate needed changes in a timely manner. To achieve this goal, several factors must be considered.

1. The total number of possible improvements is generally much greater than the resources available for a particular release.

2. The calendar time required to develop a given release is much longer than one year.

3. A change frequently has impact in more than one of the systems of the TNDS.

These factors result in a need for careful planning to choose among the capabilities to be incorporated into a release, to begin planning well before the targeted release date, and to carefully coordinate planned changes among the systems. A formal approach called the TNDS Release Cycle is used to satisfy these needs.

Table III—TNDS subsystem development and utilization

Function	Subsystem	Parameter	Percent Coverage (End 1982)
Data Acquisition	EADAS (or equivalent)	Main and equivalent main telephones	93
	TDAS/CU	Number of companies	100
Network Management	EADAS/NM	Class 1,2,3,4 and sector tandem offices	84
		End offices with over 5000 telephones	63
Central Office Equipment	No. 5 Crossbar COER	Marker groups	97
	SPCS COER	Control groups	100
	SONDS	Step offices over 2000 lines	37
	ICAN	Eligible traffic units	60
	LBS	Eligible traffic units	98
Trunking	TFS	Message and auxiliary trunk groups	84
	TSS	Message and auxiliary trunk groups	93
TNDS Performance	CSAR	TNDS systems monitored	100

4.2.1 The nature of change

TNDS software and hardware are modified and enhanced for many reasons. First of all, designers must run to stay even with the rapidly evolving telephone network equipment, services, and operating procedures. Next additional features are needed by TNDS users and operators. And to prevent the system from becoming technically obsolete, it is necessary to make changes that improve the efficiency, maintainability, and expandability of software and hardware components. Examples of changes to the telephone network that have been accommodated in TNDS include the addition of new switching system equipment such as 5 *ESS* (the management of this change is discussed further below) and the use of new extreme value load engineering procedures. Recent additions include mechanization of *ESS* busy-hour determination studies, and new reports for No. 5 Crossbar administrators. There have been technical improvements to TNDS. Some examples are run time and disk utilization improvements, the complete rewrite of the No. 5XB COER module to improve its maintainability, and the conversion of EADAS to the *UNIX** operating system, which simplified the addition of new features.

New releases of software modules usually contain a mixture of enhancement types. A recent TNDS/EQ release is typical. It contains features that support 5 *ESS* data collection, a new 2B *ESS* traffic data collection interface, and improvements to allow automatic transfer of *ESS* capacity statistics from EADAS to SPCS COER. This release also eliminates software that supported now obsolete data collection equipment. Several software functions were simplified, including the interface with one non-TNDS system, the distribution of traffic register definition listings, and company parameter tables. Also, thirteen separate changes to improve operational efficiency were made.

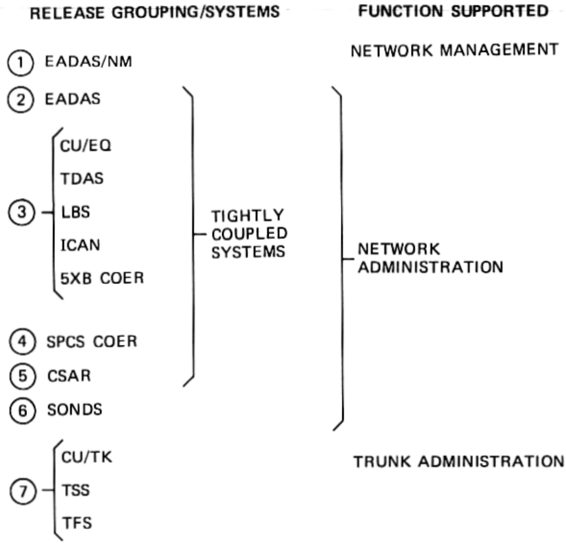
4.2.2 The release cycle

The TNDS release cycle covers the overall planning, development, and project control processes to be employed to produce the major releases of systems in the TNDS. For release purposes, these systems are grouped into seven sets as outlined in Fig. 6.

Each of these groupings has a separate release cycle, all of which are coupled to varying degrees. In particular, the cycles of EADAS, TNDS/EQ, SPCS COER, and CSAR are tightly coupled because of feature interactions. These systems all support the Network Administration function. On the other hand, release of EADAS/NM and TNDS/TK (supporting network management and trunk administration, respectively) are less dependent on the other systems and on

---

* Trademark of Bell Laboratories.



