A Study To Assist

THE STATE OF TEXAS

In Defining An Evolution Plan For The

STATE TELECOMMUNICATIONS SYSTEM

Final Report
submitted to the
Telecommunications Services Division
Austin, Texas

BNR
Mountain View

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EXECUTIVE SUMMARY

This report documents the results of a study performed by Bell-Northern Research for the State of Texas, to develop an evolution plan for the State's voice and data communications networks. The objective of this study was to develop a plan which defines the alternatives whose cost/performance exceeds that of the existing networks and recommends the functional requirements for the most attractive system alternative from the standpoint of cost and performance. The resulting evolution plan prescribes a path from the State's current systems toward a practical network that provides a reliably excellent grade of service, that is robust with respect to load growth and technological change, and that provides the potential for integration of voice and data switching and transmission, at appropriate times, over the planning period.

The Executive Summary provides an overview of the results from this study. Included are summaries of the assessment of the existing situation; definition of the major system alternatives considered; analysis of the topological, switching, transmission, and network management aspects of these alternatives; economic evaluation; and a description of the recommended evolution plan. Detailed documentation of each of these areas is contained in the main report. This summary is structured identically to the main report to facilitate the finding of detailed discussions of results that may be of particular interest to the reader.

Chapter 1: Existing Situation

The State of Texas has experienced rapid growth over the last decade, with population rising at a 2.7% annual rate and the real G.S.P. growing at a 4.8% annual rate. Prospects for continued growth and increases in demands for services will cause the number of users of the State Telecommunications System (STS) to grow as well.

STS is a private intrastate long distance telecommunications network which uses a Common Control Switching Arrangement (CCSA) for statewide voice and data communications among State agencies and educational organizations. There are four CCSA switches in the STS network, at Abilene, Austin, Dallas and Houston. These switches are interconnected by groups of dedicated analog intermachine trunks (IMT's), leased from Southwestern Bell. Cities served by STS are connected to the CCSA switches by combinations of Access Lines, Off-Network Access Lines (ONAL's), and Local Off-Network Access Lines (LONAL's). The STS network currently carries over 7,000,000 minutes of telephone traffic in a typical month, during normal business hours. It serves almost 1,300 State office locations, using over 2,200 access lines and almost 400 IMT's.

Changes in the regulatory and technical environment threaten the long range cost effectiveness of the present STS network. The STS network first came into use in the middle 1970's. Since that time technical progress has resulted in the gradual obsolescence of the current CCSA network. Newer techniques and equipment offer the promise of better service, at a potentially lower cost, than that of the current network. In addition, many of the private lines used for access lines and IMT's are provided under a TELPAK tariff, which is scheduled to be discontinued on December 1, 1985. The STS network currently accomplishes a great proportion of its cost savings through use of this tariff, and,

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as a result, its elimination is a major concern. Finally, Centrex service has experienced significant increases in rates during the past few years, and prospects are good for their continuing increase.

Early in the study, a survey was made of users of STS to determine what their perceptions were of their use of STS, their knowledge of how to use the network, and what they experienced when they used it. Results showed that users find the grade of service on STS acceptable, but inferior to that in the public switched network. Availability of the network was a key problem, as reflected in difficulty even getting onto it through access lines.

While the perception of problem areas seemed not to center on any location, users reported more trouble with communications to and from Abilene and Houston than to other STS locations. Network grade of service was identified as an issue that may, in fact, be causing STS to be suboptimal from the point of view of total State communications costs.

Chapter 2: Alternatives Considered

Four categories of alternatives, encompassing a total of fourteen network alternatives for handling voice and data traffic, were identified. The first two categories (one alternative each) proposed a continuation of the existing network and a plan which made minor cost-saving adjustments to the existing approach and configuration. The third category (eight alternatives) would give the State much greater ownership and control of its network elements, and the fourth category (four alternatives) would provide a basis for extensive delivery of broadcast video services.

The fourteen alternative plans identified were as follows:

- The current method of operation (Plan 1), continuing to lease switching and transmission equipment from the dominant carrier,
- Plan 2, which proposes minor topological changes and the leasing of alternative carriers' transmission services when they are more attractive,
- Plans 3 through 6, proposing more significant changes in STS (ownership of switching systems, four alternative schemes for switching data traffic), but proposing continuation of lease arrangements for transmission facilities,
- Plans 7-10, proposing the same data alternatives, ownership of switching systems, and going on to propose ownership of transmission facilities as well,
- Plans 11 through 14, the most significant change in the network, placing satellite transmission facilities in the backbone routes between primary switches.

These network alternatives were evaluated in the areas of topology, transmission facilities, switching, and network management.

The basis for configuring any of the alternative networks was a good model of the traffic demand that exists and is expected to exist in the State during the period 1983 to 1989. Traffic tapes supplied by the State were used to develop a traffic matrix descriptive of the present flows of voice and voiceband data traffic in the STS network. Analysis was performed on historical traffic data to arrive at the growth rates which were used to forecast the future demands to be placed on the network. The growth rates by existing CCSA switches service area are as follows:

STS TRAFFIC ANNUAL GROWTH RATE

Abilene	10%
Austin	7%
Dallas	12%
Houston	8%

For the initial design, a 1989 traffic matrix was produced, as well as the 1982 matrix and a matrix with three times the 1989 traffic (to be used for sensitivity analysis).

Establishment of the proper topology for the STS Network included consideration of the number of levels in the switching hierarchy for the STS (the public telephone network has five; three were suggested for Texas); the number and location of primary and secondary tandem switches in the hierarchy; the best homing of PBX's, Centrexes and key systems to tandem switches; and the number of links connecting the switching nodes.

The analysis of the STS network topology was based upon a set of computer programs called the NTI Network Design System (NTINDS), developed at BNR. This design system handles the choice of tandem switches, homing of nodes to tandem switches, optimization of hop-off routes, selection of primary and secondary tandem switches, determination of economical bypass access groups, and the optimization of interswitch trunking.

The determination of the optimal number and location of tandem switches was accomplished by performing multiple runs of NTINDS using the point-to-point offered traffic matrix for STS as input and assuming a P.05 grade of service objective. A sensitivity analysis was performed to ensure the robustness of the resulting topology to variations in the assumed traffic levels.

Based on 1982 traffic levels, the network has a least cost with a six-switch configuration, although the four-, five-, and seven-switch configurations are close behind. The least-cost configuration has primary tandem switches at Austin, Houston, Dallas, Lubbock, and Abilene, and a secondary switch at Harlingen. Given the number of assumptions and approximations in the process of coming up with a network solution, the cost differentials appear to be insignificant among optimum four- to seven-switch configurations.

A projected traffic level for 1989 was developed to repeat the design evaluations. In addition, a second traffic matrix, based on the pattern of 1989 but with 200 percent more traffic, was also used to evaluate network alternatives. Results of this sensitivity analysis indicated the following:

- Even with three times the expected traffic levels in 1989, the optimal network topology is unchanged – a very stable condition.

- The optimal network has six switches for the current traffic levels and has seven switches for the forecasted 1989 traffic level. The former group of switches is a subset of the latter, with Corpus Christi as a potential additional secondary tandem at 1989 traffic levels.

- Given the current and projected traffic patterns, no drastic changes in primary switch sites are foreseen.

The growth of STS seems easily carried out in an evolutionary manner. The first step should be to investigate the rehoming of several nodes to achieve immediate savings by redirecting their access lines. The next topological step will be to add Lubbock as a primary switching site and Harlingen as a secondary switcher. When the volume of network traffic reaches the projected 1989 level, another secondary switcher may be considered for Corpus Christi.

Data traffic for State agencies is presently carried either through private data networks within the agencies or as apparent voice traffic on the STS network (or public switched network). Alternatives for carrying data traffic through an STS network were evaluated as means for providing more efficient use of communications facilities and data communications test equipment and personnel.

A data traffic matrix was developed based on information supplied by 70 agencies in response to a survey and questionnaire developed by BNR and coordinated by TSD and AISAC. Several general conclusions were drawn based upon the questionnaire response content:

- Virtually all of the traffic is between computers on one end, and terminals, workstations, or job entry stations located at those and other cities on the other end.

- Based on equipment, much of the traffic is of the inquiry/response variety, but there is also significant bulk transaction traffic.

- Many of the agencies operate their own data network, though very few of these reported the network configurations.

- It was usually impossible to break out the communications-related cost components of the agencies' budgets.

Where agencies did not report the amount of data exchanged per transaction, typical numbers of characters per transaction to/from terminals were adopted from other agencies which reported them.

By inspection of the resulting traffic matrix, the likelihood was established that the total data traffic that presently passes between cities is one or more orders of magnitude smaller than voice traffic. The data traffic volume is expected to triple by the beginning of 1987, which corresponds to an annual growth rate of 24.6%.

Two fundamental alternatives for the handling of data traffic were investigated:

- some form of facilities management scheme, which improves the utilization of transmission facilities through multiplexing.
- the use of packet switching techniques for the concentration and distribution of traffic.

Analysis of these alternatives indicated that because of the relatively low volumes of data traffic and the limited need for switching of this traffic, the use of packet switching techniques cannot be justified. For the heaviest data traffic link, Austin to Dallas, a multiplexer system would cost $424.2K, while a packet switching system would cost $853.7K. The small facility savings realized by packet switching does not justify its considerably higher cost in this case.

The most effective means for handling data traffic is to obtain local concentration in the originating location, such that 9.6 kbps access lines can be used. Most of the access lines can be directly multiplexed onto T-1 (1.544 mbps) backbone facilities. The costs for the backbone multiplexers are as follows:

MULTIPLEXER COST OF INTER-NODE LINKS
(1982 Dollars x 1,000)

Link	1984	1985	1986	1987	1988
Houston-Austin	107.50	10.66	34.30	36.76	41.68
Dallas-Austin	148.36	36.76	40.04	44.96	64.24
Lubbock-Austin	82.22	30.20	32.66	14.76	59.58
Abilene-Austin	-	-	-	-	-
Harlingen-Austin	55.22	4.92	15.52	28.56	9.84
TOTAL	393.3	82.54	122.52	125.04	175.34

COST OF MODEMS AT NODES AND
INSERT/DROP POINTS
(1982 Dollars x 1,000)

	1984	1985	1986	1987	1988
Modems	1,052	256	320	388	496

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Transmission alternatives fell into the categories of leased lines for Plans 1 through 6; terrestrial microwave radio, to be owned by the State, or fiber optic systems, to be owned by the State, for Plans 7 through 10; and leased or owned satellite systems or subsystems for Plans 11 through 14.

A first-order evaluation of the owned transmission alternatives was conducted to eliminate some of the alternatives prior to performing a detailed analysis.

The use of digital transmission for an owned transmission system is strongly recommended. End-to-end digital facilities provide superior transmission quality compared to analog transmission. The cost of digital transmission systems are equivalent to or lower than analog systems. The interface between digital switching systems and a digital transmission system are also lower in cost compared to an analog connection. For data communications, digital transmission is more efficient.

A voice channel on a digital transmission can carry a 56 kbps data signal, while the equivalent analog voice channel can, at most, carry a 9.6 kbps signal.

A quantitative model was developed to capture the costs of using satellite facilities to provide all IMT's between tandems in the network. These costs were then compared against the present cost of the leased-line IMTs ($113.6K per month) to determine the economic attractiveness of using satellite facilities. Two options exist for the use of satellite facilities - use of dedicated earth stations (either owned or leased) with leased transponders, and use of satellite-based leased facilities. Analysis of the use of the dedicated earth station approach indicated a significant cost penalty over the use of leased lines, as indicated by the following:

- The lease of four ten-meter earth stations (one for each of the four existing primary centers) will cost approximately $72K per month.

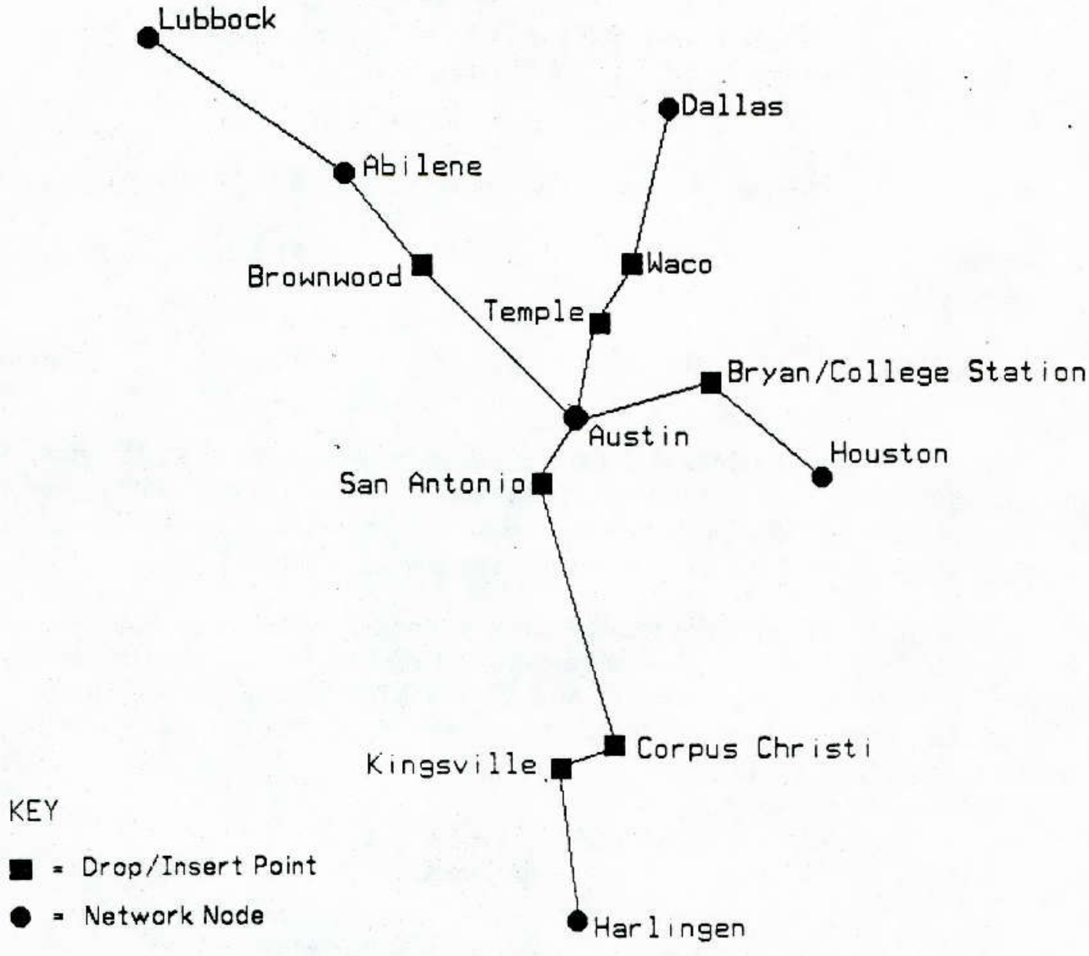
- Transponder lease will cost approximately $100K per month.

Thus, the total cost of this approach is approximately $172K per month, as compared to the present $113.6K per month for leased lines. A similar analysis of the use of satellite-based leased facilities indicates a total cost of $221K per month, approximately twice the present leased line cost.

The use of satellite transmission becomes attractive when broadband services (e.g., video) proliferate. The study team did not uncover evidence – in its interviews of major users of STS, key State planning agencies or the State University System, or in the data that it gathered – that broadband services were expected in any quantity in this decade; thus, the use of satellite transmission facilities for STS is not recommended.

The topology and circuit requirements for a state-owned terrestrial transmission system (fiber optic or microwave) was determined. As it was determined that route diversity was not of great interest to the state unless there were clear quantifiable economic benefits, the potential facilities routes were reduced to a star configuration out of Austin. The suggested routes are illustrated in the following figure:

Owned Facilities Routes



A first-order economic comparison was also made between microwave and fiber optic transmission systems. In this analysis, two major routes (Austin-San Antonio and Austin-Dallas) were selected for this comparison. The application of fiber optics has its greatest potential on these two routes, because they contain the greatest number of circuits in the STS. Two alternatives were considered for both fiber and microwave - a 45 Mbps system (Fiber-I, Microwave-I) and a 90 Mbps system (Fiber-II, Microwave-II).

The first-order cost comparisons for the fiber optic and microwave systems, using ideal repeater spacing, are as follows:

FIRST COST COMPARISONS
FOR FIBER AND MICROWAVE SYSTEMS
(1982 Dollars)

Route	Air Miles	Fiber-I	Microwave-I	Fiber-II	Microwave-II
Austin-San Antonio	73	$1,442K	$1,137K	$1,488K	$2,035K
Austin-Dallas	181	$3,452K	$2,888K	$3,606K	$4,485K

The 45 Mbps fiber optic system is considerably more expensive than the microwave system for the routes studied. It is not expected that either of these routes will exceed the 45 Mbps capacity by the year 2000 for both voice and data traffic. Thus, it is concluded that microwave is the preferred medium for a State-owned transmission system.

The costs of a State-owned microwave system were then determined in more detail. Among the factors considered in this determination were the costs of repeaters, land, shelter, site preparation, towers, fencing, radios (6 and 12 GHz), muldems, channel banks, transmission lines, antennas, power, alarm and control systems, and installation. The following table provides a summary of these costs.

STS MICROWAVE SYSTEM COST
(1982 Dollars)

Year	Austin-Lubbock	Austin-Dallas	Austin-Harlingen	Austin-Houston	Common	TOTAL
First Cost	$4,596K	$4,026K	$5,440K	$3,536K	$ 266K	$17,864K
1986	$7K	$1K	$11K	$14K		$33K
1987	$8K	$300K	$21K	$1K		$330K
1988	$20K	$24K	$28K	$2K		$74K

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If leased facilities were used instead of this transmission system, the annual charge would be $2,255,400 for 1982 circuit requirements and $2,851,000 for 1985 circuit requirements (1982 dollars). The savings in leased circuit costs would equal the initial capital investment in just over six years, without considering the cost of leased data circuits or access lines that would be carried by the system. If the lease cost savings in access lines is taken into account, the savings will equal the capital investment in just over three and one half years, using the 1985 savings of $2,029,000. Thus, it is clear that an owned microwave system is an attractive transmission system for the State.

Chapter 5: Switching

Several alternative plans for meeting the switching requirements for the STS voice communications network were identified and evaluated. This analysis includes the requirements for both tandem trunk and local PBX switching.

Uniform control and functionality of the STS tandem backbone network is a critical element that will assure the successful operation of the network as an integrated system. It is strongly recommended that a single vendor of switching equipment be considered for the tandem nodes, but this is not as essential with PBX switches, since they are designed to operate outboard of the tandems.

The functional requirements for the STS tandem switches include the provision of uniform dialing, least-cost routing, special routing when satellite circuits are used, four-wire circuit paths, stored program control, and a user-friendly interface to facilitate administration and maintenance of the network. The previously described results of the topological analysis recommended a six-switch tandem network, with five primary tandems in Abilene, Austin, Dallas, Houston, and Lubbock and a secondary tandem in Harlingen. The sizes of each of these tandem switches are determined by the summation of all the facility requirements at each of these locations, including IMTs, Access Lines, Off-Network Access Lines, and Off-Net WATS-like circuits. The total tandem terminations and PBX lines associated with each of the six principal STS cities are summarized below.

TOTAL TERMINATIONS

	1984	1985	1986	1987	1988	1989
ABILENE						
- Tdm Term	432	468	504	540	576	612
- PBX Lines	350	375	400	425	450	475
AUSTIN						
- Tdm Term	2231	2386	2541	2696	2851	3006
- PBX Lines	5218	5577	5936	6295	6654	7013
DALLAS						
- Tdm Term	1603	1732	1861	1990	2119	2248
- PBX Lines	2978	3217	3456	3696	3934	4173
HARLINGEN						
- Tdm Term	490	518	546	574	602	630
- PBX Lines	448	472	496	520	544	568
HOUSTON						
- Tdm Term	1424	1525	1626	1727	1828	1929
- PBX Lines	6886	7329	7772	8215	8658	9101
LUBBOCK						
- Tdm Term	509	543	577	611	645	679
- PBX Lines	8130	8695	9260	9825	10390	10955

Four STS network switching alternatives were identified, with a fifth – the Present Method of Operation (PMO) adjusted to give a grade of service comparable to Alternatives A, B and C – added for perspective. The alternatives:

- The PMO @ P.07;
- The PMO @ P.02/P.01;
- Plan A - Replace CCSA with owned tandems;
- Plan B - In addition to Plan A, replace Centrex with PBX's which are separate from the tandem switches;
- Plan C - In addition to Plan A, replace Centrex with PBX's which are combined with the tandem switches.

A decision on the switching functions is dependent on both switching and network management costs, in the areas of both capital and expense. For that reason, economic comparisons between alternatives are made later in the report, after network management costs are characterized.

Chapter 6: Network Management

The functional requirements for operating the STS network were developed. Based on these requirements and the STS network configuration, network management equipment configurations and costs were then estimated. The staffing, organization, salaries and overhead costs in operating the network were also derived, based on pay scales for the independent telephone industry. In addition, spare parts and repair expenditures were estimated.

The major network management functions required to provide adequate day-to-day communications for the STS users are:

- maintenance: ensure the smooth day-to-day operations of the network and remedy problems before they become severe.
- traffic control: ensure that the network provides adequate traffic carrying capacity.
- administration: provide an appropriate mechanism for equipment/facility procurement and inventory, station moves and changes, and on-line directory.
- accounting: provide equitable chargeback to the individual agency for its network usage.

In addition, there should be a long range planning program to allow periodic redesign of the network.

It is recommended to deploy a centralized organization with a centralized Network Management Center (NMC) to perform these functions. The network management organization should consist of staff at the central site and at regional sites where the tandem switches reside. The central staff has responsibility for network-wide maintenance, administration, and control. The regional site staff has responsibility for maintenance and administration of the tandem switch and transmission facilities under the domain of the region. The NMC should be located at the central site and may consist of several systems.

Planning prices were developed for the equipment required to provide the network management functions identified above. This equipment was categorized into three major areas: Switch Network Management Center, Transmission Quality Test Equipment, and Transmission Facility Maintenance. The first cost associated with this equipment in the six tandem switch locations is summarized on the next page.

NETWORK MANAGEMENT COSTS
(1982 dollars)

	Netwk Mgmt Center	Trans Facility Maintenance	Trans Quality Test
Abilene	$ 0	$10,000	$ 79,900
Austin	500,000	35,000	234,300
Dallas	0	10,000	165,100
Harlingen	0	10,000	33,400
Houston	0	10,000	146,750
Lubbock	0	10,000	41,650
TOTAL	$500,000	$85,000	$701,100

Seven staff categories were identified for the STS network management. These categories and their corresponding salary estimates are as follows:

- Operations Manager - $39,757
- System Administrator - $32,620
- Telecommunications Analyst - $22,302
- System Operator I - $22,302
- System Operator II - $15,695
- Technician - $22,637
- System Clerk - $13,690

For network operations, the number of staff personnel in the Operations Department will require an increase from nine positions currently to 20 positions when the private network is installed. The Telecommunications Division overhead costs will increase from $568,906 to $867,102 when the new network is installed. If the STS operates all PBX's as specified in the switch configuration, 39 additional technicians are required in 1986.

Appropriate spare parts should be stored strategically in each network node site and central site to ensure that parts are readily available for repair. Specific spare parts inventories required are as follows:

- tandem switching systems - $364,000
- emergency power supplies - $147,000
- PBX equipment - $197,600
- digital radio systems - $75,000
- emergency power generators - $94,500

The annual maintenance for the network management equipment is expected to be $40,400. The repair expenditures for tandem switching systems is expected to be $53,790 in 1986 and for PBX systems to be $361,990 in 1987. Digital radio repair and miscellaneous expenditures are estimated to be $56,000 per year.

Chapter 7: Systems Level Evaluation

A detailed economic analysis of each alternative plan is presented and supplemented with a discussion of non-quantifiable issues that impact the decision process leading to selection of the recommended arrangements. The alternatives examined in this section are:

- The PMO @ P.07;
- The PMO @ P.02/P.01;
- Plan A - Replace CCSA with owned tandems;
- Plan B - In addition to Plan A, replace Centrex with PBX's which are separate from the tandem switches;
- Plan C - In addition to Plan A, replace Centrex with PBX's which are combined with the tandem switches.

Plans A, B, and C also include the replacement of the present leased IMT circuits with the owned microwave system as described earlier and the establishment of the centralized network management organization and NMC.

The basic method employed is a discounted cash flow analysis. A study period of ten years was chosen, permitting the full depreciation of most major capital investments. The first five years were designated as the planning period, during which capital and expense (including growth) were shown. The second five years were used as a complementary period, during which no new capital or expense for growth was shown. Only recurring expenses associated with the network as of 1988 were carried on into the second five years.

A composite cost of money for tax payers of twelve percent was chosen. That cost of money was used to discount all net cash flows after the beginning of the study, thus allowing all cash flows to be reflected in equivalent 1984 (beginning of study) dollars. The sum of these "present worths" was the indicator used to judge the relative economic actractiveness of the plans. The following table summarizes results of the economic analysis.

PRESENT WORTH OF EXPENDITURES (PWE)

PMO (P.07)	$464.0M
PMO (P.02/P.01)	$516.2M
PLAN A	$390.3M
PLAN B	$321.5M
PLAN C	$322.6M

In looking at Plan A versus the PMO, it is clear that ownership of the tandems and radio facilities yields significant savings of at least $73M in 1984 dollars while providing a significantly better grade of service than the present network. Plans B and C consider the replacement of all Centrex and leased PBXs with owned PBXs. The economic analysis shows virtually no difference between Plans B and C, but either plan yields an additional PWE savings of nearly $68M over Plan A.

Results were tested for their sensitivity to the cost of capital assumption. Rates of ten and fourteen percent yielded no significant change in economic results, with PWE savings for Plan B (over the PMO) of $163.7M for the ten percent assumption and $121.1M for a fourteen percent assumption.

It is clear that the State of Texas should own its tandem network and the PBX's providing service to the State's agencies. Network ownership saves at least $73M and PBX ownership another $68M for a total PWE savings of at least $141M over the life of the study.

Chapter 8: Recommended Plan

Two plans are recommended, depending on whether or not STS operates the PBX's in all network node locations (Plan C) or not (Plan B) as discussed in the preceding section. Included in these plans are consideration of equipment, staffing, and capital and expense requirements. In addition, floor space requirements are specified. The capital and expense requirements for the recommended plans (Plans B and C) are listed below in nominal (inflated) dollars. In the case of a standalone tandem, the operation of the PBX's at each of the tandem locations might or might not be the responsibility of STS. The capital and expense requirements are shown in the next table.

It should be noted that the following tables show the *inflated* dollar values expected in the respective years. These expenditures are intended to take care of continuing existing demand and also line, trunk and traffic demand in STS. It should also be noted that the presence of owned radio was reflected not only in its cost (in the categories of radio, network management and operations), but also in its impact on the leased facilities that are required in 1985 and thereafter. There will still be a substantial requirement for leased access facilities, as is shown in the table, but it is likely that, as a detailed microwave path search is completed, opportunities for further savings in lease charges (by putting access lines on the owned radio) will be identified. Finally, the PBX/Centrex lease charges in 1987 and 1988 (and some in 1986) reflect the charges for connecting PBX's to the public network and also for such features as AIOD and DID that would make the PBX's feature-comparable with the existing Centrex service.

CAPITAL AND EXPENSE REQUIREMENTS
STAND-ALONE TANDEMS
($000)

	1984	1985	1986	1987	1988
Capital					
Tandem	$ 1,569	$ 7,858	$ 0	$ 683	$ 0
PBX	0	258	44,022	0	2,481
Radio, Modems, Multiplex	8,631	15,429	647	1,239	1,184
Network Management	0	1,948	35	38	42
Subtotal	10,200	25,493	44,704	1,960	3,707
Expense					
Leased Facilities	$15,472	$16,742	$19,346	$22,707	$27,242
Leased PBX/Centrex	17,641	20,554	13,841	4,468	5,206
Leased Tandems	2,692	1,574	0	0	0
Operations (Network)	811	1,378	1,697	1,873	2,067
Operations (PBX)	0	0	1,692	2,539	2,937
Subtotal	36,616	40,248	36,576	31,587	37,452
TOTAL	$46,816	$65,741	$81,280	$33,547	$41,159

The capital appropriation needed in 1983, for 1984 expenditures, is therefore $10,200,000, and the appropriations for the succeeding years follow in the same manner, with an appropriation for 1985 capital expenditures of $46,664,000 needed in the 1983 session, for example.

In the case of a combined PBX/tandem, STS would own and operate all of the PBX's that were being used as tandems. In this case, there is a small facilities saving in that some local access lines would be eliminated. This alternative's requirements are shown in the next table.

CAPITAL AND EXPENSE REQUIREMENTS,
COMBINED PBX/TANDEMS
($000)

	1984	1985	1986	1987	1988
Capital					
Tandem	$ 2,004	$12,726	$ 0	$ 431	$ 0
PBX	0	258	42,593	0	2,236
Radio, Modems, Multiplex	8,631	15,429	647	1,239	1,184
Network Management	0	2,601	35	38	42
Subtotal	10,635	31,014	43,275	1,708	3,462
Expense					
Leased Facilities	$15,472	$16,403	$19,020	$22,328	$26,802
Leased PBX/Centrexes	17,641	20,554	13,841	4,468	5,206
Leased Tandems	2,692	1,574	0	0	0
Operations (Network)	811	1,378	1,735	1,915	2,113
Operations (PBX)	0	0	1,692	2,539	2,937
Subtotal	36,616	39,909	36,288	31,250	37,058
TOTAL	$47,251	$70,923	$79,563	$32,958	$40,520

The capital appropriation needed in 1983, for 1984, is $10,635,000. As in the previous chart, any years' capital appropriation must be made during the preceding year.

The implementation schedules are broken into three parts: radio, tandem switching/network management and PBX. Key steps are described on the next page.

The key steps for the radio installation are:

- radio path survey in early 1983
- preparation of an RFQ by June 1983
- contract award by November 1983
- FCC permit approved by June 1984
- first group (Austin-San Antonio, Austin-Abilene) cut by December 1984
- second group (Austin-Dallas, Lubbock-Abilene) cut by April 1985
- third group (Austin-Houston, Harlingen-San Antonio) cut by August 1985

The key steps in the tandem and network management installation are as follows:

- preparation of an RFQ by July 1983
- switch award by April 1984
- first group (Austin Tandem, NMC, Abilene Tandem) cut by February 1985
- second group (Dallas Tandem, Lubbock Tandem) cut by June 1985
- third group (Houston Tandem, Harlingen Tandem) cut by October 1985

The key steps in the PBX installation are as follows:

- preparation of an RFQ by January 1985
- first group (Austin, Abilene) cut by January 1986
- second group (Dallas, Lubbock) cut by May 1986
- third group (Houston, Harlingen) cut by September 1986

These three implementation schedules have been coordinated to provide a smoothly phased service transition.

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1 EXISTING SITUATION

The State of Texas has experienced rapid growth over the last decade. According to the Texas 2000 Commission report, published in March of 1982, the population of Texas increased at an annual rate of 2.7% during the 1970's while the population of the nation as a whole rose at a 1% annual rate. The report estimates that the total population of Texas may total 22 million by the end of the century. The same report states that Texas' real Gross State Product grew at a 4.8% annual rate during the last decade, compared to a 3.6% rate for the Gross National Product.

The Texas 2000 Commission is part of the Texas 2000 Project, which is looking at the future of Texas to the end of the century. It proposes that the population and economic growth experienced in Texas during the 1970's is expected to continue through the rest of the century. Prominent challenges to the State will therefore be the productive and careful development of natural resources, and the provision of government services that are essential and economical.

State government services are provided by various agencies, boards and commissions, which have historically operated autonomously and are expected to continue to do so. Autonomy among State agencies implies that the agencies will most likely continue to specify their own requirements for communications and their own equipment for data processing.

Although there has been a call for data processing plans from all State agencies by the Automated Information Systems Advisory Council (AISAC), it is perceived that many of these plans are only in their formative stages. As a result, any planning for a communications system or network that includes these agencies must assume that a variety of systems will be served, with their respective protocols, line speeds, and modes of operation (batch, interactive, centralized, distributed, etc.). Also, the agencies can be expected to develop applications and uses unevenly.

The State Telecommunications System (STS), once (and still often) called the Tex-an Network, was implemented to provide these agencies, and several educational campuses and organizations in the State, with interlocation communications services at lower costs than these organizations could get individually. The next section describes STS in greater detail, and a following section presents the issues that have made a rethinking of the network necessary. Appendix A was included to describe some of the major users of the STS network. These descriptions provide a brief overview of the organizations, their communications needs and their concerns, as expressed in several interviews with the study team.

1.1 The STS Network

STS is a private intrastate long distance telecommunications network which uses a Common Control Switching Arrangement (CCSA) for statewide voice and data communications among State agencies and educational organizations. Access also exists from STS to the public telephone network for access to locations that are not served directly by STS.

There are four CCSA switches in the STS network, at Abilene, Austin, Dallas and Houston. The serving switch for an STS number is indicated by the second digit of the STS number -- 4 or 6 for Abilene, 2 or 8 for Austin, 3 or 9 for Dallas, and 5 or 7 for Houston.

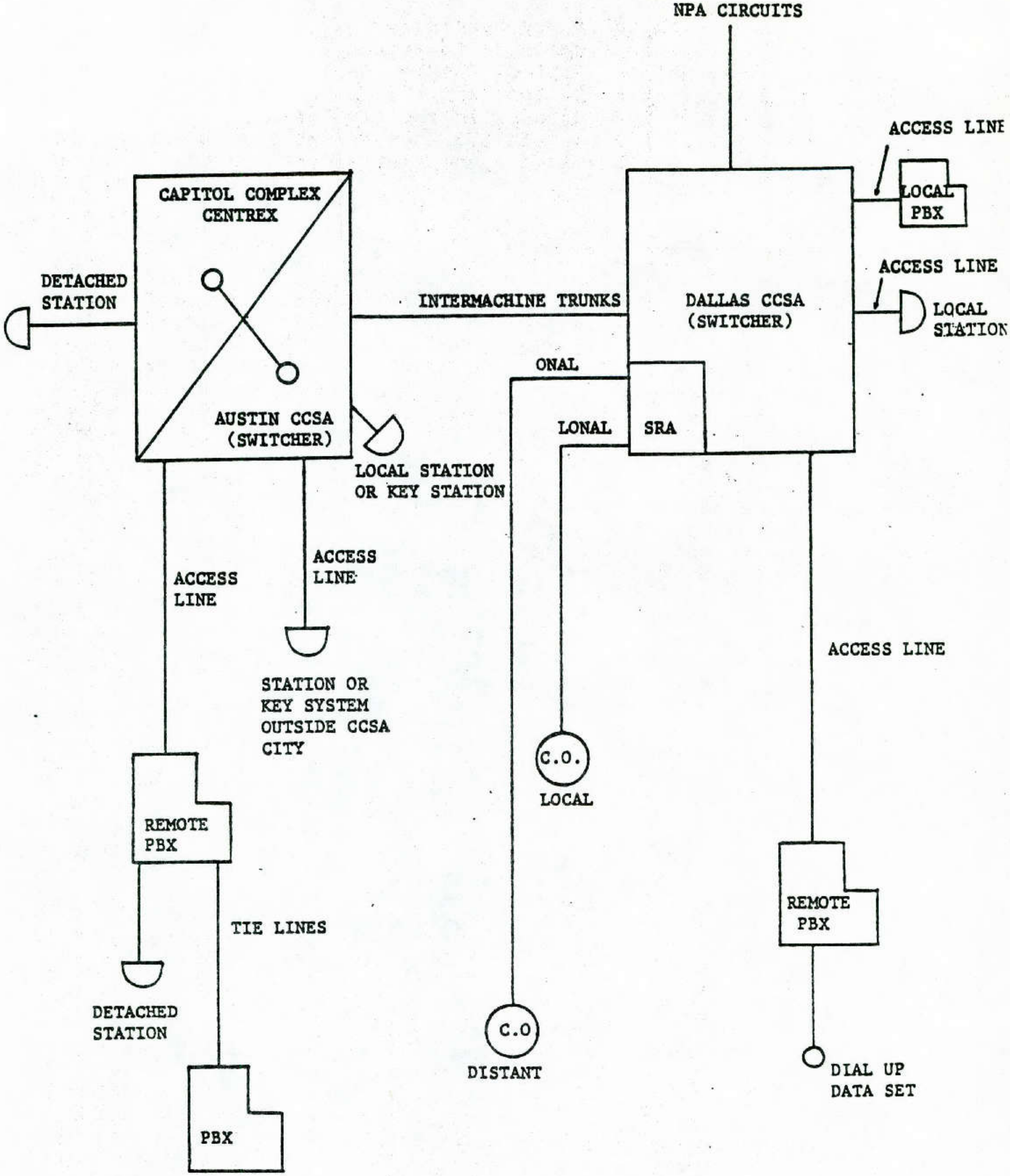
The CCSA switches are connected to each other by groups of dedicated analog Intermachine Trunks (IMT's), leased from Southwestern Bell under the Private Line Service Tariff filed with the Public Utility Commission of Texas. The majority of these channels are provided under the TELPAK section of the tariff.