NOTE: TNDS/EQ AND TNDS/TK NOT PREVIOUSLY CITED

5XB COER – NO. 5 CROSSBAR CENTRAL OFFICE EQUIPMENT REPORTS
CSAR – CENTRALIZED SYSTEMS FOR ANALYSIS AND REPORTING
CU/EQ – COMMON UPDATE/EQUIPMENT
CU/TK – COMMON UPDATE/TRUNKING
EADAS/NM – ENGINEERING AND ADMINISTRATIVE DATA ACQUISITION SYSTEM/NETWORK MANAGEMENT
ICAN – INDIVIDUAL CIRCUIT ANALYSIS
LBS – LOAD BALANCE SYSTEM
SONDS – SMALL OFFICE NETWORK DATA SYSTEM
SPCS COER – STORED PROGRAM CONTROL SYSTEMS CENTRAL OFFICE EQUIPMENT REPORTS
TDAS – TRAFFIC DATA ADMINISTRATION SYSTEM
TFS – TRUNK FORECASTING SYSTEM
TSS – TRUNK SERVICING SYSTEM

Fig. 6—TNDS release coupling.

each other. Finally, SONDS is a complete mini-TNDS for a specific class of offices (SXS CDOs), and consequently is more independent of intersystem interactions than other systems in the TNDS.

The following discussion applies in general to all the TNDS systems, but in detailed examples, the release cycle for TNDS/EQ will be used.

4.2.3 Project phases

The project phases in the release cycle define a continuing development process. The phases are divided into major categories and subcategories as shown in Fig. 7 and as listed below:

1. Planning
2. Implementation
    a. Requirements
    b. Design, code, and test
    c. Soak

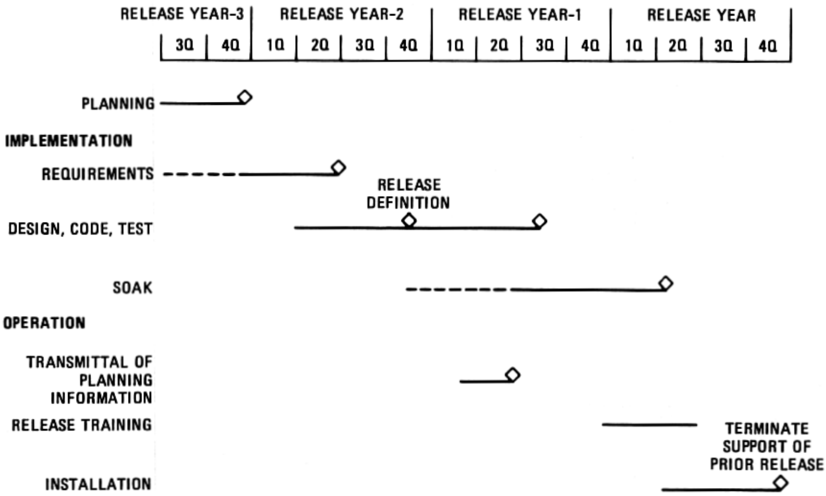


Fig. 7—TNDS release cycle.

3. Operation
   a. Transmittal of planning information
   b. Release training
   c. Installation.

4.2.3.1 Planning. For the continuing development process, inputs come from many sources—operating companies, AT&T, and Bell Laboratories. Operating companies submit change requests to the AT&T project managers. These managers as well as Bell Laboratories designers and systems engineers also initiate proposals. These inputs are diverse. They range from requests to fix bugs or design errors to major development programs. The AT&T project managers and Bell Laboratories systems engineers, often with the advice of telephone company user representatives, perform an initial screening and classification of the inputs. In this step the inputs are classified into maintenance items, desirable improvements, and rejected suggestions. Maintenance items are transferred to the maintenance organization for the component system involved. Rejects are returned to the originator with an explanation of the reason for rejection. Desirable improvements are included in one or more "feature" packages.