Cities served by STS are connected to the CCSA switches by combinations of Access Lines, Off-Network Access Lines (ONAL's), and Local Off-Network Access Lines (LONAL's). The latter two facility types connect the CCSA switches to telephone company central offices, instead of to Centrex's, PBX's or key systems. ONAL's and LONAL's provide service to State locations that do not have STS Access Lines, as well as to and State employees who are away from State offices. These circuits also allow State employees to call State citizens over the STS network. Many offices have Detached Stations (D/S's) which are served by either TELPAK, Interexchange Channels (IXC's), or local office channels, depending on their locations with respect to the serving PBX. Direct Distance Dialing (DDD) and intrastate Wide Area Telephone Service (WATS) circuits provide access to cities not provided with dedicated circuits (Access Lines, ONAL's or LONAL's). The State currently utilizes Local Area WATS (sometimes referred to as Area Code or NPA WATS), which permits unlimited outward calling within a designated Area Code or Codes over an access line for a flat monthly fee. This service is being phased out in favor of the more traditional forms of intrastate WATS, with statewide service areas. Figure 1.1 details the general structure of the STS network.

On-network to off-network calls originate at State offices served by STS Access Lines and terminate, via other than STS facilities, at locations <u>within</u> the State. In this case the normal ten-digit public network telephone number is dialed instead of an STS number. If the call's originating and terminating points are served by the same CCSA switch, the call is carried to the serving switch by an Access Line and from there by an ONAL, LONAL, or WATS circuit.

FIGURE 1.1

COMPONENT PARTS OF THE STS



Off- to on-network calls are handled by STS operators located near each of the four CCSA locations, at the Abilene State School in Abilene, the Capitol Complex Centrex in Austin, the University of Texas at Dallas, and the University of Texas System Cancer Center in Houston. In the case of off-to-on calls, the user dials the nearest STS Operator number (published in the STS Directory), provides appropriate identification, and is connected by the operator.

1.2 STS Traffic and Analysis

Management of the STS network is provided by the Telecommunications Services Division of the State Purchasing and General Services Commission, with assistance from Southwestern Bell in the provision of traffic usage data and technical services. The STS staff determines facility changes, monitors the quality of the network, provides for trouble reporting, and publishes an STS directory. The STS staff also evaluates the cost-effectiveness of new requests for service, as well as performing other services.

During the period October 1981 to March 1982, the STS network carried a monthly average of over 5,400,000 minutes of telephone conversations during normal business hours. As of April 1982 the network served 1,279 different State office locations using 2,203 access lines and 380 intermachine trunks, many of which are leased under the TELPAK tariff. The network also used 796 ONAL's, 132 Local Area WATS circuits, 71 tie lines and 760 detached stations. The STS network also provides dedicated circuits, which are also leased in bulk under the TELPAK tariff. These dedicated circuits are used primarily for data communications and totaled 96,827 circuit-miles in fiscal 1981. Appendix B details the current facilities of the STS network and recent traffic statistics. This appendix includes a list of cities served by the STS network and the facilities used to serve these cities. The appendix also includes a copy of STS report 135-D which details traffic carried on the STS network by CCSA switcher for March 1982 and the preceding six months. Finally, the appendix contains an excerpt from the annual report to the legislature on the cost effectiveness of the State Telecommunications System, detailing the dedicated circuit mileage by agency and total STS voice usage by agency for fiscal 1981.

1.2.1 User Survey

Early in the study a survey was made of users of STS, to determine what their perceptions were of their use of STS, their knowledge of how to use the network, and what they experienced when they used it. The survey questionnaire was distributed to a largely random sample of users (46% of whom were in the Austin area), and the questions, user answers and analysis results can be found in Appendix F.

The results showed that users felt somewhat to very comfortable with their knowledge of the network (87% felt that way), although almost half the users either didn't know or thought it impossible to dial an on-net call from an off-net location (45%), and again almost half (48%) reported that they didn't know who to talk to when they experienced a problem using STS.

With respect to the performance of the network, 87% thought that STS performance was at least good for calls between network locations, and 86% felt that way for on-net to off-net calls. This compared acceptably well with their responses regarding the performance of the public DDD network (97% felt that local call quality was good or better; 96% felt that regular long distance conversations were at least of good quality). There is room for improvement here, however. The most frequently cited troubles with connection quality were noise on the line (37%) and mid-call cutoffs (32%).

The other area of perceived difficulty seemed to be in just being connected through STS to the called party. When asked what led them to use other means than STS to complete a call to other STS locations, 32% said the reason was that the network was busy, and another 24% said that they did this because STS "wasn't working". When queried about the geographical areas in which they seemed to have the most problems with connection and with transmission quality, users replied fairly uniformly, with Abilene and Houston cited more often as places where quality-of-connection troubles were experienced.

1.3 <u>The Problem:</u>

While there are some operational improvements that seem appropriate in the network, the following problem statement was derived as the key issue in this study:

<u>Changes in the regulatory and technical environment threaten the long range cost effectiveness of the present STS network.</u>

1.3.1 Regulatory Environment

Recent regulatory decisions in the Federal Courts, The Federal Communications Commission and at the State level threaten to greatly increase the cost of services leased by the State of Texas from Southwestern Bell and other common carriers. Throughout the 1970's the telecommunications industry has slowly moved from being a highly regulated industry, to one in which competition is becoming the norm. A series of Federal Court decisions (and related decisions at the FCC), have made the continuing move toward competition inevitable. Probably the most important of these decisions are the Carterfone, Execunet and the recent AT&T-Justice Department Consent Decree. The Carterfone decision opened the door to the provision of terminal equipment (telephones, PBX's, key sets etc.) by the so-called interconnect industry (companies unrelated to the operating telephone company that compete in the same serving area).

The Execunet decision provided for the development of competition in the provision of long distance services. As a result of this decision several companies currently provide long distance services in competition with the telephone industries long distance, Private Line and WATS services. The recently revised AT&T-US Department of Justice Consent Decree, separates the provision of local service (which is generally provided on a monopoly basis) from the provision of long distance services, with the two services being provided by unrelated companies. Of the recent regulatory decisions, the following three areas will have the most impact on the existing STS network. These decisions are largely a direct result of the Federal Court decisions just discussed. The critical decisions have been:

(1) An outgrowth of the Execunet decision was a series of decisions by the FCC to allow the resale of long distance telephone services. This decision allows firms to purchase long distance services (WATS, Private Line, etc.) in bulk from AT&T and other common carriers and resell them to smaller users at a profit. The then-current AT&T interstate tariffs contained quantity discounts that assumed that resale would not exist. It was possible under these tariffs for a reseller to purchase Full Business Day WATS lines and TELPAK circuits and greatly undercut AT&T charges for smaller users, while making a large profit. As a result of this, AT&T greatly revised its interstate WATS tariff and withdrew its interstate TELPAK tariff, eliminating much of the problem. The same pressures which resulted in the new interstate WATS tariff may result in the eventual elimination of Full Business Day WATS at the intrastate level. Local Area WATS, which is currently used by the STS network to access cities not served by ONAL's or LONAL's, has been limited to existing users of this service. Most likely this service will eventually be eliminated in favor of more expensive Measured Time WATS services. The intrastate TELPAK tariff is being phased out by Southwestern Bell. This service offering is scheduled to be eliminated December 1, 1985. The STS network currently accomplishes a great proportion of its cost savings through the use of voice circuits provided under the TELPAK tariff. As a result, its elimination is of major concern.

(2) Telephone toll service revenues (from normal toll calling and WATS) currently subsidize the cost of local service. With the development of competition in the provision of

long distance services, this subsidy will become increasingly hard to maintain, given past regulatory decisions. These decisions include the ENFIA agreement which provides that competitors to AT&T, who do not receive as high a quality connection to the facilities of the local operating company, pay only 55% of the subsidy. Those competitors that do not utilize these facilities do not pay any of the subsidy. Other decisions will remove terminal equipment and inside wiring from the local telephone company's rate base, upon which the subsidy is based. Finally, recent changes in the depreciation rates prescribed by the FCC will also affect telephone rates. The result of these decisions will be higher intrastate rates for telecommunications services provided by operating telephone companies. Some recent legislative proposals at the federal level have attempted to lessen the impact, by slowing the loss of the subsidy. If the fate of the recent bill introduced by Representative Tim Wirth of Colorado is any indication, the near term prospects of legislation are not good.

(3) Although the recent AT&T-US Department of Justice Consent Decree is cited as potentially causing large rate increases, the decree itself will have little effect on rates. Instead, the decisions mentioned previously are some of the major causes of these potential rate increases. The decree may have the effect of making attempts to reverse these decisions more difficult.

1.3.2 Technical Environment

The STS network first came into use in the middle 1970's. Since that time technical progress has resulted in the gradual obsolescence of the current CCSA network. Newer techniques and equipment offer the promise of better service at a reduced cost, relative to maintaining the current network. CCSA is an older AT&T offering and is not being offered to new customers by Southwestern Bell. CCSA has been succeeded by the Enhanced Private Switched Communications Service (EPSCS) and the Electronic Tandem Network (ETN) offerings from AT&T and competitive offerings from interconnect vendors. CCSA switches can currently be located in four cities in Texas under the current tariff (the cities in which the STS CCSA switches are located); it.is unlikely that the number of available cities will be expanded.

Centrex, like CCSA, utilizes common control central office equipment leased from an operating telephone company. This arrangement, which may also include equipment located at the customer's premises, provides enhanced voice features, directed to the business market. As a general rule AT&T operating companies are phasing out this service, by raising the price. State agencies make use of this service in a number of locations. Section 5 of this report contains recommendations relative to the Capitol Complex Centrex, which serves a large portion of the State facilities in Austin.

2 ALTERNATIVES CONSIDERED

Agreement within the study team was reached concerning four categories of alternatives, encompassing a total of fourteen network alternatives for handling voice and data traffic. The first two categories, including just one alternative each, proposed (1) a continuation (as closely as possible) of the existing network and (2) a plan which made minor cost-saving adjustments to the existing approach and configuration. The third category included eight alternatives that made more extensive changes, giving the State much greater ownership and control of its network elements. The fourth set of alternatives, containing four alternatives, proposed a network which would be largely owned and would provide a basis for extensive delivery of broadcast video services -- a capability that is somewhat-to-considerably more difficult to deliver in the other alternatives.

2.1 Plan 1, Present Method of Operation (PMO)

The first alternative proposed the continuation of a leased CCSA switching arrangement and the use of leased private line facilities from the dominant carrier (even after the withdrawal of the Telpak tariff) for tie lines and dedicated data lines. Some low-speed dial-up data traffic would be carried via the voice network. The topology of the network would remain unchanged in this alternative, with homing arrangements as they are today.

2.2 Plan 2 (Base Plan), Minor Cost Reductions

The second alternative, Plan 2, considered minor modifications to the existing arrangement where costs and availability made them appropriate. The theme of this plan was to improve the cost characteristics of STS with minimum rearrangements or additional equipment. All of the modifications that are part of this plan are expected to be recommended as immediate steps to improve STS costs without adversely affecting service. As a result, this plan represents the base against which other major alternatives will be judged later in the study

The rehoming of certain access line groups, the use of INWATS for access from off-net locations to STS, and the use of Specialized Common Carrier facilities (where cost and availability made them advantageous) were considered in this and later alternatives, to better reflect communities of interest and to reduce the total cost of STS. The potential rehomes, which are further investigated in the detailed analysis of alternatives, are shown in Table 3.13.

2.3 Plans 3 - 10, Fundamental Changes

Plans 3 through 10 considered progressively more extensive modifications to the network, increasing the ownership and also the operational and cost controls that the Telecommunications Services Division would have over voice and data communications. All of the alternatives proposed changes in the topology of the STS to optimize its economics, and also changes in its switching systems. Alternatives 3 through 6 present four different ways of dealing with data traffic -- separate (from voice) circuit switching, integrated (with voice) circuit switching, separate packet switching, and a hybrid system that uses circuit switching (or its equivalent) for voice and packet switching for data. Plans 7 through 10 repeat that distinction, varying only in the transmission systems that were considered. In all of these alternatives the voice and data traffic could share transmission facilities. This sharing could range from obtaining facilities in bulk for both services from a common carrier (as is done today) to utilizing the same trunk groups. The extent to which the facilities could be shared would depend on the traffic patterns of the voice and data traffic, as well as the types of switching vehicles that are employed.

2.4 Plan 3, Separate C.S. Data, Leased Transmission

Plan 3 proposes putting primary tandem switches at locations where the cost to serve expected demand is minimum, rather than constraining them to locations where there are CCSA switching systems. This calls for separately owned or leased voice switching systems for STS. In addition, Plan 3 calls for separate circuit-switched arrangements for switched data traffic and the use of the most cost-effective common carrier connecting facilities between nodes in the network.

2.5 Plan 4, Integrated C.S. Data, Leased Transmission

Plan 4 proposes the topological changes, independent switch lease or ownership, and use of common carrier private lines that were part of Plan 3, but proposes the integration of voice and data circuit switching in the same systems, rather than separating them.

2.6 Plan 5, Separate P.S. Data, Leased Transmission

Plan 5 varies from Plans 3 and 4 only in that it proposes separate packet switching arrangements for data traffic.

2.7 Plan 6, Hybrid P.S. Data/C.S. Voice, Leased Transmission

Plan 6 proposes a hybrid switching arrangement that permits appropriate data traffic to be packet-switched. Access to bandwidth in the transmission facilities will be controlled by software in the hybrid switching system. It should be noted that no such system exists in the market today; such a system should be available in the mid-to-late 1980's, however.

2.8 Plans 7 through 10: More Extensive Changes

Plans 7 through 10 deal with the same variety of data switching alternatives as in Plans 3 through 6, but they differ from those plans in that they consider the application of owned transmission facilities between major network nodes. These more extensive transmission options include microwave radio and fiber optic transmission systems, as described below.

2.9 Plan 7, Separate C.S. Data, Owned Transmission

Plan 7 proposes the changes in network topology, the independent leasing or ownership of switching systems, and the separate circuit-switched data network that was proposed in Plan 3, with the exception that an additional step toward complete autonomy was proposed, in the ownership of either digital microwave radio or fiber-optic transmission systems to link the primary STS tandem locations.

2.10 Plan 8, Integrated C.S. Data, Owned Transmission

Plan 8 is structured as is Plan 7, but with data and voice traffic integrated in the same circuit switching system and carried in the same transmission facilities. As in Plan 7, the transmission system to carry that traffic will either be microwave radio or fiber-optic in the backbone links.

2.11 Plan 9, Separate P.S. Data, Owned Transmission

Plan 9 proposes separate packet switching systems for data traffic, but the same voice systems as in Plans 7 and 8, and with some of the channels in the backbone transmission routes being used to carry traffic between the packet switching systems.

2.12 Plan 10, Hybrid C.S. Voice/P.S. Data, Owned Transmission

Plan 10, as in Plan 6, proposes an arrangement in which the packet data switching devices and the circuit voice switching devices are colocated, and transmission bandwidth is dynamically alterable to handle the incident loads (at the time) of data and voice traffic.

2.13 Plans 11 through 14, the Wideband Broadcast Options

The most effective option for dealing with large quantities of point-to-multipoint transmission -- for example, for public broadcast video -- employs satellite facilities for access to, e.g., rooftop r/o antennas. Such a medium could also be used, then, for the backbone links in the STS network if transmit-receive earth stations were set up. Plans 11 through 14 have been framed to represent the most significant changes to the STS network, capturing the satellite option as having the greatest range of possibly economic high-bandwidth and broadcast capabilities.

2.14 Plan 11, Separate C.S. Data, Satellite Backbone

Plan 11 proposes a separate circuit-switched data capability, with earth stations placed at the primary tandem locations (Abilene, Austin, Dallas, Houston and Lubbock) and satellite circuits used to connect the primaries and as links in the circuit switched data network. Wideband broadcast capabilities could then be provided at each of the major switch locations.

2.15 Plan 12, Integrated C.S. Data, Satellite Backbone

Plan 12, as Plans 4 and 8 did earlier, proposes the circuit switching of data in the same systems as used for voice in STS.

2.16 Plan 13, Separate P.S. Data, Satellite Backbone

Plan 13 follows Plans 5 and 9 in proposing a separate packet switching arrangement for data traffic.

2.17 Plan 14, Hybrid C.S. Voice/P.S. Data, Satellite Backbone

Plan 14 proposes the same approach put forward in Plans 6 and 10, using a packet switching device for data, colocated with the circuit-switched primary voice switching systems.

2.18 Discussion of Issues Relating to Particular Plans

The following subsections of 2.18 discuss some of the issues raised by one or a small number of these 14 alternatives. It should be noted here that a basic discussion of packet switching and voice/data integration is included in Appendix C.

2.18.1 Switching

Some of the first-order screening process took place in the framing of the alternatives themselves, based on the experience of the study team (e.g., the selection of two or three levels for the network hierarchy). The same approach was taken with respect to possible voice switching alternatives, and what follows are supporting arguments for decisions regarding ownership versus leasing, analog versus digital switching, packet versus circuit switching for voice, blocking versus non-blocking systems, and stand-alone versus combined end office/tandem systems. Data switching and integration are dealt with in Chapter 3 of this report and in Appendix C.

2.18.2 Owned Transmission Options

Fiber optics and owned microwave radio are generally the most cost-effective media for moderate- to high-density routes of the lengths expected in the backbone routes for STS, and thus they are considered as alternative media for each of Plans 7, 8, 9 and 10. Satellite communications become a factor if heavy broadcast opportunities may exist in the network.

The appearance of volume broadcast opportunities will tend to drive the introduction of satellite links, and so it is generally safe to wait until those applications seem ready to take shape. Although no such demand has been noted thusfar, Plans 11-14 were proposed as ways of dealing with that environment, and some first-order cost analysis was done (as presented in Chapter 4) to assess whether satellite transmission had economic potential in STS without there being a large broadcast demand present.

2.18.2.1 Microwave Radio

Microwave radio is well suited for a wide range of traffic densities over a wide range of distances, including cross-country routes. The availability of frequencies may prove to be the main limiting factor in applying this alternative, especially in the metropolitan areas that are likely to be recommended as primary tandem switching locations.

The microwave alternatives assumed bandwidth requirements greater than 5 MHz, putting systems into at least the 6 GHz range. It was assumed that the land for towers, the towers themselves, power, shelter, radios and antennas would have to be provided. First-order assumptions were that a DS-3 rate digital system would be placed, not using any existing towers. Sections 4.1 and 4.2 deal with the analysis of routes using this medium.

2.18.2.2 Fiber Optics

While microwave systems have the edge in ease of (especially rural) siting, there are environmental and security reasons for considering the other primary terrestrial option -- fiber optic systems. Fiber optic technology has advanced greatly in the last few years, and significant cost-affecting improvements are expected in the next two years. Siting costs can be high in rocky ground or extremely uneven terrain, but the major routes in Texas do not seem likely to present many siting problems outside the primary cities.

For this alternative, a four-fiber graded index cable was considered optimum, using one pair as the active pair and one pair as a spare. Common assumptions were made for both microwave and fiber optic systems to provide a reasonable basis for cost comparisons.

Single-mode fiber systems, which are expected to be commercially available from several vendors by the end of 1984, will increase the repeaterless span over that possible with today's multimode technology while requiring more expensive fiber cable. From the economic viewpoint, the single-mode fiber optic systems will be more expensive than the current multimode fiber optic systems in the 1984-1986 time frame for the routes in the backbone network.

An FT-3 transmission rate was chosen for this alternative (44.7 Mbps, yielding 672 voice-grade channels), although rates of 135 Mbps will be possible with that repeater spacing. FT-2, yielding 96 channels, was too low a rate for some routes (Austin-Dallas and Austin-Houston).

Fiber optics may be especially attractive in areas where extreme electromagnetic atmospheric conditions, heavy rainfall, or microwave frequency congestion exist, and all of these are possible in some of the likely intermachine trunk routes of STS. Section 4.1.3 details a first-order analysis of the fiber-optic trunk option in STS backbone routes.

2.18.2.3 Satellite

As mentioned above, satellite transmission is particularly well-suited to broadcast applications or for high-bandwidth, long-haul (over 1,000 airline miles) situations. None of these conditions was uncovered in Texas, although the prospect for increases in public video broadcasting could appear with little advance notice. Further analysis was considered appropriate in order to demonstrate how good or bad an alternative this was.

There are several options to employing satellite transmission facilities. These include State ownership, leasing, or sharing the ownership of transponders and earth stations. The number and location of the earth stations is also of concern. Finally, the transmission scheme that is utilized must be decided.

There was no justification identified for ownership of a satellite. Communications requirements, including voice, identified private line data, and public broadcast and educational video requirements, were not expected to load up a single transponder. Both ownership and leasing of the antennas were considered in the first-order analysis, and leasing of the interlocation channels was considered. The provision of 10-meter antennas at the major tandem switching sites was the alternative that was expected to handle the traffic levels between tandems adequately and be the most competitive with other transmission options, although no satellite alternative seemed likely, given the distances involved.

The longest likely distance, Houston to Lubbock, was approximately 460 airline miles, and the next longest distance was 330 airline miles, between Austin and Lubbock. If Abilene were chosen instead of Lubbock as a major tandem location, no airline distance would be over 320 miles, and the second longest distance would be approximately 220 miles. An industry rule of thumb in considering satellite circuits is that links between locations that are under 500 miles apart are "next to impossible" to justify economically; 500-1,000 miles is a "gray zone" of some specific possibilities (e.g., where terrain and/or weather make other options more expensive than they would normally be); and airline distance separations of greater than 1,000 miles start producing good head-to-head comparisons between typical microwave and typical satellite cost profiles.

As discussed previously in this chapter, a digital network from end to end was considered an important objective for STS. For the satellite alternatives, therefore, Time Division Multiple Access/Demand Assignment (TDMA/DA) was chosen to be the preferable digital technique, due to the likely traffic levels on a satellite system. The use of Time Assignment Speech Interpolation (TASI) may also be desirable for voice traffic, although that eliminates the transmission of data traffic on those channels.

2.19 Discussion of Issues Relating to All Alternatives

The following subsections of 2.19 discuss some of the issues that are common to all alternatives, or to almost all of them (the base plans -- Plans 1 and 2 -- may not be included).

2.19.1 Topology

Establishment of the proper topology for the network would include reconsideration of the number of hierarchical levels in STS, the homing arrangements in the network, the number and location of primary (and perhaps secondary) tandem switching locations in STS, and the number of links connecting the switching nodes.

2.19.1.1 Network Links

Determination of the optimum link arrangement is a natural output of the NTI Network Design System (NTINDS) computer programs; it follows after decisions are made about the other topological characteristics of an evolving STS, as described in the sections immediately following this one. For that reason, no alternatives have been identified in this chapter for specific numbers of links or for specific connections of nodes in the network. Such results will come automatically from NTINDS.

2.19.1.2 Hierarchical Levels

The proper number of levels in the hierarchy of a network is a determinant of cost and network reliability, with cost the most significant product in most networks. The factors which determine the optimum cost (and therefore the optimum number of levels) tend primarily to be the number of network locations, the volume and dispersion of network traffic, and the distances between locations.

The North American public telephone network has five levels in its hierarchy; the major Specialized Common Carriers in the U.S. have two or three levels in their tandem hierarchies (yielding a total of four levels when the telephone companies' local offices are considered as the only access points to the SCC networks); almost all private networks have two or three levels in their hierarchies; STS currently has the functional equivalent of three levels in its network, although the great majority of switches are on the bottom and top levels.

Both two- and three-level network topologies seemed reasonable as alternatives, based on the moderate level of network traffic, the moderate number of network locations, and the limited distances between locations (relative to national or international networks). The network design computer programs used by BNR determine which nodes are best suited as primary and secondary tandem locations, given a designer-specified total number of tandem switch locations. Economic results then point to a recommendation about the optimum number of levels in the hierarchy.

2.19.1.3 Number of Tandem Switching Centers

The current STS network utilizes four tandem switches, in Abilene, Austin, Dallas and Houston. The future network will almost certainly contain at least three tandem sites, in Austin, Dallas and Houston, due to the large volumes of traffic in these locations and their geographical relationships (no two are extremely close to each other, as are Austin and San Antonio or Dallas and Fort Worth). For the geographical reason, it is considered unlikely that San Antonio or Fort Worth will be found to be a good tandem switching candidate. The number and location of additional tandem switches is less obvious, but several runs of the NTINDS network design tool will permit identification, of the optimum locations for tandem switching, given a designer's choice of the total number of tandem systems to be considered in each run.

The approach to be taken in the first-order analysis was to find the optimum number and location of these tandems through iterative runs of NTINDS, specifying a different total number of tandems for each run. It was expected that a graph of network cost as a function of numbers of tandems would be concave upward, and the study team was looking for the number (and identification) of tandem locations that would bring a minimum cost. Therefore, the topology alternatives chosen began with one location for a primary tandem switching site. That location was to be determined by NTINDS, although it could be guessed with some confidence that the optimum single-node network would have Austin as its primary tandem node.

It was also decided that the maximum number of sites would be decided on as the analysis proceeded, based on the results of NTINDS runs with increasing numbers of tandem locations specified. Runs would stop when it was clear that an alternative had been found which yielded a cost minimum (i.e., when an alternative was found which was significantly more expensive than the alternative with one fewer tandem switching locations).

2.19.1.4 Bypass Access Lines

Special one-way access line groups could be constructed from a tandem switching system in one area directly to an end office in a distant location, without having to switch through a tandem in the distant area (see Figure below). This would allow one or more locations in one area that had a large community of interest with a location in a distant area to have more direct connections to that distant location. In the current STS network, for example, bypass access lines from an Austin tandem directly to Bryan (Texas A&M) may be justified, based on a community of interest (as reflected in volumes of traffic) between several locations served by the Austin tandem and the Bryan location. First-choice routing from Austin to Bryan would then be on the bypass access line group, and the route via Houston would be taken as an alternate. The use of this type of access arrangement can be economically desirable, in addition to the potentially improved transmission quality.

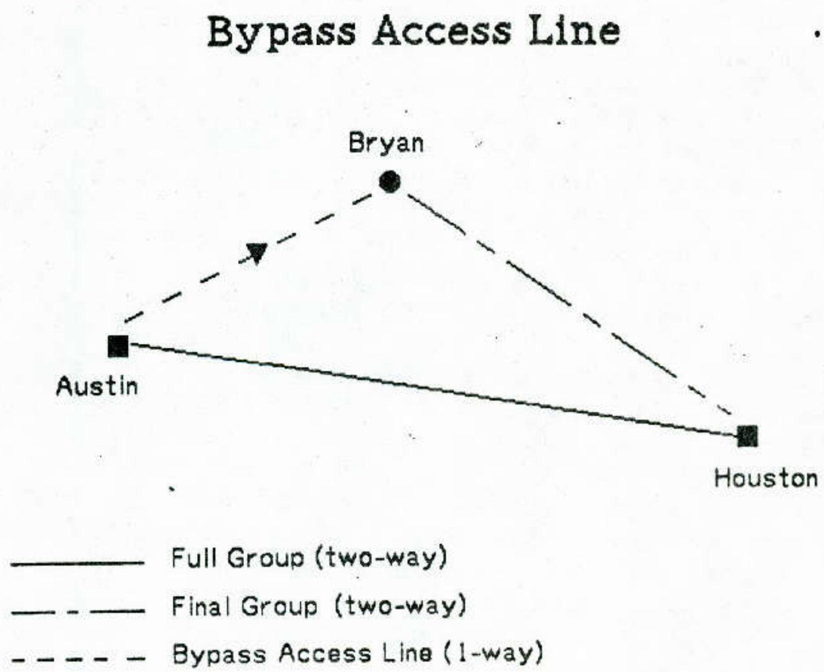


Figure 2.1

2.19.1.5 Network Grade of Service

The grade of service (probability of blocking) rendered by the network is a particularly important issue in STS and one which affects communications costs significantly, because individuals or agencies have a choice whether or not to use STS in completing calls, and because user questionnaire respondents gave network availability as the most common reason for their dialing around the STS network (56% cited it in one form or another).

One way of guaranteeing good cost performance in STS is to pack traffic tightly into facilities. That can be done by keeping blocking levels relatively high, thus forcing some users to alternate means to complete their calls. This approach can lead to two problems, however, and they may be present already in STS.

The first problem is that the cost of total government communications higher than need be, even though the cost performance of STS alone may be quite good. Though the information that the study team has seen on traffic bypassing the network is not conclusive, there are data that suggest a relatively high level of blocking (even higher than the relatively high design levels for the network), especially in the access lines to STS. The result may be a less-than-optimal total cost for State telecommunications as users choose an expensive public network connection, because their STS attempts were unsuccessful (or, even worse, were assumed likely to be unsuccessful, and the attempt wasn't even made).

The second problem is a longer term one -- that a significant difference between the grades of service in STS and the public network may lead many more potential users of STS to choose the public network and to ignore STS. If the economic differences between private networking and not networking at all continue to be reduced, then users may not even perceive that the cost advantage of STS offsets the time they must take trying to get a connection, and the economic interest that supports the existence of STS might be heavily eroded.

With the increasing penetration of electronic switching systems with stored program control, the routing decisions at systems connected to STS will more often be made by the systems than their users. This will increase the potential for agencies to guarantee that STS will be attempted first for calls to other locations which are served by STS (or, potentially, the reverse). Until this occurs, the education of users about the existence and proper use of the network will continue to have an important impact on network traffic. Even as agencies put these PBX's in place, attention must be paid to both the cost and the level of service provided by the network.

2.19.1.6 Off-net Calls via the Network

The current STS network provides intrastate off-net access through the use of intrastate WATS and FX lines. STS could expand this service by acquiring interstate WATS and FX circuits. In this way all national long distance calling could be handled by the new network. Small users, who do not have enough traffic to justify their own interstate WATS or FX lines, may find that STS provides them with opportunities to get big savings on some long distance traffic. If interstate service were instituted, then both interstate and intrastate traffic could be used to justify an STS access line, thereby increasing the universe of potential users.

2.19.1.7 On-net Locations

The selection of on-net locations will also affect the design of the network. For this study, all cities now served by STS have been included in designs of a future network.

2.19.1.8 Access from Off-Net Locations

An aspect of topology that is not explicitly covered in the network design process, and one which seems important to be covered in this network, is the access to it from locations that are not on it. Presently, users can get access to an STS operator by dialing a telephone number that is singular to a serving area. Many, if not most, users do not know the number for their own area, much less carrying or having access to an STS directory that would give them a number when they were on the road and not at a location that was served by STS directly.

A simplifying and user-convenient possibility, but one which does not have the data that might economically justify it yet, is to establish 800 Service lines for STS that would allow anyone to dial a single number from any location and get access to an STS operator. This is even more appealing, given that STS directories are not printed in sufficient quantity that all users receive one. In the experience of the study team, the economics of using the network for calls between off-network points, and from off-net to on-net points, cannot be easily captured. Most often, a trial is proposed that would offer the service for a period of several months to a year (a year period here permits the inclusion of dialing information in the published directory). Both the proper sizing of the number of circuits required, along with an economic analysis of the tactic, are then best executed after the service has been put in place and actual traffic data are available.

2.19.1.9 Analog versus Digital Switching

Although the vast majority of switching systems in public and private telephone networks are analog, virtually all systems being introduced now are digital, with good reason.

From the standpoint of transmission quality, end-to-end digital connections are superior. The use of regenerators in digital transmission systems, rather than the amplifiers used in analog systems, allows for a significant reduction of noise, especially in long-distance communications. The digital bit stream can also be sampled for errors, often permitting the identification of some impairments before a human can detect them. These same benefits also apply to data traffic, which is more sensitive to errors than the human ear.

The negative transmission aspect of digital systems comes at the interface with analog systems, where echos, singing or excessive loss (due to hybrid imbalances) and quantization noise can be introduced. If there are several analog-to-digital (A/D) or digital-to-analog (D/A) conversions in a connection, the cumulative result can be much worse than an end-to-end analog connection. Thus, the transmission benefits of digital systems are maximized when all systems are digital.

From the standpoint of cost, stability in the cost per circuit for digital transmission and switching systems, while analog systems have increased in relative price, have made digital systems more attractive. Also, there is greater cost in the A/D interface than there are in A/A or D/D interfaces, and therefore, from a system view, cost tends to a minimum when there are no A/D interfaces and the systems are digital.

The primary driver for the current rapid move toward end-to-end digital systems has been the proliferation of cost-effective digital short- to long-haul transmission systems, which has prompted almost all manufacturers to develop digital switching systems as their flagship offerings. It is for all of these reasons that analog switching is not considered a good choice for STS; digital switching only is recommended for all alternative plans.

2.19.1.10 Circuit versus Packet Switching For Voice

Another pair of techniques which are conceivable alternatives for voice traffic are circuit and packet switching. In the voice domain, there are no systems commercially available which offer packet switching although laboratory systems have been developed, and the concept of a switching system which assigns bandwidth upon demand (from a shared "bandwidth pool"), under software control, is an economically appealing one.

Voice packet switching systems are not expected to be widely commercially available before 1985 at the earliest; the nature of STS leads the study team to recommend that packet switching for voice not be implemented until it has been demonstrated that highly reliable systems can be built which also provide for better network economics than does circuit switching, as well as satisfactory delay characteristics under conditions of heavy load.

Since implementation plans for the first STS switching centers must be completed in 1984, circuit switching was the only alternative considered for the initial voice systems.

3 NETWORK TOPOLOGY

3.1 Voice Network

The basis for configuring any of the alternative networks was a good model of the traffic demand that exists and is expected to exist in the State during the period 1983 to 1989. Voice and voiceband data traffic has been thoroughly measured and recorded in STS. Traffic tapes containing those data were used to develop a traffic matrix, as described in the following sections.

3.1.1 Development of the Voice Traffic Matrix

A traffic matrix is an n-by-n matrix whose elements are traffic between points 1 through n. For example, element 3,8 of the matrix (row three, column eight) would contain all traffic that originated at location three and terminated at location eight. Traffic in the opposite direction would be contained in element 8,3 of the matrix. In the case of the State of Texas' STS network, a 160-by-160 matrix was constructed (a total of 25,600 entries) for voice and switched voiceband data. The 160 locations consisted of cities served by the STS network, possible out-of-state FX candidates, WATS bands, etc. Thus the matrix consisted of point-to-point traffic between Texas cities served by the STS, and traffic from these cities to all other locations (both intra- and inter-state), by serving WATS band or, if traffic warranted, by the local calling area served by an interstate FX.

3.1.1.1 Matrix of 1982 Traffic

The first traffic matrix that was developed, modeled the busy season busy hour traffic currently offered to the network.

3.1.1.1.1 Input Data

The initial matrix was based on data derived from the STS 20% traffic sample for October 1981. October was selected, as it contained one of the highest volumes of traffic, the Universities (a major source of STS traffic) were in session, and data was readily available. This traffic sample contains call records for 20% of the calls handled by the STS during the month. The call records contained both the originating and terminating telephone number, the time and duration of the call, and other information.

3.1.1.1.2 Reformatting the Traffic Records

The raw traffic data from October was processed by the FX Extractor, a series of programs developed by BNR. These programs, using standardized traffic records, identify potential

FX candidates and produce a standard point-to-point traffic matrix. Some additional software was required to modify the format of the STS traffic data records to a form that could be read by the FX Extractor. These modifications permitted the extraction of the necessary data from the STS record (originating and terminating number, duration and time of the call, etc.) and and the assignment of a call to a time period (for this study a clock hour) based on the call's start time. For example, a call starting at 10:29 AM would be marked as taking place in the 10:00 to 10:59 time period.

3.1.1.1.3 Busy Hour Determination

The next step in developing the traffic matrix was to examine the reformatted STS traffic records to determine the busy hour, because busy hour traffic is the standard base from which network engineering proceeds. A frequency count of the number of call records by hour determined that 10-11AM was the busy hour. With this information, the traffic records were screened to eliminate all records except those that occurred in the busy hour. Weekend and holiday traffic records were also eliminated. From this process 39,117 records were selected from the 316,462 traffic records in the October sample (after records from Saturday and Sunday records were eliminated). Table 3.1 describes the distribution of calls over one hour periods for the STS network. The data in the table has been multiplied by 5, so that it represents 100% of the traffic.

Table 3.1

Number of Calls by Hour, October 1981

Hour	Number of Calls	Hour	Number of Calls
00:00-00:59	830	12:00-12:59	66,370
01:00-01:59	510	13:00-13:59	181,790
02:00-02:59	335	14:00-14:59	192,240
03:00-03:59	220	15:00-15:59	183,715
04:00-04:59	215	16:00-16:59	153,850
05:00-05:59	325	17:00-17:59	26,600
06:00-06:59	1,500	18:00-18:59	14,455
07:00-07:59	14,210	19:00-19:59	12,310
08:00-08:59	145,630	20:00-20:59	10,900
09:00-09:59	194,025	21:00-21:59	6,605
10:00-10:59	195,585	22:00-22:59	3,920
11:00-11:59	174,685	23:00-23:59	1,485

3.1.1.1.4 Aggregation By City

The resulting records were then aggregated by city. The aggregation was done to reduce the number of nodes to a manageable number for analysis by BNR's computer programs. To account for each on-net location with a separate node would have required upwards of 500 defined locations and thus 250,000 entries in a 500-by-500 traffic matrix. This number of entries would result in extremely long run times for the network design programs, as well as exceeding current software limitations on the size of the matrix. This aggregation process mapped all traffic record telephone numbers in a city to a single ten-digit telephone number representing that city. For example, in all cases where an Austin telephone number appeared in the traffic records that number was changed to a single telephone number for Austin (in this case 512-327-0059). In like manner, any STS or public network telephone number for a city served by the STS network were mapped to a single "master" number for that city. The master numbers were derived by arbitrarily selecting a valid NPA-NXX for the city in question and adding the four-digit STS city code as the last four digits of the number. Thus, in the case of Austin, the "0059" in the master telephone number is it's STS city code. In summary, the program took each of the 39,117 records, compared the originating and terminating number of each record against a table, which mapped valid STS numbers and NPA-NXX combinations to master numbers, and substituted the appropriate master number. About 1,500 records were required to produce the table.

This aggregation process will introduce some inaccuracies in the results, relative to the number of access lines. As all traffic sources from a city are combined the network design tool will tend to understate the access line requirements.