Feature packages are specific development items that can be assigned individual priorities. They usually involve only one component system, but may be dependent on feature packages for other component systems for implementation. The assignment of individual items to feature packages has several advantages. Related items can be developed more efficiently as a group rather than separately. Items with similar objectives can be combined or modified to create improvements with more global and more universally useful objectives. And since improvements often are suggested in terms of implementation, the same objectives sometimes can be accomplished as part of an already scheduled or more easily accomplished feature.

Certain time-critical features may be worked into ongoing development of forthcoming releases. These "expedited enhancements" generally must be small and very important because they displace other planned work. The level of management approval required for expedited enhancements depends upon the nature of the work being displaced. The remaining features are subjected to a much longer obstacle course. They must compete for the limited resources available for TNDS ongoing development.

Feature packages are carefully evaluated by Bell Laboratories systems engineering and development, by AT&T project managers, and by telephone company user representatives to establish their priority. Metrics for comparative evaluation include economic benefits, estimated development cost, and estimated length of time to develop. Other intangible factors that are considered in setting priorities are potential quality-of-service improvements, needs to adhere to AT&T corporate policies or operating practices, and the need to respond to FCC or state regulatory commission requests for data.

Feature lists in priority order are maintained on a permanent basis and are updated periodically. Separate lists are maintained for TNDS/TK, TNDS/EQ, SPCS COER, EADAS, and EADAS/NM. Any dependencies on other TNDS or non-TNDS features are noted. These priority lists are used as input for planning specific new TNDS software releases. Priorities may be time-dependent, that is, a certain feature, such as support of a new switching entity may not be needed until some future date. After that date, the importance of the support increases with the expected deployment of the switch.

Release planning is the responsibility of Bell Laboratories systems engineers working with each of the TNDS component systems. They consider the engineering resources available, the priority of proposed features, and length of time for development to formulate the content of proposed releases. These proposals are reviewed by AT&T project managers, telephone company user representatives and, when appropriate, Western Electric product line managers. Changes, if any, are made, and the priority of each of the features in the release package is established. This release priority is used to eliminate work when the inevitable resource constraints and expedited enhancements arrive. While approvals for the proposed release packages are being obtained, work will usually start on requirements for the features in the proposed package. Sign work, however, starts after final approval.

4.2.3.2 Implementation. The first step toward implementing a release is to complete detailed requirements for each feature. These are reviewed and approved, and they are one of the key project control documents.

The design step then translates the requirements into the code changes to be made. Design is divided into two parts: (1) system design, which identifies the modules, files, and interfaces (e.g., transaction and report layouts, intersystem interface definitions) to be changed; and (2) detail design, which identifies the coding changes to be made in each module. After system design is complete, the development organizations formally commit themselves to the contents and schedule for the release. After detail design, the changes are then coded and tested.

Finally, a soak test of the product is performed in one operating company site. The soak process determines if the end product performs in accordance with the requirements, is capable of satisfying user needs, and is worthy of systemwide release. The soak site is selected based on environmental requirements needed to exercise the features in the release. Soak periods vary by system but usually last from three to six months. After a soak is successfully completed, the release is made available for installation in other sites.

4.2.3.3 Operation. The first step an operating company takes in installing a release is receipt of planning information in the form of a Product Release Description, which is usually made available approximately four months prior to the general availability date.

Also prior to general availability, release training information is made available and training classes are held. Documentation for the release is also made available in this time frame.

When the release is available it is installed in other sites. Each site is expected to install the release within a reasonable period (usually six months), at which time continued support of the previous release is terminated.

General availability dates are usually chosen to allow installation during a time period that is not in the traffic busy season when data collection is critical.

4.2.4 Release cycle timing

The phases of the release process are integrated into an overall release cycle as shown in Fig. 7. This figure depicts the major activities within the cycle and the time intervals typically required to conduct each of these activities. Roughly three years are required to complete all of the phases for a particular release. With releases planned for annual delivery, this implies that at any point in time, development activities will be in progress on three different releases. The overlapping of releases is shown in Fig. 8.