After the records were aggregated, like records (those with the same origination, destination and time period) were summed together. Thus if, during the busy hour, there were two calls from Austin to Alpine with durations of five and seven minutes, the calls would be summed together, and a single call record with a duration of twelve minutes would be output.

After these steps took place, the summed records were used as an input to the remaining programs. These programs examined the traffic data for potential FX candidates and output a series of reports detailing the point-to-point traffic from each node. After the FX candidates were identified and the reports were created, the final program created a point-to-point traffic matrix of the busy hour traffic in CCS. The point-to-point traffic matrix created by this process is normally then used as the primary input to BNR's network design programs. In this case, however, a few adjustments to the matrix were required.

3.1.1.1.5 Adjustments to the Matrix

After the traffic matrix based on the 20% STS sample was created, three adjustments to the matrix were performed.

(1) Normal scaling to full October 1981 levels was performed.

(2) Based on traffic history data, February was selected as the reference month for developing the traffic matrices. Although February does not have the highest total traffic level during the year, its "normalized" (to 21 working days) daily traffic is greatest. October data were therefore scaled up to forecasted February levels to represent the busiest time of the year.

It was found that the growth rate for traffic levels in the overall network and the growth rate in traffic for each of the areas served by primary tandem switching systems were different. As a result, correction factors were developed as an additional adjustment in the October 1981-to-February 1982 scaling process. Thus, traffic originating at cities served by the Austin tandem switcher were multiplied by one factor, while traffic from cities served by the Dallas tandem were multiplied by a different factor.

The factors were developed by dividing the originating monthly traffic (by serving switcher) by the number of working days in the month to give the average daily traffic by serving switcher. The average daily traffic by serving switcher for February 1982 was then divided by the average daily traffic by serving switcher for October to yield the correction factors. These factors were then applied to the traffic matrix.

In the case of October 1981 data the factor for all entries in the traffic matrix that originated in a city served by the Austin switcher was 1.0474, while the factors were 1.0497, 1.0280 and 1.0092 for the Dallas Houston and Abilene switchers respectively.

(3) After the previous adjustments to the matrix were performed, one final scaling factor was applied to account for the difference between the observed carried traffic levels, as measured by records of completed calls and as reflected in the STS traffic tapes, and the actual offered traffic levels, which form the basis for network engineering.

Blocking formulae such as Erlang-B and Poisson require offered traffic and not carried traffic. Thus if carried traffic is used in these formulae, the resulting grade of service will be somewhat worse than the designer intended.

To correct for this problem the traffic matrix must be scaled up, such that the traffic levels in the matrix approximate the offered traffic load. The simplest way of arriving at this factor is to estimate the average grade of service on the existing network. Once this estimate is arrived at, the traffic can be scaled up appropriately to account for the blocked traffic.

An estimate of end-to-end grade of service was arrived at by using the current STS engineering criteria, which call for a blocking probability of 7% on STS access lines and ONALS and a 7% blocking probability on the inter-machine trunks (IMT's). One should note that the current IMT blocking criteria is a bit higher than that published in the 1981 annual report to the Legislature (7% instead of 6%). An examination of the STS traffic history reports showed that about 52% of all STS calls were destined for a PBX (or the public network) served by the same switcher on which that the call originated. Thus 48% of the calls accessed an inter-machine trunk in the process of getting to another CCSA switcher.

The end-to-end blocking was calculated for the case when an IMT was used with the formula $P=a+(1-a)(b+(1-b)c)$ where P was the end-to-end blocking, a was the originating access line blocking, b was the IMT blocking, and c was the terminating access line or ONAL blocking. If no IMT's were used, the formula is

$$P = a + (1-a)c$$

The results indicate that 48% of the calls during the busy hour experienced a grade of service of P.196 (7% for the access line, 7% for the IMT and 7% for the terminating access line or ONAL), assuming that the network is currently meeting its engineering criteria for grade of service on these links. The other 52% experienced a grade of service of P.135, as an IMT is not used in this case. Combining these two grades of service yields an average grade of service of P.164. This also assumes that the blocking characteristics of the CCSA switchers are such that their effect can be ignored. If the blocking of the PBX's are taken into account, then the grade of service would be P.189 (P.01 for the originating traffic and P.02 for the terminating traffic).

Therefore, in the case of the STS network, the average end-to-end grade of service was estimated to be P.164.

Using these results, one can calculate a correction factor to adjust the traffic to the offered load. To do this the following equation must be solved:

$$X = 1/(1-p)$$

where p is the probability of blocking in the network and X is the correction factor. Solving this equation, the correction factor was found to be 1.197 (or 1.233 if PBX blocking is considered). The traffic matrix was then multiplied by this factor (1.197) to arrive at the final matrix of offered traffic.

3.1.1.2 Traffic Forecasting

In arriving at a recommended topology, network designs were required for several points in time. To predict traffic levels that might be present in a future STS network, several forecasting techniques resident in the Empire software package (a package from Applied Data Research Inc.) were applied to historical traffic data obtained from the STS traffic history reports. In addition to the computerized analysis, several hand calculations were made by BNR and the STS staff.

The data consisted of overall network originating traffic, originating traffic by CCSA switcher service area, and the number of working days in each month from STS report 135-D covering the April 1978 to March 1982 time period. With this, a data base was constructed for the Empire software package that contained originating traffic by switcher service area, normalized to 21 working days. This was accomplished by multiplying the originating traffic (by switcher) by the fraction obtained by dividing 21 by the number of working days in the month from which the data was obtained. In this way variations in monthly traffic levels due to changes in state holidays could be largely eliminated. This also eliminated variations in an individual month's traffic due to the day of the week on which a state holiday fell (as the State of Texas does not observe the state holiday on the preceding Friday or following Monday if a holiday falls on a weekend).

The "normalized" traffic data was analyzed by several techniques resident in the Empire software package, including simple regression, exponential smoothing, moving averages and seasonal analysis. Of these techniques seasonal analysis with an additive trend provided the closest match to the monthly traffic data for the past two years. This result was then compared to the results of BNR and STS hand calculations and a growth rate was agreed on.

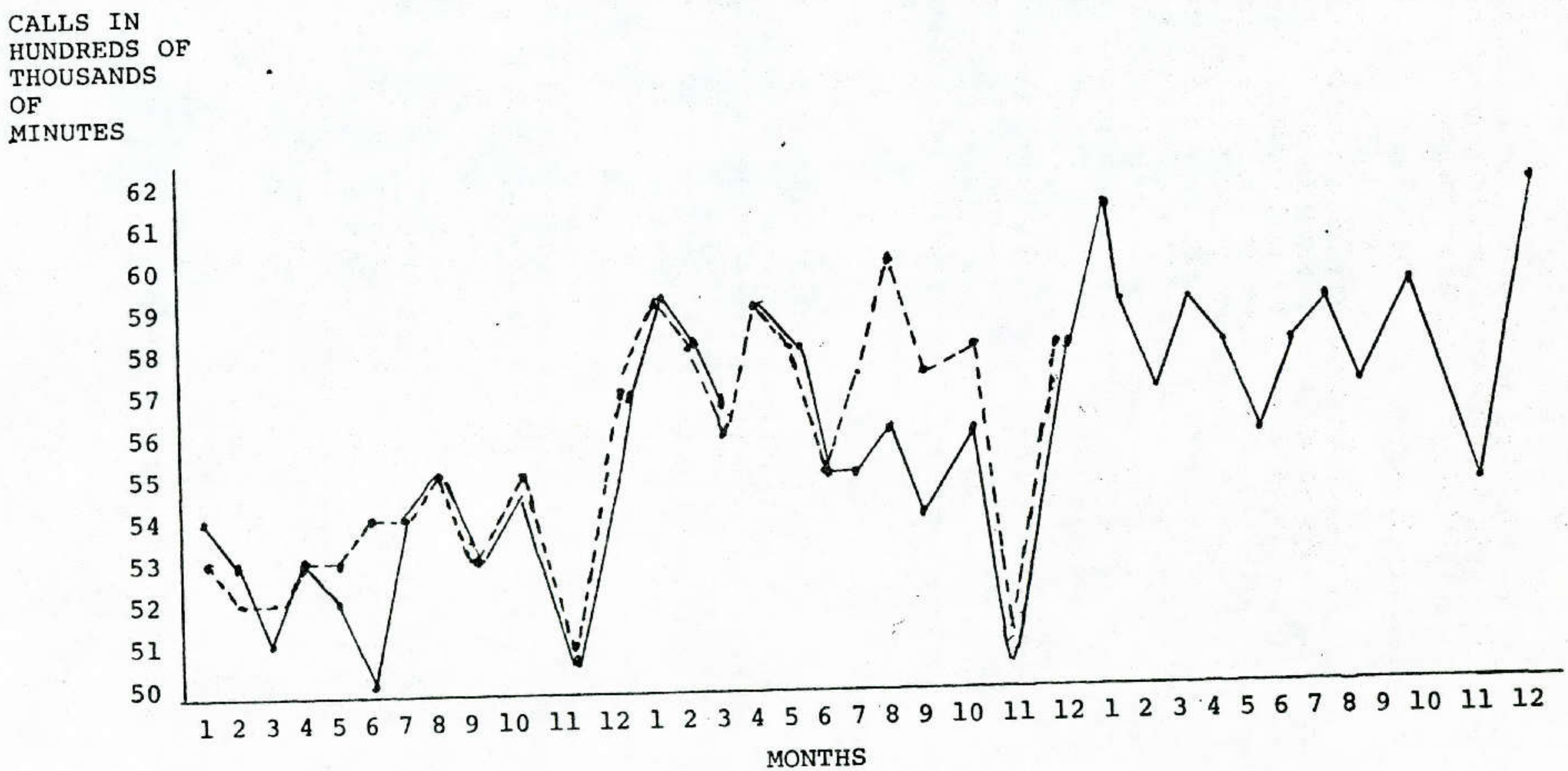
3.1.1.2.1 Seasonal Analysis

This section will provide a brief overview of the principals of seasonal analysis. In its simplest form, seasonal analysis can be thought of as breaking down a time series of data into the underlying trend of the data, a seasonal factor and some residual randomness. The trend is the underlying growth in the data which might be expressed in the form Y=aX + b, where Y is the predicted underlying trend, X is the number of time periods from the first data point, and a and b are constants. The result for any time point could then be multiplied by a constant that reproduced the seasonal variation in the data for that time --the seasonal factor. Finally the variations in the data that cannot be explained by the preceding factors comprise the residual randomness.

In the case of the traffic data from the STS network, a bit more complex form of seasonal analysis was used. In the STS network, traffic levels varied from month to month, but there were good correlations between the same months in different years; thus 12 seasonal factors were used (one for each month of the year). The algorithm used in the analysis is considered proprietary by the creators of the software package. However, a copy of the documentation accompanying the Empire software package is contained in Appendix D. This documentation gives some details on the operation of the software package. Figure 3.2 illustrates the results from one of the seasonal analysis runs. This particular run used the total monthly network traffic "normalized" to 21 working days. The dotted line represents the actual data, while the forecast is represented by a solid line.

FIGURE 3.1

SEASONAL ANALYSIS



Dotted Line = Actual
Solid Line = Forecast

This particular forecast was not used in determining the STS network growth, as the seasonal analysis predictions based on individual CCSA switcher service areas provided a better fit.

3.1.1.2.2 Hand Calculations

In addition to the computerized analysis of data from the past two years, other calculations were performed. As February was found to have the highest average daily traffic levels, the annual growth rate, February to February, was calculated for the last three years (February 1979 to February 1982). Finally, the average annual growth rate for the last three years was calculated by the STS staff using the average traffic levels for April to September and October to March. Thus, the average STS traffic level from April to September 1978 was compared to the average traffic level for the same period three years later, and a growth rate was derived. In like manner the growth rate for the October to March period was calculated. It should be noted that in this last analysis, the number of working days included in each of the samples was not held constant, as consequence the results reflect variations in the number of working days.

3.1.1.2.3 Forecasting Results

For all of the calculations the total originating traffic was examined, as well as traffic by serving CCSA switcher. It was found that traffic growth rates experienced by individual CCSA switchers were significantly different from each other and from the overall network growth rates to warrant developing a traffic model which took into account traffic growth by switcher. For example, according to the seasonal analysis, traffic levels experienced by the Houston CCSA switcher exhibited almost no growth over the last two years, while the Dallas switcher showed a growth rate significantly higher than that experienced by the network as a whole over the same time period.

The results from the different analysis techniques yielded traffic growth rates by existing CCSA switcher service area. These results were then compared with each other and a series of growth rates were agreed to by BHR and the STS staff. The selection of a growth rate consisted of analyzing the result from the various techniques along with other other information to arrive at an estimation of the future growth rate. For example, the Seasonal Analysis results reflect the recent recession; also, results of the user survey indicated that Houston and Abilene region users perceived greater difficulties in reaching other locations than in reaching locations in the same area. Both of these factors may influence the use of STS as measured on the network proper.

In like manner, some calculations of growth did not take into account variations in the number of working days over the sampled period. Finally, extraordinary events, such as the addition of a very large user, have affected some results (e.g., in Dallas), such that the 1980-81 growth rate was significantly higher than the actual underlying growth rate. Table 3.2 delineates the results of the analysis and the growth rates that were used to derive the future traffic matrices (labeled Future Matrix).

Table 3.2

STS Traffic Annual Growth Rates

Area	April-Sept. 1978-1981	October-March 1978-1982	February 1979-1982	Seasonal Analysis	Future Matrix
Abilene	16.1%	14.2%	11%	4%	10%
Austin	8.6%	5.1%	5%	4%	7%
Dallas	19.4%	14.1%	12%	11%	12%
Houston	10.4%	8.1%	6%	0%	8%

As the network growth could be quite different from the expected rate, performing sensitivity analysis with the results is crucial. For the initial design, a matrix reflecting three times the projected 1989 traffic was produced to test the affect of a large change in the growth rates on the designs. Further sensitivity analysis will be performed in the process of developing the detailed designs.

3.1.1.3 Deriving the Future Traffic Matrix

Using the agreed upon growth figures, the traffic matrix was scaled up to the predicted future traffic levels. These future traffic matrices were then used by BNR's network design tools as part of the detailed network design process. For the initial design a 1989 traffic matrix was produced, as well as the 1982 matrix and the three times 1989 traffic matrix. Additional matrices for 1983, 1984 and 1986 will be used in the detailed network designs.

3.2 Switching Network Anylysis of the STS

3.2.1 A Description of the Network Design Tool

The analysis of STS is based on a set of computer programs called the NTI Network Design System (NTINDS), developed at BNR. It presently consists of eight modules which handle the choice of tandem switches, homing of nodes to tandem switches, optimization of hop-off routes, selection of primary and secondary tandem switches, determination of economical bypass access groups, and the optimization of interswitch trunking. The choice of initial tandems is based on the traffic load of each node; those nodes not chosen as tandems are homed to the tandem closest to them in the initial design.

After the switches are determined, the same procedure is used to pick primary and secondary tandems. The bypass access group is configured when a tandem switch has sufficient one-way traffic to economically terminate on a node not homing to it.

NTINDS chooses among a number of options to calculate private line costs. The user may specify up to four Specialized Common Carrier (SCC) tariff schedules to be used, as well as the three schedules of Southwestern Bell's intrastate tariff. NTINDS selects the first SCC tariff that is available for the city in question, using the ATT260-equivalent tariff as it's last choice.

NTINDS also allows the user to bypass the program's algorithms and to select his own primary and secondary tandems. NTINDS then takes his selection and tries to optimize the alternatives chosen. This feature gives the user a chance to apply his insight into the design process.

3.2.2 Network Design Limitations

Although the network design tool is fairly sophisticated, the results of analysis only indicate the relative efficiencies of network configurations, rather than their absolute costs, for the following reasons:

(1) Due to program limitations, traffic parcels for all PBX's in one city are pooled together as a single large traffic source for the program. As a result, access line quantities tend to be understated in the output, since a single large traffic parcel requires fewer circuits to serve it than several small parcels whose sum equals the large parcel. In other words, the actual access line cost is expected to be higher than the cost calculated by NTINDS. Thus, manual calculations of access line requirements are used for sizing switches and transmission facilities in the detailed alternatives.

(2) Traffic tapes of all types measure the carried traffic of a PBX, while Erlang B or other models always consider offered traffic as an input parameter. Carried traffic is equal to offered traffic minus traffic that is blocked or is abandoned before billing information could be recorded on the call (usually during the process of completing the call). For example, at P.10 (blocking probability = 0.10), a group of 20 trunks can be offered 634 CCS, based on the Erlang B model; however, due to lost calls, the actual traffic carried by the trunk group is only 571 CCS [634 x (1 - 0.10)], which is the traffic normally appearing on a billing tape. Although adjustments to traffic matrices (offered traffic = 1.197 x carried traffic, reflecting a current network blocking of 0.164) have been made to change traffic from carried traffic to offered traffic before it is input to the model for calculations, the modifications may not be accurate for all traffic levels.

As a reasonableness test, the network design tool was used to calculate the trunking requirements of the present STS network, based on current access line homing arrangements and the present traffic and blocking probability of no more than 0.07 on access lines and intermachine trunks. The IMT requirements for the present switches were estimated as follows:

Table 3.3

Trunking Requirements of the Current Network

Link	Busy Hour Load(CCS)	Blocking	No. of Trunks*	Existing Trunks
Austin-Houston	4599	0.066	128	123
Austin-Dallas	4230	0.068	118	105
Austin-Abilene	1929	0.067	57	61
Houston-Dallas	1596	0.067	48	48
Houston-Abilene	386	0.053	15	21
Dallas-Abilene	569	0.061	20	24

* For a cost breakdown for this network, see Appendix G

The total number of trunks required to meet the grade of service objective (P.07) is 386 from the above Table 3.3. The existing number of trunks is 382. Note that the above estimate of trunks was based on the existing homing arrangements in STS; unrestricted runs of NTINDS, which allows the program to pick the least cost homing arrangement, will give results that are somewhat different.

While the total facilities numbers are very close, there are also local variations which seem to bear further investigation. The Houston-Abilene and Dallas-Abilene routes seem to be somewhat overtrunked, especially as a percentage of total trunks (although percentages begin to be deceiving at these numbers of trunks, because of the lower levels of per trunk CCS capacity in groups of this size). The Austin-Dallas route, however, seems to be somewhat undertrunked, according to traffic levels processed in the design tool. Although the differences are not stark, the question of Austin-Dallas traffic being routed via Abilene (as a possible overflow route when Austin-Dallas direct trunks are busy) is an obvious one.

3.2.3 Basic Assumptions and Tariffs

The intrastate tariff of Southwestern Bell Telephone was used to calculate the monthly communications costs of the STS. The channel termination charge is $4.50 for each end of a connection. Therefore, the base cost in the following mileage and rate table (Table 3.4) is the sum of a basic monthly charge for the specific mileage range plus (2 x $4.50). Thus the mileage charge is for the increment, as the basic monthly charge covers the mileage charge for the preceding range. For example, the monthly line charge for two PBX's 80 miles apart would be $110.00 for the basic monthly charge, which covers the first 50 miles, $1.4 x 30 for the last 30 miles and $4.5 x 2 for the termination charge for a total of $161 on Schedule AA.