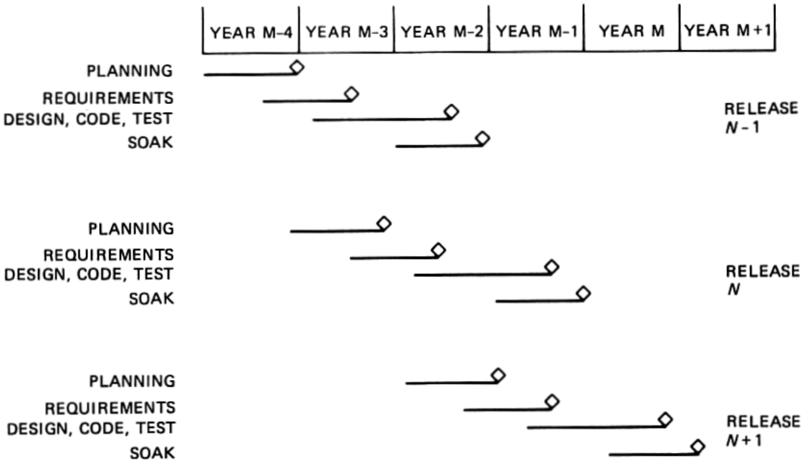


Fig. 8—Parallelism between releases.

4.2.5 *Interproject coordination*

For the subset of TNDS features that involve development in multiple component systems or in non-TNDS systems, an interproject coordination activity must be overlaid on the internal TNDS control process. Features in this category are few but often large, important development efforts. An example of such a development is supporting a new switching system like the 5 *ESS* system. Coordination involves establishing overall requirements for TNDS support, identifying specific "features" to be developed in each component system, and negotiating a coordinated development program for these releases. The development program may involve work in both TNDS and non-TNDS systems. Often, project committees are formed to coordinate requirements, design, testing, and soak of both the hardware and software components. Always there is an exchange of documentation at each step in the process. Interfaces are defined and documented as early as possible.

To make the continuing development process work, it is essential that continual communication among all the people involved be maintained. A permanent AT&T, Bell Laboratories, Western Electric management committee has the responsibility to see that communications are maintained and that problems in the continuing development process are resolved. The process has enabled TNDS to evolve with changes in the telephone business, become more efficient, grow in services to its users, and introduce new technologies, where appropriate.

4.3 The organization structure

TNDS software engineering takes a large number of people working effectively together with well-defined individual responsibilities. Because of the size of TNDS, the organization is structured functionally with each organizational group having responsibility for one or more of the project phases defined above and for one or more of the systems in the TNDS.

4.3.1 Functional structure

Three types of organizations divide up the work in the release cycle—Systems Engineering, Development, and Western Electric Product Engineering Control Center (PECC).

4.3.1.1 Systems engineering. Systems Engineering organizations have responsibility for the planning and requirements phases, and they participate in the soak evaluation.

4.3.1.2 Development. The development organizations are responsible for design, coding, and test, and they also participate in the soak evaluation.

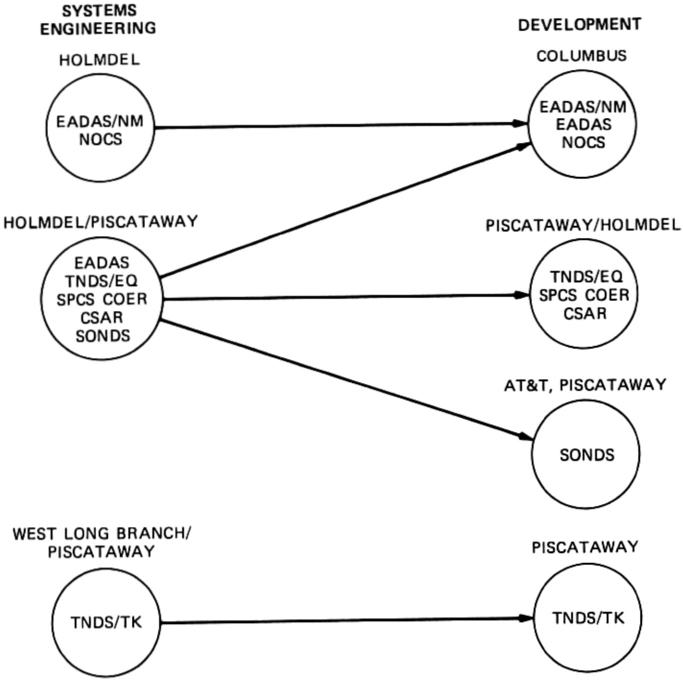
4.3.1.3 Role of Western Electric. Western Electric PECC organizations are responsible for (1) developing documentation, (2) developing training and giving classes, (3) coordinating and performing soak evaluation, (4) maintaining installation support, and (5) providing customer consultation.