The Intrastate Schedule AA is the equivalent of AT&T260 Schedule AA. The designation A is for a city with high volume intercity traffic; thus its tariff (primary rate) is lower than a city with low volume intercity traffic, designated by B. The combined two capital letters denote the classification of two endpoints of a connection.

For estimating total communications costs, an additional "PBX termination charge" needs to be included, which is the average amortized per line cost of owning a PBX or leasing the facility. It is an estimated average cost, which does not consider the details of the equipment, such as age, type and so on.

In the State of Texas, the following cities are classified as primary (A) rate centers:

Abilene, Amarillo, Austin, Beaumont, Corpus Christi, Dallas, Freeport, Fort Worth, Harlingen, Houston, Laredo, Longview, Lubbock, Midland, San Angelo, San Antonio, Sweetwater, Waco.

All other cities not in the above list are in the B category.

Table 3.4

ATT260 Equivalent Texas Intrastate Rate Table

Schedule AA

Low(mi)	High(mi)	Base($)	Increment($/mi)
0	50	9.00	2.2
51	150	119.00	1.4
151	9999	259.00	1.2

Schedule AB

Low(mi)	High(mi)	Base($)	Increment($/mi)
0	50	9.00	3.8
51	150	199.00	2.4
151	9999	439.00	1.4

Schedule BB

Low(mi)	High(mi)	Base($)	Increment($/mi)
0	50	9.00	4.4
51	150	229.00	3.0
151	9999	529.00	1.8

There are four major cities (Houston, Dallas, Austin and San Antonio) in Texas that have SCC services (both origination and termination). These were considered in the analysis of transmission alternatives which are described in Section 3.3.

The following assumptions were also used in the calculation:

(1) Access line blocking = 0.015

Interswitch blocking = 0.020

Approximate point-to-point blocking = 0.050

Calculation of blocking is based on the Erlang B (loss) formula.

(2) PBX termination charge = $30.00 per line termination

Switch termination charge = $50.00 per line termination

3.2.4 The Four-Switch Configuration

The result of cost calculation for the STS with four primary switches can be summarized in the following table, where the dollar amount is the total monthly communications expenses of the network.

Table 3.5

Four-Switch Network Cost Comparisons

4 Primary Switches				Monthly Cost ($)
Austin	Houston	Dallas	Sweetwater	761,020
Austin	Houston	Dallas	Abilene	762,008
Austin	Houston	Dallas	Lubbock	766,234
Austin	Houston	Dallas	Harlingen	784,016
Austin	Houston	Dallas	El Paso	807,682
Austin	Houston	Dallas	San Antonio	813,374

It is interesting but not surprising to note that the three major traffic centers (Austin, Houston and Dallas) are picked by the program as primary switches in the optimal configuration. Using Abilene, one of the current switches, as the fourth primary is very close to the optimum solution. It is clear from the above table that any of the four locations (Sweetwater, Abilene, Lubbock and even Harlingen) as the site for the fourth primary switch is acceptable from a cost point of view.

According to NTINDS, all four switches should be primary switches without homing to a higher hierarchical level. Reducing the number of primaries and making them secondaries, which home to the primary switch, will reduce the efficiency of the network and increase the overall communications cost.

3.2.5 The Five-Switch Configuration

In the design of a network with five tandem switches, the program gives the best result at four primary switches and one secondary switch which homes on one of the primaries. The results of calculation are summarized in the following table.

Table 3.6

Five-Switch Network Cost Comparisons

4 Primary Switches				Secondary	Monthly Cost($)
Austin	Houston	Dallas	Sweetwater	Harlingen	749,670
Austin	Houston	Dallas	Abilene	Harlingen	751,224
Austin	Houston	Dallas	Lubbock	Harlingen	755,969
Austin	Houston	Dallas	Lubbock	Abilene	756,451
Austin	Houston	Dallas	Lubbock	San Angelo	761,023
Austin	Houston	Dallas	Lubbock	Corpus Chr	768,027

It can be observed that the four primary switches in the optimal four-switch network also constitute the core members in the optimal five-switch network. The fifth switch serves as a traffic concentrator to route diversified sources of traffic to the home primary switch to reduce trunking requirements. It is clear that the monthly charge for the five-switch optimal network is lower than that of the four-switch one, although not by a great margin.

3.2.6 The Six-Switch Configuration

The optimal design of a six-switch network comprises five primary switches and one secondary. The primaries are Abilene, Austin, Dallas, Houston and Lubbock with a secondary in Harlingen. The overall cost of the system is somewhat reduced by this substitution. The second best configuration is the optimal design in the five-switch network, adding a secondary at Corpus Christi; however, the overall cost is not improved by this arrangement.

A summary of cost comparisons of several configurations is given in the following table.

Table 3.7

Six-Switch Network Cost Comparisons

First line: Primary Switches Second line: Secondary Switches					Monthly Cost ($)
Austin Harlingen	Houston	Dallas	Lubbock	Abilene	745,078
Austin Harlingen	Houston	Dallas Corpus Christi	Sweetwater		750,249
Austin Harlingen	Houston	Dallas Corpus Christi	Abilene		750,442
Austin Harlingen	Houston	Dallas Corpus Christi	Lubbock		756,603
Austin Harlingen	Houston	Dallas El Paso	Sweetwater		766,057

3.2.7 Summary of Results

The calculation of an optimal solution for a network with seven or more switches will not be detailed here; however, the results are tabulated in the following table for the comparison of relative efficiency of network design.

Table 3.8

A Summary of Network Cost Comparisons

No. Sw	First line: Primary Switches / Second line: Secondary Switches					Monthly Cost($)
4	Austin	Houston	Dallas	Sweetwater	--	761,020
5	Austin Harlingen	Houston	Dallas	Sweetwater	--	749,670
6	Austin Harlingen	Houston	Dallas	Lubbock	Abilene	745,078
7	Austin Harlingen	Houston	Dallas Corpus Christi	Lubbock	Abilene	748,246
8	Austin Harlingen	Houston	Dallas Corpus Christi	Lubbock	Fort Worth El Paso	786,409

As can be seen from the above table, the network has a least cost with a six-switch configuration. However, the five- and seven-switch designs are close behind. It is interesting to note that Sweetwater proves in as a fourth primary site, as shown in the four- and five-switch designs; however, when the number of primary switches grows to five, the total network cost is reduced as Sweetwater replaced by Lubbock and Abilene (six- and seven-switch configurations).

Although not shown in the table, if Sweetwater is replaced by Abilene in the five-switch configuration the cost penalty is very small -- on the same order as the penalty for using it in the four-switch configuration (less than one percent).

Given the number of assumptions and approximations made in the process of coming up with a network solution, the cost differentials appear to be insignificant among optimum four- to seven-switch configurations. The choice of design was thus dependent on future growth and on considerations in the real network, rather than on these aspects of network topology.

In order to determine whether the optimal design of STS at current traffic level will remain optimal in the future, a projected traffic level for 1989 was developed to repeat the design evaluations. The new traffic value assumes different growth rates at various regions of the network. In addition a second traffic matrix, based on the pattern of 1989 but with 200 percent more traffic, is also used to evaluate network alternatives.

The results of studies with forecasted traffic for 1989 and beyond are summarized in the following tables.

Table 3.9

Comparisons of Network Design Based on 1989 Traffic

No. SW	First line: Primary Switches Second line: Secondary Switches					Monthly Cost($)
4	Austin	Houston	Dallas	Sweetwater	--	1,187,154
5	Austin Harlingen	Houston	Dallas	Sweetwater	--	1,172,134
6	Austin Harlingen	Houston	Dallas Lubbock	Abilene	--	1,160,413
7	Austin Harlingen	Houston	Dallas Corpus Christi	Lubbock	Abilene	1,158,938
8	Austin Harlingen	Houston	Dallas Corpus Christi	Abilene	Fort Worth El Paso	1,195,232

Table 3.10

Network Design Based on Three Times 1989 Traffic

No. SW	First line: Primary Switches Second line: Secondary Switches					Monthly Cost($)
4	Austin	Houston	Dallas	Sweetwater	--	3,041,183
5	Austin Harlingen	Houston	Dallas	Sweetwater	--	3,008,307
6	Austin Harlingen	Houston	Dallas	Lubbock	Abilene	2,966,852
7	Austin Harlingen	Houston	Dallas Corpus Christi	Lubbock	Abilene	2,945,150
8	Austin Harlingen	Houston	Dallas Corpus Christi	Abilene	Fort Worth El Paso	3,032,820

By comparing Tables 3.8 through 3.10, several interesting points can be observed:

- o Even with three times the expected traffic levels in 1989, the optimal network topology is unchanged -- a very stable condition.
- o The optimal network has six switches for the current traffic levels and has seven switches at the forecasted traffic level. The former group of switches is a subset of the latter.
- o Given the current and projected traffic patterns, no drastic changes in primary switch sites is foreseen.

3.2.8 A Detailed Breakdown of Cost Components in the Network

To provide further insights into the cost structure of the STS network, the total network cost has been broken down to four major components: Inter-Machine Trunks (IMT's), access lines, PBX ports and tandem switch costs. The cost breakdown is based on the PBX termination charge and tandem switch termination charge quoted earlier. The same approximate point-to-point blocking of 0.05 as in the previous calculations is used here, however, its breakdown is slightly different this time: 0.02 for access line and 0.01 for IMT blocking, which reflects the practical service requirements better than previous breakdown, since blocking constraint on IMT's is usually more stringent than that of access lines.

The effect of this change is that the network cost in most configurations is reduced by about 1%, which indicates that the cost saving of changing blocking from 0.015 to 0.02 on access lines (higher blocking requires less circuits) is more significant than the cost increase of reducing IMT blocking from 0.02 to 0.01. In general, this would be true when the cost of access lines is the dominant cost component in the overall network cost. The slight change in network cost due to the new blocking breakdown does not alter the relative efficiency of various configurations under consideration.

Only two configurations at a 1982 traffic level will be detailed here. They are the current network of four switches and the optimum network of six switches; other selective network configurations are included in the appendix.

(1) Cost Breakdown of Current Network (4-SW: Austin, Houston, Dallas, Abilene)

Table 3.11

Major 4-SW Network Cost Components

	From	To	Cost	% Total Cost
IMT	Austin	Houston Dallas Abilene	$38,770 $44,545 $23,546	
	Houston	Austin Dallas Abilene	$38,770 $15,250 $ 7,350	
	Dallas	Austin Houston Abilene	$44,545 $15,250 $ 8,311	
	Abilene	Austin Houston Dallas	$23,546 $ 7,350 $ 8,311	
Subtotal :			$137,774	18.3
Access Lines Cost/Location		Austin Houston Dallas Abilene	$158,180 $ 76,569 $ 80,412 $ 97,739	
Subtotal :			$412,900	54.8
PBX Ports		Austin Houston Dallas Abilene	$ 23,010 $ 13,440 $ 14,070 $ 7,920	
Subtotal :			$ 58,440	7.8
Tandem Switch Cost/Switch		Austin Houston Dallas Abilene	$ 57,400 $ 33,050 $ 34,650 $ 19,300	
Subtotal :			$144,400	19.1
Total Network Cost :			$753,514	100

(1) Cost Breakdown of 6-SW Network With 5-Primary and 1-Secondary(Harlingen)

Table 3.12

Major 6-SW Network Cost Components

	From	To	Cost	% Total Cost
IMT	Austin	Houston	$35,222	
		Dallas	$44,545	
		Lubbock	$24,700	
		Abilene	$10,091	
		Harlingen	$27,975	
	Houston	Austin	$35,222	
		Dallas	$15,250	
		Lubbock	$ 7,615	
		Abilene	$ 3,215	
		Harlingen	$ 2,913	
	Dallas	Austin	$44,545	
		Houston	$15,250	
		Lubbock	$ 6,966	
		Abilene	$ 5,445	
		Harlingen	0	
	Lubbock	Austin	$24,700	
		Houston	$ 7,615	
		Dallas	$ 6,966	
		Abilene	$ 4,009	
		Harlingen	0	
	Abilene	Austin	$10,091	
		Houston	$ 3,215	
		Dallas	$ 5,445	
		Lubbock	$ 4,009	
		Harlingen	0	
	Harlingen	Austin	$27,975	
		Houston	$ 2,913	
		Dallas	0	
		Lubbock	0	
		Abilene	0	
Subtotal :			$187,950	25.6

Continued

Access Lines Cost/Location	Austin Houston Dallas Lubbock Abilene Harlingen	$85,257 $63,287 $80,415 $44,699 $21,644 $38,284	
Subtotal :		$333,586	45.4
PBX Ports	Austin Houston Dallas Lubbock Abilene Harlingen	$ 18,720 $ 12,720 $ 14,070 $ 4,830 $ 3,090 $ 5,010	
Subtotal :		$ 58,440	8.0
Tandem Switch Cost/Switch	Austin Houston Dallas Lubbock Abilene Harlingen	$ 53,350 $ 31,650 $ 34,950 $ 12,850 $ 8,900 $ 12,100	
Subtotal :		$153,800	21.0
Total Network Cost :		$733,776	100.0

3.2.9 Intra-State Network Recommendations

In conclusion, the current STS network, with primary switches at Dallas, Houston, Austin and Abilene, seems equivalent to the least cost design for a four-switch configuration, given current traffic and the number of assumptions used in the analysis.

In the optimal configuration, without limiting the number of switches to four, the network has five primary switches (Austin, Dallas, Houston, Lubbock and Abilene), and one secondary switch at Harlingen. Under assumed growth rates, the optimal configuration for the 1989 traffic levels includes the same six switchers, plus a potential additional secondary at Corpus Christi. A sensitivity run at three times the expected 1989 traffic levels showed no change in the recommended configuration for the network.

The growth of STS seems easily carried out in an evolutionary manner. A first step, before the addition of other tandems, should be to investigate in further detail the rehoming of the following switches:

Table 3.13

REHOME CANDIDATES

Switch #	LOCATION	CURRENT HOME SWITCH	"OPTIMUM" HOME SWITCH
37	Wichita Falls	Dallas	Abilene
39	Vernon	Dallas	Abilene
41	Holiday	Dallas	Abilene
42	Eastland	Dallas	Abilene
44	Childress	Dallas	Abilene
45	Stephenville	Dallas	Abilene
57	Brownsville	Austin	Houston
72	Rockport	Austin	Houston
73	Port Aransas	Austin	Houston
79	Waco	Austin	Dallas
87	Bryan	Houston	Austin
114	Alto	Houston	Dallas
116	La Grange	Houston	Austin

First-order analysis has identified theses as likely rehome candidates, and immediate savings may accrue to redirecting their access lines.

The next topological step will be to add Lubbock as a primary switching site and Harlingen as a secondary switcher, if CCSA is found not to be cost-effective when Telpak is discontinued.

When the volume of network traffic reaches the projected 1989 level, another secondary switcher may be considered for Corpus Christi. In this way, no costly change of switch location is needed, and the simplicity of adding another switcher without a major reconfiguration of the network can be realized.

3.2.10 Interstate Access

This section will describe the results of an analysis of potential interstate FX candidates if the STS network were to provide interstate service. The analysis was performed using selected data tapes supplied by users of the STS network. These data sources included interstate call records from Texas Tech, the Capitol Centrex and a study of off-net calling patterns performed by STS.

The data were analyzed by a series of programs collectively called the FX Extractor. These programs, developed by Bell-Northern Research, are designed to identify opportunities for FX facilities. This set of programs compares call records against a data base of local calling areas for major metropolitan areas of the United States. The program then "assigns" the call records to the largest calling area that can serve the traffic in question, and sums the calls to a specific calling area. Thus the total volume of traffic for each potential FX group can be evaluated.

Due to the nature of the source data, the number of interstate FX facilities that would be needed for STS, if this service were to be provided, cannot be accurately determined. This is due to the fact that the source data is not comprehensive, but only covers some of the users of the STS network. Also, if interstate FX service were offered, not all calls to these areas would not travel on the STS network. For these two reasons the number of required facilities cannot be estimated.

It is possible to identify likely cities, where the provision of interstate FX service would be financialy beneficial to the State. If the State were to provide interstate service on the network, the State could lease FX facilities to these communities and provide coverage to other areas through the use of interstate WATS facilities.

Initially the State could lease a small number of these facilities, using interstate WATS facilities, to provide an overflow facility as well as providing service to areas where FX groups do not appear to be economical. Using the traffic data generated by the initial offering of this service, the State could then correct the size of the leased facilities appropriately. The most promising areas for interstate FX facilities are listed below, in Table 3.14:

Table 3.14

Interstate FX Possibilities

City	Area Code	Comments
Atlanta	404	
Denver	303	
Gardena	213	Greater Los Angeles
Los Angeles	213	Calling Zone 9
Nassau	516, 212	Greater NY Area, Calling Zone 2
New Orleans	504	
Oak Park	312	Greater Chicago
Oklahoma City	405	
San Francisco	415	Calling Zone 1
Washington, DC	202	Calling Zone 1
THE FOLLOWING HAVE LOWER TRAFFIC VOLUMES THAN THE PRECEDING.....		
Boston	617	
Cleveland	216	
Indianapols	317	
Kansas City	816	
Mayfair	313	Greater Detroit
Minneapolis	612	
Philedelphia	215	
Santa Ana	714	Orange County
San Diego	619	Formerly 714 Area Code
Walnut Creek	415	

It may be economically beneficial for the State to offer two services, one providing coverage to the entire United States while the other would provide service only to those areas serviced by FX facilities. For larger users of the STS network, the provision of interstate WATS service by the network may not be financially attractive. For these users, it would be more attractive for WATS service to be provided directly by the serving PBX, as the added trunking efficiencies achieved by the STS network would not offset the access line or overhead cost. For these users, only the FX facilities would be of interest. For small users who do not have sufficient traffic to require large WATS groups, the added efficiency of an STS-provided WATS service would be attractive.

The two services could be implemented by providing two classes of service, one which allows calls to the entire US while the second would allow only calls to areas served by FX facilities. These two services would then have different rates, with the more restricted service having a lower cost per minute. An alternative would be to bill the calls at different rates, with calls to areas not served by dedicated facilities being billed at a higher rate, reflecting their greater cost. Either of these concepts could also be applied to intrastate facilities, to achieve similar results.

3.3 Data Network

Data traffic for State agencies is presently carried in either of two ways:

- o through private data networks within the agencies (with dedicated circuits sometimes provided by STS);
- o as apparent voice traffic, dialed through the State network or the public network.

A future alternative is provided by carrying data traffic through an STS data network. This approach could provide for more efficient use of communications facilities; will provide for more efficient use of data communications (datacom) test equipment and highly skilled data communications maintenance personnel; and thus may permit, on the average, more consistently effective testing and repair of datacom facilities.

Chapter 2 summarized the alternatives for switching data traffic through STS. The following sections detail the evaluation methods, analysis and recommendations for those switched alternatives and also for a more rudimentary alternative--that of simple data facilities management, through the use of concentration or multiplexing equipment.

3.3.1 General Analysis Procedure

No collective specification or evaluation of existing or forecasted data traffic was identified by the study team as having been already done by the State. Because such a specification was a necessary base from which alternatives could be constructed, a data questionnaire (Appendix D) was generated as a means of gathering sufficient information to permit the study team to develop its own estimates of current and future traffic quantities, by agency, between city pairs.

Once these traffic "parcels" were quantified, they could be processed into a point-to-point data traffic matrix. From this matrix of existing traffic, an estimate could be produced, using consistently mentioned growth assumptions, of future data traffic requirements for all State agencies. Manual network engineering and some of BNR's integrated network analysis software could be applied to these requirements to determine the equipment requirements and costs associated with packet and circuit switching alternatives and with multiplexing alternatives.

In addition, the bandwidth requirements for on- and off-net access circuits and STS intercity backbone transmission facilities could be calculated, to permit the calculation of facilities requirements. Finally, the impact of data networking on network management equipment, procedures and staffing could be determined.

The results of this methodology would then be:

- o A recommendation regarding the TSD's role in providing data communications facilities for the State's organizations,
- o Estimates of the data circuit requirements for backbone and access facilities in STS, and
- o Estimates of the equipment, procedural and staffing requirements for proper network management.

3.3.2 Development of the Data Traffic Matrix

The objective of traffic modeling was the construction of a city-to-city traffic matrix which described the aggregate requirement or demand for data movement to be met by any statewide network alternative plan. The starting point for constructing a traffic matrix was the questionnaire responses of some 70 State agencies. The traffic matrix was then used to accumulate the digital data loads on various links of the STS network topology, and then to determine facility requirements.

3.3.2.1 Data Questionnaire Analysis

Information from which the traffic matrix was derived was drawn from that supplied by 70 agencies in response to BNR's survey and questionnaire coordinated by TSD and AISAC. Many agencies, in addition to direct responses to specific questions, sent packets of information describing their equipment, development plans submitted to AISAC's reviewers, and, in some cases, information describing their own existing private data networks. This survey covered several topics; with regard to data traffic modeling the relevant information is the following:

(1) Nature of the agency's business.

(2) Location of host computers on which agency application software is resident.

(3) Location(s) of terminal equipment, by city.

(4) Numbers and types of terminal equipment at these locations.

(5) Reported (measured or estimated) transaction volumes.

(6) Amount of data transferred per transaction.

(7) Expected future growth.

For many agencies it was clear from this information that data traffic requirements were local (intra-complex or intra-city), were of negligible volume, or were carried by another agency. It was assumed that any agency with an appreciable traffic requirement made this clear in the survey response.

By the above criteria, the following significant contributing agencies were identified as those which were to be aggregated to estimate the total data requirement.

Department of Human Resources
Department of Health
Purchasing and General Services
Industrial Accident Board
Department of Mental Health and Mental Retardation
University of Texas System
Comptroller
Department of Highways and Public Transportation
Department of Public Safety

Several general conclusions were drawn based upon the questionnaire response content.

- Virtually all of the traffic is between computers (located at the major cities) on one end, and terminals, workstations, or job entry stations located at those and other cities on the other end.

- Based on equipment, much of the traffic is of the inquiry/response variety, but there is also significant bulk transaction traffic (remote job entry, printing, graphics, etc.)

- Many of the agencies operate their own data networks, though very few of these reported the network configurations.

- It was usually impossible, and occasionally difficult, to break out the communications-related cost components of agencies' budgets.

There was considerable variability among agencies as to which figures were reported. Some assumptions were made by the study team, in order to complete the model from available information and to simplify the process by omitting detail which will not improve the requirements estimate. Where agencies did not report the amount of data exchanged per transaction, typical numbers of characters per transaction to/from terminals were adopted from other agencies which reported them.

Where terminals were stated but not volume of traffic (characters or transactions), volume per terminal was adopted from other agencies. Where numbers of terminals at each city location were not available, or the numbers were large and the mix of terminals was typical at each location, traffic was spread uniformly among these locations. Where a centralized traffic volume was known or inferred, and its spread to/from the agency's city locations was not given, traffic spread was assigned proportional to equipment (number of terminals) at the various cities. Where host locations were not otherwise explicitly stated, they were taken to be at the principal business address of the agency (most often Austin).

The result of the process just described was a series of lists, one for each contributing agency. Each list exhibited the city locations (by suitable numerical code) at which the agency has terminal equipment, the volume of traffic to and from the host processor, and the host location. Overall there were approximately 1,500 tributary parcels of traffic, partitioned by agency and city.

3.3.2.2 Derivation of 1982 Matrix

Expected 1982 transaction traffic volumes were translated into offered, busy hour communications traffic, under a set of assumptions about that traffic.

(1) Transport time for data traffic does not exceed 250-750 milliseconds. This constraint is intended to result in a short enough response time for inquiry/response applications. This delay is to be interpreted as the overall average required. Some traffic is bulk information transfer and tolerates much higher delay without observable effect on its applications.

(2) Bit overhead on the network will total 20% of carried content bits, added to the information transferred. This accounts for framing and protocol information, error checking, start/stop bits for asynchronous data, retransmissions, etc.

(3) Each character is comprised of eight bits.

(4) It was assumed that 17% of the day's data traffic is in the data busy hour. BNR studies of public and private voice and data networks have shown that data and voice peaks closely correspond in organizations which have moderate proportions of data traffic. 17% is a standard

figure used for telephony traffic analyses. Busy hour voice traffic in STS was 12% of the total business day's traffic during the period for which taped information on carried point-to-point traffic was summarized; however, the 17% figure was chosen as a more conservative position, i.e., so as not to underestimate the requirements for handling data traffic.

(5) Tolerable error is contributed by the portion of data traffic which has been carried on voice facilities and has been registered as voice traffic on STS billing tapes, while at the same time being included here as data traffic. Dialed data traffic has lower usage characteristics (fewer calls and at lower speeds), on the average, than the remaining types of data traffic. Secondly, some of this traffic will remain dial voice in the future. Third, this would compensate for low-side estimates of data traffic due to any agencies which have substantial data traffic but did not represent themselves adequately in the questionnaire responses.

BNR constructed a preprocessor to account for these traffic assumptions, so that traffic parcels generated for the list of Texas agencies could be processed into equivalent offered communications traffic volumes, and further processed into a city-to-city traffic matrix. The complete intercity traffic matrix is included in Appendix D, following the data questionnaire.

By inspection of the traffic matrix, the likelihood was established that total data traffic that passed between cities was one or more orders of magnitude smaller than voice traffic. Given that, and the fact that the predominant volume of traffic followed the backbone routes that were already developing voice traffic, further calculations in generating quantities of data facilities assumed that the data backbone network would follow that for voice. Thus the following intercity matrix was derived for data traffic between STS voice tandem nodes, expressed in Kbit/sec (Kbps) for the "base year", i.e. beginning of study, corresponding to a point in time at the boundary of 1981 and 1982, prior to any 1982 growth. Diagonal entries are not shown, as they are irrelevant.

Table 3.15

Data Traffic Between Network Nodes (Kbps)

FROM: | TO:	1 Austin	2 Houston	3 Dallas	4 Lubbock	5 Abilene	6 Harlingen
1 Austin	.	86.1	148.1	91.6	34.9	53.5
2 Houston	36.7	.	22.9	13.2	6.0	4.8
3 Dallas	55.5	16.9	.	13.7	6.0	4.8
4 Lubbock	28.0	4.4	4.7	.	0.0	0.0
5 Abilene	11.3	2.0	2.0	0.0	.	0.0
6 Harlingen	15.4	1.6	1.6	0.0	0.0	.

Based on these point-to-point volumes, the data traffic on backbone transmission facilities was developed for each city, Houston, Dallas, Lubbock, Abilene, and Harlingen:

(1) Select the larger of the traffic from the city to another node and that from the other node to the city.

(2) Add all these traffic volumes to get the total link traffic between the city and Austin. (Austin is physically linked to all other nodes and serves as a hub for data traffic between nodes.)

The resulting backbone inter-node link loads are shown below. This again is for the base year, with no growth applied.

Table 3.16

1982 Data Traffic on Inter-Node Links

Links	Data traffic load (Kbps)
Houston - Austin	133.0
Dallas - Austin	195.5
Lubbock - Austin	118.5
Abilene - Austin	46.9
Harlingen- Austin	63.1

3.3.2.3 Derivation of Future Inter-Node Link Traffic

Very few agencies stated growth estimates in their responses to the questionnaires. Some gave indications that they had growth in mind but abstained from stating this as a forecast pending approval of their proposals. A few stated that they expected zero growth. Where stated, growth was expressed variously in terms of equipment, traffic, budget, or personnel. If an agency stated any growth, we have assumed that the factor would apply to traffic volume. Based on the limited sample of growth factors, the centroid of opinion was estimated to be an increase of activity by a factor of three by the end of 1986, at the end of the present five-year State planning interval. This corresponds to an annual growth rate of 24.6% under a geometric growth assumption. The resulting growth factors and the corresponding data traffic projection by the beginning of the year within the period of this study are as follows:

Table 3.17

Data Traffic Growth Factors

YEAR	GROWTH FACTOR
1982	1.0
83	1.246
84	1.55
85	1.93
86	2.41
87	3.00
88	3.74
89	4.66

Table 3.18

Data Traffic on Inter-Node Links (Kbps)

Links	1983	1984	1985	1986	1987	1988	1989
Houston-Austin	165.7	206.2	256.7	320.5	399.0	497.4	619.8
Dallas-Austin	243.6	303.0	377.3	471.2	586.5	731.2	911.0
Lubbock-Austin	147.7	183.7	228.7	285.6	355.5	443.2	552.2
Abilene-Austin	58.4	72.7	90.5	113.0	140.7	175.4	218.6
Harl.-Austin	78.6	97.8	121.8	152.1	189.3	236.0	294.1

The above growth rate projection may be optimistic due to the move toward distributed computing environment. The major reasons for a transaction being transmitted to a mainframe are:

(1) It needs the power of a large computer.

(2) It needs data which are stored centrally.

The first need is reduced rapidly due to the increasing usage of local computers. The second need, a centralized data base, important to some, but not all data, because the locally significant data needs not be stored in the central site. Thus, since an increasing number of transactions will be processed locally, a significantly smaller portion of transactions may have to be transmitted to a central mainframe. Overall, the communication traffic may very well be a net decrease in the volume of communication with mainframe computers residing at a central site.

3.3.3 Analysis of Traffic Handling Alternatives

Two fundamental alternatives exist for the handling of data traffic:

(1) some form of facilities management scheme, which improves the utilization of transmission facilities through multiplexing, and

(2) the use of packet or circuit switching techniques for the concentration and distribution of traffic.

There was very little demand expressed for access to multiple hosts from single terminals--even in presentations of future plans. For this reason, switching was seen more as a means of gaining efficiencies in facilities utilization than as a means of getting access to many locations. Circuit switching is already used (for dialed data) as a means of providing that access for users that need it.

A completely digital STS network will position the State to accept increasing quantities of that traffic type via users' voice/data PBX's and digital access lines that will be available in the next few years. To reiterate, the demand for this kind of access is forecasted to be very small through 1986. STS's position may be considered to be insurance against the appearance of large volumes of data traffic that requires access from a single terminal to any of several hosts or other terminals.

In terms of facilities utilization, two scenarios were pursued in further detail.

(1) The first was the use of packet switching systems to concentrate the incoming data traffic for routing on the appropriate backbone facilities.

(2) The second was the use of concentrators without a switching capability, and the use of multiplexing equipment, to gain somewhat less efficient concentration.

3.3.3.1 Access Lines

Because of the relatively small traffic volumes, the most cost-effective method for moving data traffic to the cities where it could gain access to the backbone network was to obtain local concentration in the originating towns and cities, such that 9.6 kbps access lines could be used. This is already being done by most agencies that have data communications demands of any volume (i.e., that are handling more than dialed data). As another means of achieving this concentration on access lines, for those few locations where 9.6 kbps lines do not exist but could if traffic were grouped, the cooperative use of concentrators or STS's provision of concentrators is suggested.

For the plans in which the owned transmission facilities existed, several cities have enough traffic to use the backbone transmission facilities to access the homed network nodes via insert/drop points. The projected throughput requirements for those backbone insert/drop links were derived from the intercity traffic matrix, shown in Appendix D, and the data traffic growth factors, shown in Table 3.17.

Table 3.19

Data Traffic on Insert/Drop Links (Kbps)

Routes	1982	1983	1984	1985	1986	1987	1988	1989
Belton/Temple-Austin	1.6	2.0	2.5	3.1	3.9	4.8	6.0	7.5
Brownwood-Abilene	8.4	10.5	13.0	16.2	20.2	25.2	31.4	39.1
Bryan/College Station -Austin	8.7	10.8	13.5	16.8	21.0	26.1	32.5	40.5
Corpus Christi -Harlingen	22.8	28.4	35.3	44.0	55.0	68.4	85.3	106.3
San Antonio-Austin	32.7	40.7	50.7	63.1	78.8	98.1	122.3	152.4
Waco-Dallas	9.0	11.2	14.0	17.4	21.7	27.0	33.6	41.9

The access lines not operated by STS were assumed to be realized from voiceband lines tariffed under the Texas intrastate tariff, and with D1 conditioning additional in order to make the lines suitable for 9.6 kbps transmission. The lease cost of those dedicated data access lines will not be included in the economic evaluation for the plans using owned backbone radio facilities. It is negligible compared to total data transmission costs. In addition, this portion of cost can not be easily extracted from the total cost of the current dedicated circuits.

Access line costs did not affect the decision about backbone concentration techniques and therefore were not considered in the comparisons of packet switching and concentration at the major network nodes.

3.3.3.2 Concentration And Intercity Backbone Facilities

The following assumptions applied to the calculation of intercity backbone facilities requirements:

(1) Trunking (between key cities) efficient (approximately 99%) is gained when multiple 9.6 kb/sec data channels are carried on trunk circuits by means of bit-interleaved time division multiplexing techniques compared to conventional methods of taking a channel in T1 (56 kbps) for an input data channel (e.g., 9.6 kbps).

The net data efficiency on the trunks is thus approximately same as the access lines, i.e., 50%.

(2) Further data efficient is gained by combining access line traffic on the packet network trunks. The net data efficiency on the trunks is approximately 90%.

Rationale: the problem of STS data trunking between the six hub cities was studied separately with a BNR design tool ("HYBRID") which sizes facilities for packet switching using well-established formulas for bandwidth allocation derived from queuing theory. This study established that an STS data network can run at an average link utilization of 90%. (The network resulting from this study is irrelevant since it does not follow the topology constraints.)

Appendix L shows the cost comparsion of multiplexers and packet switches for the heaviest data traffic link, Dallas-Austin, because it is where the packet switch most probably may prove in. For the expected volumes of traffic, and their lack of need for switching (at least, for distribution purposes), it is not surprising that the expected first cost of a packet switching system cannot be supported.

3.3.4 Recommended Strategy in Handling Data Traffic

Based on the previous sections, it is recommended that STS initially provide multiplexers at access cities to multiplex access lines (at 9.6 kbps) to backbone trunks. This approach does not prevent future data communication enhancements such as providing local access networks and a backbone packet network. The rationale for this phased approach is:

(1) It is a major undertaking for STS to provide high quality voice communications service (the dominant traffic type). The success of this service is the most important mission of STS. To provide additional sophisticated data communication services on top of this may increase the risk of not being able to provide high quality voice communications. Furthermore, STS still can provide an inexpensive data transport service using its owned digital facility and achieving adequate bandwidth utilization through multiplexers.

(2) Due to a lack of information about the distribution of data traffic within each location, it is not reasonable to configure the access network for data traffic. In addition, most agencies already have access networks to optimize cost and maximize bandwidth utilization. There is a definite opportunity for STS to provide local access networks for the small agencies. At this time, it seems that the return on investment (both capital and expense) for STS providing local access networks will be much lower compared to that for the voice network.

(3) There are political issues in terms of control, should STS decide to provide an integrated voice/data network. This is especially true if the heavy data usage agencies are involved.

(4) The data traffic * is much less than the voice traffic. Any dramatic increase of data traffic will at most advance the capital investment of transmission equipment, but not the total amount of investment as detailed in the next chapter.

3.4 Voice/Data Circuit Requirements

The following section will describe the circuit requirements for the new six-tandem network. The tables which follow describe the year-by-year circuit requirements for both voice and data.

3.4.1 Voice Circuit Requirements

The intermachine trunk (IMT) voice circuit requirements were determined by using the results from the network design tools for 1982 and 1989 and extrapolating these results, in a straight line manner, to obtain projections for the other

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* Because digital facilities are used, the traditional way of calculating the number of data circuits for an analog facility is invalid. For example, an analog circuit can carry at most 9.6 kbps data, while a digital circuit can carry 56 kbps data. Each of these circuits is equivalent to a single voice circuit. This is one of the major reasons for the myth that the number of data circuits will exceed that of voice circuits soon.

years. The results are as follows:

Table 3.20

Voice IMT Circuit Requirements

IMT Group	1982	1983	1984	1985	1986	1987	1988
Austin-Houston	139	151	162	174	185	197	208
Austin-Dallas	151	166	180	195	209	224	238
Austin-Lubbock	52	56	61	65	70	74	79
Austin-Abilene	33	36	38	41	44	47	49
Austin-Harlingen	68	72	77	81	86	90	95
Houston-Dallas	44	48	53	57	61	65	70
Houston-Lubbock	12	13	14	15	15	16	17
Houston-Abilene	7	8	8	9	9	10	10
Houston-Harlingen	7	8	8	9	10	11	11
Dallas-Lubbock	16	18	19	21	22	24	25
Dallas-Abilene	19	21	23	25	27	29	31
Dallas-Harlingen	0	1	1	2	2	3	3
Lubbock-Abilene	16	17	19	20	22	23	25
Lubbock-Harlingen	0	0	0	0	0	0	0
Abilene-Harlingen	0	0	0	0	0	0	0

As was mentioned earlier, the network design reflects a P.01 grade of service for IMT's and P.02 for access lines. The access line and PBX requirements were derived somewhat differently, in that the existing number of circuits were used as a base.

In the case of access lines (including LONAL's and CNAL's) the network design tool results could not be utilized directly. Due to program limitations, the network design program assumed that all traffic sources within a city were served by a single access group. This resulted in the access line requirements being understated. To arrive at an approximation of the circuit requirements a model was developed which utilized the existing circuit quantities as a base. To arrive at future circuit requirements, growth rates predicted by the network design tools were used. The results then required one final correction to approximate the effect of changing the grade of service on access lines from P.07 to P.02. To arrive at a correction factor, the effect of changing the grade of service was examined in Dallas. These results were assumed to be representative of the network as a whole. From this study, a factor (1.44) was derived which was the ratio of P.02 to P.07 circuit requirements for Dallas. This factor was then applied to the predicted circuit requirements to obtain the P.02 circuit requirements.