4.3.2 Project structures

Figure 9 shows the structure of the TNDS organization in terms of responsibility for systems engineering and development. Each circle represents a separate department in Bell Laboratories. Those organizations on the left are responsible for systems engineering, and those on the right for development. The systems for which the organization is responsible are indicated in the circle. Also indicated above the circle is the physical location of the organization (Holmdel, Columbus, Piscataway, West Long Branch, and AT&T Data Systems in Piscataway). Note that many Western Electric organizations involved in TNDS are not shown on the chart.

4.4 A continuing development example—the marriage of TNDS and 5 ESS

The 5 *ESS* switching system is a new, Bell Laboratories-designed system that recently went into service with full TNDS support in place. Planning and implementation of this support has occurred in parallel with the development of the 5 *ESS* switching equipment. To illustrate the TNDS continuing development process, we will use the history of TNDS support for 5 *ESS* switching equipment.



CSAR – CENTRALIZED SYSTEMS FOR ANALYSIS AND REPORTING
EADAS/NM – ENGINEERING AND ADMINISTRATIVE DATA ACQUISITION SYSTEM/NETWORK MANAGEMENT
NOCS – NETWORK OPERATIONS CENTER SYSTEM
SONDS – SMALL OFFICE NETWORK DATA SYSTEM
SPCS COER – STORED PROGRAM CONTROL SYSTEMS CENTRAL OFFICE EQUIPMENT REPORTS
TNDS/EQ – TOTAL NETWORK DATA SYSTEM/EQUIPMENT
TNDS/TK – TOTAL NETWORK DATA SYSTEM/TRUNKING

Fig. 9—TNDS organizational interactions.

Almost four years before the scheduled cutover of the first 5 *ESS* switching equipment, its development organization began to consider alternatives for handling the traffic data, and the needs for specific types of measurements. A joint AT&T, Bell Laboratories task group was formed to consider 5 *ESS* traffic data-handling needs. Experts on 5 *ESS* development, traffic engineering methods, TNDS, and telephone company data needs were assigned to the group. This task force recommended an overall strategy for handling 5 *ESS* traffic data and identified a number of specific work efforts needed to implement the strategy. The recommendations of this group established the objectives for the several work activities that followed. Key recommendations of this group included:

1. Allocating all traffic data-handling functions except basic measurement and measurement distribution to TNDS.

2. Using extreme value engineering techniques for timing and sizing of 5 *ESS* additions.

3. Collecting traffic data for trunk and switching equipment engineering, division of revenue, service provisioning, switching administration, and network management through EADAS.

4. Selecting peak values in EADAS for extreme value engineering.

Work activities included:

1. Developing extreme value engineering methods and measurement requirements for 5 *ESS* switching equipment.

2. Formulating a TNDS plan to support 5 *ESS* switching equipment.

3. Formulating requirements for 5 *ESS* features needed to deliver required measurements to EADAS.

The task group's recommendations were accepted by AT&T and Bell Laboratories managers, and work started on the above tasks. The work proceeded in parallel.

The first step in the TNDS planning effort was identifying TNDS outputs required for 5 *ESS* switching equipment and the TNDS developments needed to provide these outputs. Descriptions were developed, by individual component system, of the feature packages needed to support 5 *ESS* switching equipment. Table IV identifies the changes needed to TNDS. Following identification of the necessary features a tentative schedule was established for requirements formulation and component system design. This schedule was coordinated with the estimated schedules for the engineering methods work,

Table IV—TNDS developments for initial 5 ESS service

System	Development Required
EADAS	X.25 interface with 5 *ESS* switching equipment Peak measurement selection Complete Network Operation Report Generation (NORGEN) report package
EADAS/NM	No development for first service. (Full EADAS/NM support will be provided in stages with development of advanced versions of 5 *ESS* switching equipment.)
TDAS CU/EQ	5 *ESS* measurement identification Peak measurement handling 5 *ESS* statistics for CSAR
SPCS COER	Complete package of engineering and administrative reports for processing extreme value statistics 5 *ESS* statistics for CSAR
LBS	No development needed for first service. (Development to support a new 5 *ESS* load balance index will be required later.)
TSS, TFS, CSAR	No development required as current software is sufficiently general to handle 5 *ESS* switching equipment.
5XB COER ICAN SONDS	These systems support electromechanical switching entities. No changes for 5 *ESS* switching equipment required.

and the 5 *ESS* development work. The resulting TNDS "Integration Plan" for 5 *ESS* switching equipment was reviewed by Bell Laboratories and AT&T management, and then was distributed to all organizations having responsibility for the TNDS component systems. The TNDS integration plan was completed two years before the scheduled first 5 *ESS* service.

At this point the features needed to support 5 *ESS* switching equipment were added to the feature priority lists for each of the TNDS component systems. These 5 *ESS* features thus became part of the overall continuing development process for TNDS. Because of the expected widespread deployment of 5 *ESS* switching equipment in the operating companies and the large economic penalties that would occur without TNDS support for 5 *ESS*, the 5 *ESS* packages generally received the highest priority for development. Approval for development and for requirements formulation was obtained for each of the component systems in time to meet the initial 5 *ESS* service date. Work then started on requirements and design under the normal TNDS release process.

Three interface definitions (5 *ESS* switching equipment and EADAS, EADAS and TNDS/EQ, TNDS/EQ and SPCS COER) were formulated. These were required because of the decisions to utilize an X.25 protocol between EADAS and 5 *ESS* switching equipment, and the need to specify new schedules for extreme value data being selected by EADAS. Other requirements for new EADAS, SPCS COER, and TNDS/EQ reporting and processing were written. Actual design and coding of the various TNDS features began one to two years before the scheduled first 5 *ESS* service.

A committee of development representatives was formed to coordinate development activities for first service. Experts from 5 *ESS* switching equipment, EADAS, and TNDS/EQ served on it. This group worked out problems in design details and coordinated laboratory-to-laboratory testing activity, which generally proceeded in stages from basic hardware communications to application process communications. In addition, load simulators were used in the development organizations to do further interface testing and debugging. A large number of measurement definition changes occurred during the 5 *ESS* development. These changes had to be accommodated in the TNDS during development.

The first 5 *ESS* is owned by the Illinois Bell Telephone Company. To test the TNDS features designed to support the 5 *ESS* switching equipment, it was necessary to arrange soak testing of EADAS, TNDS/EQ, and SPCS COER releases in Illinois Bell. Planning for this soak testing began about one year before the scheduled first office service.

Final end-to-end laboratory tests were conducted three months before first service. Initial soak testing with the first 5 *ESS* began about six weeks prior to service. A simulated call load on the 5 *ESS* switching equipment was used for these tests. When the 5 *ESS* switching equipment started handling live traffic, TNDS was in place to measure the traffic. Coordinated testing of TNDS components under live traffic conditions continued for several months after first service. Then the new release packages were made available to other TNDS users.

TNDS was ready to serve the first 5 *ESS* switching equipment because the need for TNDS support and planning was recognized by the 5 *ESS* developers early in their development cycle. Planning, requirements formulations, design, code, test, and soak proceeded in an orderly manner with careful coordination at each step. Problems in scheduling, interface details, and detailed measurement definitions were all solved through close coordination of the development efforts.

4.5 Future directions

TNDS will continue to evolve gradually. Setting the direction of this continuing evolution is the purpose of TNDS long-range planning. Long-range planning for the TNDS is a continuous process whose output is a series of TNDS feature packages designed to avoid obsolescence and to take advantage of new technology. The results of recent long-range planning studies have indicated that further major improvements are desirable and appear to offer significant economic benefits. Several improvements relating to additional support for network administration functions are being studied. These studies are aimed at reducing the volume of paper reports produced by the TNDS, and providing users more direct control of TNDS operations, and flexible user-defined output reports. These objectives are planned to be achieved through on-line updating capabilities, expanded user programmability features, and provision of a simple standardized human interface to TNDS component systems. The next steps are to expand the scope of the planning work to include support for other telephone company organizations and to define the specific features that will be implemented. Through this process of continuous renewal guided by a periodically revised long-range plan, it is expected that TNDS will continue to serve the traffic-data handling needs of operating companies into the next decade and beyond.

REFERENCES

1. R. L. Martin, "Automated Repair Service Bureau: System Architecture," B.S.T.J., *61,* No. 6, Part 2 (July–August 1982), pp. 1115–29.
2. R. F. Grantges, et al, "Central Office Equipment Reports for Stored Program Control Systems", B.S.T.J., this issue.

AUTHORS

George W. Riesz, B.S. (Mechanical Engineering), 1950, M.S., (Electrical Engineering), 1952, Princeton University; Bell Laboratories, 1952—. Mr. Riesz joined Bell Laboratories in 1952 as a member of the Analog Computer Design Group. During 1955 and 1956 he served in the U.S. Army at Redstone Arsenal, where he participated in the initial ballistic missile defense studies. In 1956, he joined Nike-Zeus Systems Engineering, and from 1958 to 1960, was responsible for the design of Nike-Zeus battery control equipment. In 1962, he became Head of the Advanced Design Department. He then worked as Head of the Discrimination Measurements Department in Kwajalein from 1963 to 1965, when he became Head of the Nike-X Systems Analysis Department. In 1968, he was named Head of the CAMAR Data Systems Department, working on data systems design for advanced measurements radar. In 1970, he became Head of the Resource Allocation Studies Department, and in 1971, Head of the Traffic Network Studies Department. In 1974, he was named Head of the Network Administration Department. He assumed his present position as Head of the Operations Systems Implementation Planning Department in 1979. Mr. Riesz holds one patent and is the author of several technical articles. Member, Phi Beta Kappa, Sigma Xi.

J. Wayne Steifle, B.S. (Electrical Engineering), 1968, Clemson University; M.S. (Electrical Engineering), 1969, Stanford University; Bell Laboratories, 1968–1983; American Bell, 1983—. After joining Bell Laboratories, Mr. Steifle worked on radar and ABM system studies, and then spent three years in the Air Force working at NASA on guidance systems for manned space programs. After returning from military leave, he worked on guidance design for Safeguard, and later on systems engineering and development of various Business Information System projects. From 1977 to 1980 Mr. Steifle was Supervisor of the TNDS/EQ Engineering Group, where he was responsible for systems engineering for the TNDS/EQ systems. He is currently Supervisor of the Interconnect Software Group in the AIS/NET 1000 Node Hardware Department at American Bell. Member, IEEE.

John A. Kohut, B.A. (Mathematics), 1964, Gannon College; M.S. (Systems Engineering), 1967, Stevens Institute of Technology; Bell Laboratories, 1964–1977, 1980—; AT&T, 1977–1980. Early in his career at Bell Laboratories, Mr. Kohut evaluated the performance of various antiballistic missile systems using computer simulation techniques. From 1970 to 1977, he analyzed the behavior of the message telephone networks and various control systems during failure and overload conditions. From 1977 to 1980, he worked at AT&T, where he was the project manager of an operational support system that aids in the real-time management of the network. Presently, Mr. Kohut is Supervisor of the Trunk Servicing Engineering Group, which plans new capabilities for the Trunk Servicing System (TSS).

Milton S. Hall, Jr., B.E.E. 1959, Georgia Institute of Technology; M.E.E. 1962, New York University; Bell Laboratories, 1959–1968, 1970—; AT&T, 1968–1970. Initially Mr. Hall worked in the data systems engineering organization. His responsibilities there included computer performance analysis, requirements for store-and-forward switching, and plans for wideband data services. He also spent six months on active duty for training in the U.S. Army Signal Corps. In 1968, he transferred to AT&T, where he was involved in long-haul transmission facilities planning. Then in 1970, he returned to

Bell Laboratories to supervise traffic engineering studies. In addition, his group designed a large, on-line system for processing telephone traffic data. From 1977 to October 1981, when he assumed his current assignment, Mr. Hall supervised a group responsible for network administration systems planning. In this work, his group investigated on-line access to information and records as a means to eliminate paper reports and to provide direct user updating of a distributed datebase. Since October 1981, he has supervised a group responsible for operations systems evolution planning. Member, IEEE, ACM, Tau Beta Pi, Phi Kappa Phi, Phi Eta Sigma.