To estimate the number of PBX stations that might be connected to a combined PBX/tandem over the planning period, the 1982 station requirements, supplied to the study team by the State, were used as a base. For station growth, the composite growth rate for the access lines homed on the PBX/Tandem in question was used (as predicted by the network design tools). These same growth rates were used to project increases in intrastate WATS lines from their 1982 level. The results of this analysis are as follows:

Table 3.21

Voice Access Circuit Requirements

	1984	1985	1986	1987	1988
ABILENE					
Acc Lns	267	286	305	324	343
Off Net	56	60	64	68	72
WATS	10	11	12	13	14
PBX Lns	350	375	400	425	450
AUSTIN					
Acc Lns	1415	1512	1609	1706	1803
Off Net	250	267	284	301	318
WATS	49	53	57	61	65
PBX Lns	5218	5577	5936	6295	6654
DALLAS					
Acc Lns	970	1048	1126	1204	1282
Off Net	321	347	373	399	425
WATS	38	41	44	47	50
PBX Lns	2978	3217	3456	3696	3934
HARLINGEN					
Acc Lns	291	307	323	339	355
Off Net	101	106	111	116	121
WATS	11	12	13	14	15
PBX Lns	448	472	496	520	544
HOUSTON					
Acc Lns	859	922	985	1048	1111
Off Net	290	309	328	347	366
WATS	32	34	36	38	40
PBX Lns	6886	7329	7772	8215	8658
LUBBOCK					
Acc Lns	292	312	332	352	372
Off Net	98	105	112	119	126
WATS	11	12	13	14	15
PBX Lns	8130	8695	9260	9825	10390

3.4.2 Data Circuit Requirements

The number of 9.6 Kbps backbone circuits for inter-node and insert/drop links was derived from the data traffic requirements, shown in Tables 3.16, 3.18 and 3.19, with the assumption of 50% bandwidth utilization.

Table 3.22

Data Backbone Circuit Requirements (9.6 Kbps)

Circuit Group	1982	1983	1984	1985	1986	1987	1988	1989
Inter-Node Link								
Houston-Austin	28	35	43	54	67	84	104	130
Dallas-Austin	41	51	64	79	99	123	153	190
Lubbock-Austin	25	31	39	48	60	75	93	116
Abilene-Austin	10	13	16	19	24	30	37	46
Harlingen-Austin	14	17	21	26	32	40	50	62
Insert/Drop Link								
Belton/Temple-Austin	1	1	1	1	1	1	2	2
Brownwood-Abilene	2	3	3	4	5	6	7	9
Bryan/College Station-Austin	2	3	3	4	5	6	7	9
Corpus Christi-Harlingen	5	6	8	10	12	15	18	23
San Antonio-Austin	7	9	11	14	17	21	26	32
Waco-Dallas	2	3	3	4	5	6	7	9
TOTAL	137	172	212	263	327	407	504	628

Two alternative configurations of a link are:

(1) multiplexers: multiplexing data circuits to a T1 facility with an efficiency of about 99% of aggregate rate. This configuration will occupy a whole T1 facility for the data

traffic. *

(2) data channel banks: unpacking data circuit to occupy a voice channel in a T1 facility by repeating the data. This configuration uses the bandwidth much less efficiently. For example, a 9.6 Kbps data circuit occupies a voice channel utilizing 64 Kbps bandwidth. On the other hand, this configuration allows the small data traffic be mixed with the voice traffic on a single T1 facility.

If the projected data circuit capacity will require an additional digital radio facility using the data channel banks, it is more economic to use the multiplexers to delay digital radio facility installation. Otherwise, it is more economic to use data channel banks. In this case, the less efficient usage of bandwidth does not cost anything except maybe some additional T1 interface circuits. The total cost for the data channel banks and T1 interface circuits is still lower than that of multiplexers.

Based on the above criterion, all inter-node links should be configured utilizing multiplexers and interfacing to a T1 facility directly, except Abilene-Austin link. Only the Dallas-Austin link will require an additional T1 facility for the 1989 traffic. The multiplexer cost ** for the inter-node links, based on the cost parameters detailed in Appendix L, is:

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* Currently there is no multiplexer product which can directly interface with PCM voice.

** The cost is based on the data circuit capacity requirement of the next year.

Table 3.23

Multiplexer Cost of Inter-Node Links ($1,000)

Link	1984	1985	1986	1987	1988
Houston-Austin	107.50	10.66	34.30	36.76	41.68
Dallas-Austin	148.36	36.76	40.04	44.96	64.24
Lubbock-Austin	82.22	30.20	32.66	14.76	59.58
Abilene-Austin	-	-	-	-	-
Harlingen-Austin	55.22	4.92	15.52	28.56	9.84
TOTAL	393.3	82.54	122.52	125.04	175.34

All insert/drop links and the Abilene-Austin inter-node link will be configured using data channel banks, because they do not require additional radio facility. * The cost of these circuits will be detailed in the next chapter for the T1 configurations with combined voice and data.

In addition to the above data equipment, modems are required. A 9.6 Kbps modem costs about $2,000. The cost of modems at the network nodes and insert/drop points is:

Table 3.24

Cost of Modems at Nodes and Insert/Drop Points ($1,000)

	1984	1985	1986	1987	1988
Modems	1,052	256	320	388	496

The cost of the customer's data equipment and access lines is not included:

* It should be pointed out that 9.6 Kbps data circuits are assumed. If some data circuits have lower speeds, the Abilene-Austin, San Antonio-Austin and Corpus Christi-Harlingen links may be more economic to use multiplexers depending on the data circuit mixtures.

(1) modems and multiplexers/concentrators at the customer's premises;

(2) 9.6 Kbps access lines between customer's premises and network nodes or insert/drop points which would most likely be leased from a common carrier.

4 TRANSMISSION

Given that the voice network topology is stable over time and that ownership of the network's voice switching systems is recommended, it is appropriate to consider alternatives to conventional facilities leased from a common carrier to connect these systems. Transmission alternatives fell into the categories of leased lines (from any of several lessors) for Plans 1 through 6; terrestrial microwave radio, to be owned by the State, or fiber optic systems owned by the State, for Plans 7 through 10; and leased or owned satellite systems or subsystems for Plans 11 through 14.

The following sections describe the specific analysis methodology used in determining what the proper applications are (if any) for each of these alternative transmission media; describe the derivation of broad-gauge and more detailed costs for these systems, as applied in the State of Texas; and make recommendations regarding the alternatives which seem best suited for a future STS network.

The intermachine trunk network was considered as a primary analysis candidate. In addition, likely drop and insert points for terrestrial routes (fiber optic or microwave) were identified, to be included in this analysis. In the interim report a first-order analysis was presented on several potential microwave and fiber optic paths, concluding that owned transmission systems merited further investigation. The following sections will describe the analysis of the owned transmission alternatives, the selection of the initial routes for the system, and year-by-year planning level costs for the recommended alternative.

4.1 First-Order Evaluation of Transmission Alternatives

In order to eliminate some of the transmission alternatives before performing a detailed analysis, a first-order evaluation was performed. This evaluation compared satellite, microwave and fiber optic transmission systems. In the sections which follow the results of this analysis are presented, along with an analysis of the necessary circuit quantities needed for a State-owned system. This analysis is divided into three major sections: "Satellite Transmission Facilities", "Terrestrial Transmission Routes and Circuit Requirements", and "Terrestrial Transmission Facilities".

4.1.1 Satellite Transmission Facilities

A quantitative model was sought for satellite facilities that could be used to capture the costs of handling all IMT's between tandems in the network. Because of the significant cost of an earth station, however, a simple allocation of earth station cost among the routes served by it would grossly understate the cost of providing satellite facilities for just one or two IMT routes. In addition, there are many ways in which satellite services are being offered, thus complicating the analytical process significantly.

For this reason, the analysis was undertaken in piecewise fashion, with an attempt being first made to determine whether a satellite serving scheme for the entire network's IMT's was even remotely attractive. If there was any promise for satellite facilities in the network, further work would be done to clarify what the bounds of those opportunities were.

A cost model was developed for a typical ten-meter earth station, along with leased costs for transponder bandwidth. The cost model included civil works/construction costs, a shelter for the antenna, de-icing gear (a gas system), the antenna and its erection, redundant low noise and high power amplifiers, an intermediate frequency link, up- and down-converters, backup power, and a few pieces of test equipment. The sum of these contributions totals approximately $390K per earth station, or $1,560K to serve the four existing primary centers. A rather rough maintenance figure of $2.3K per month per earth station should apply.

Lease of a ten-meter earth station, with local access, is expected to cost approximately $18K per month as an option. Additive to either of these is a charge for transponder lease of approximately $100K per month. Neither of these alternatives pays back against the cost for leased lines ($113.6K per month).

Satellite-based leased facilities are another option that is now available. The breakdown of charges usually falls into an access component and a bandwidth utilization component. An example of a competitive charging arrangement includes an access charge of $7.5K per location-month, with $250 per voice port as a monthly bandwidth charge. Data charges would be additive to this.

In STS, with four primary locations in the existing network, $30K per month would be required for network access from STS locations. With 386 IMT's in service today, 763 voice ports would be required; at $250 per voice port, the voice charge would total $221K per month, approximately twice what it would cost with leased lines (at $114K per month). For economic reasons, unless significant opportunities are identified for point-to-multipoint wideband transmission, or significant long-haul interstate traffic of any type is identified, the use of satellite transmission facilities for the STS is not recommended. As a result it is appropriate to limit more detailed first order evaluations to terrestrial transmission alternatives.

4.1.2 Terrestrial Transmission Routes and Circuit Requiremets

This section will develop the topology and circuit requirements for a State-owned terrestrial transmission system (fiber optic or microwave).

After several discussions with the State of Texas, it was determined that route diversity was not of great interest to the State, unless there were clear, quantifiable benefits to the State which would justify the greater cost purely on economic grounds. As a result, route diversity was not considered in the analysis which follows. This means that if a path fails, the alternate means of reaching that State facility would be the use of the public network until the problem is resolved.

Once route diversity was eliminated from consideration, the potential facilities routes reduced to a star configuration, with Austin at its center, such that, with the exception of Lubbock-Abilene, all IMT's took a physical route through Austin. The routes would consist of a route connecting Lubbock to Abilene and four routes connecting Abilene, Dallas, Harlingen and Houston to Austin for a total of five routes. This would provide for the necessary logical connections between tandems, with the minimum number of routes. As an example, for an IMT needed between Dallas and Houston, the physical path would be via Austin. One should note that in this situation the Austin Tandem would NOT be involved in the route; instead, the required connection would be hard-wired through the Austin terminal without ever entering the Austin Tandem. Thus, as far as the Dallas and Houston Tandem are concerned, a direct physical connection exists between these two cities.

Seven potential drop/insert points were identified along the five routes. These points consist of the cities of Temple (with leased lines connecting State offices in Belton and Killeen to the drop/insert point) and Waco on the Austin-to-Dallas route; the cities of San Antonio, Corpus Christi and Kingsville on the Austin-to-Harlingen route; the city of Brownwood on the Austin-to-Abilene route; and the cities of Bryan and College Station (served by the same drop/insert repeater) on the Austin-to-Houston route. Some of these drop/insert points will require a longer route than would be required if the route went directly between the tandem cities. The differences in length depend to some extent on the transmission medium that is used. Figure 4.1 illustrates the topology of the potential terrestrial transmission facilities.

Owned Facilities Routes

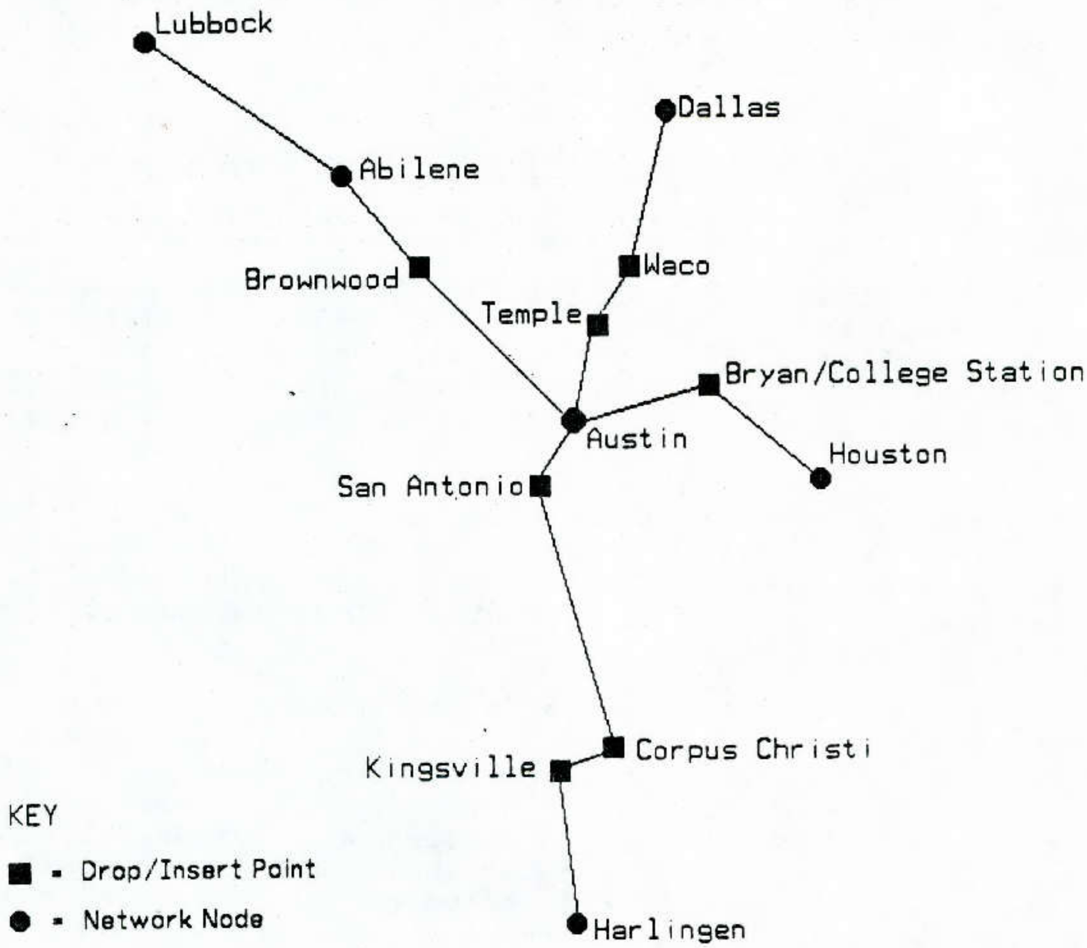

Figure 4.1

After the transmission routes that merited investigation were identified, the year-by-year circuit requirements for these routes could be determined. The voice circuit requirements for a route (without considering drop/insert points) consist of the number of IMT's needed between the cities in question and the through circuits destined for another city. As an example, in the case of Houston, the circuit requirements for this route consist of the voice trunks needed between Houston and Austin as well as the voice trunks needed to all other tandems. Thus, the IMT's needed between Houston and Lubbock would physically travel from Houston to Austin to Abilene to Lubbock. In like manner the IMT's needed between Houston and Dallas would physically travel from Houston to Austin and then to Dallas. When these various combinations are added together the circuit requirements are as follows:

Table 4.1

Circuit Requirements (Voice Bandwidth)

IMT's	1982	1983	1984	1985	1986	1987	1988	1989	1990
Austin-Abilene	139	151	163	175	188	200	212	224	236
Abilene-Lubbock	96	104	113	121	129	137	146	154	162
Austin-Dallas	250	270	290	310	331	351	371	391	411
Austin-Houston	209	227	245	263	281	299	317	335	353
Austin-Harlingen	75	81	86	92	98	104	109	115	121

The circuit quantities for 1982 and 1989 were derived from results from BNR's network design tools for the recommended six-switch topology. The circuit quantities for the other years were developed using a straight-line interpolation of the 1982 and 1989 results.

Access line traffic that could be carried by a state transmission system was identified manually. Cities located close to the proposed paths were examined and those with relatively large circuit requirements were chosen for drop/insert points. In two cases (Bryan/College Station and Belton/Killeen/Temple) traffic from nearby cities was included in the circuit requirements for the respective drop/insert points. Once the actual repeater locations are determined, the state could expand this effort to pull additional access line traffic onto the state owned transmission system. At that point the actual length of an access line required to reach the drop/insert point would be clear, allowing an economic comparison between utilizing a state transmission facility for part of an access line route against reaching the tandem switch directly via leased facilities.

The circuit requirements for access lines which could be carried by a State transmission system were derived somewhat differently than those for IMT's, due to current limitations of the network design programs. The programs could not accommodate the number of distinct access line groups present in the STS network. As a result, the traffic parcels from all access lines, etc., in a community were added together, making the access line groups appear more efficient than they actually are (for a detailed description of this problem see the Network Topology Analysis section of the report).

Although IMT requirements over time could be accurately calculated through this approach, access and tie line quantities and growth had to be determined manually. As a result, the actual number of circuits serving these communities at a P.07 grade of service was used and a scaling factor was developed to simulate the change in circuit requirements if the grade of service were changed from P.07 to P.02. The factor was developed by examining the difference in the required number of circuits in Dallas if the grade of service were changed. This factor (1.44) was then applied to the actual number of circuits presently serving the communities in question to arrive at an approximation of the number of circuits that would be required if the grade of service were changed.

The 1989 circuit requirements were arrived at by multiplying the results by the growth predicted for these communities in the network design program, and then interpolating the intermediate years' requirements in a straight line fashion. The results are as follows:

Table 4.2

Circuit Requirements (Voice Bandwidth)

Access Lines	Actual	1982	1983	1984	1985	1986	1987	1988
Belton/Killeen/Temple	35	50	53	55	58	61	64	66
Brownwood	25	36	39	42	45	47	50	53
Bryan/College Station	78	113	123	133	143	153	163	173
Corpus Christi	76	109	117	125	133	141	149	157
Kingsville	19	27	29	30	32	34	36	37
San Antonio	144	207	223	239	255	271	287	303
Waco	66	95	102	109	116	124	131	138

The data requirements for these routes are listed below. These results describe the number of 56 Kbps channels required for each route segment (each 56 Kbps channel is equivalent to one voice channel). It is interesting to note that even if data circuit requirements were several times the projected level, these requirements would still be quite small when compared to the voice requirements. The tables which follow present the 56 Kbps circuit requirements for the backbone route and intermediate drop and insert points, which are homed on the same cities as the voice traffic from those communities.

Table 4.3

Circuit Requirements (Voice Bandwidth, 56 Kbps)

Data	1982	1983	1984	1985	1986	1987	1988	1989
Austin-Abilene	1	1	1	1	2	2	2	2
Abilene-Lubbock	1	1	1	1	1	1	1	1
Austin-Dallas	1	1	1	1	1	1	1	2
Austin-Houston	1	1	1	1	1	1	1	1
Austin-Harlingen	1	1	1	1	1	1	1	1

Drop/insert Circuit Requirements (9.6 kbps)

Belton/Killeen/Temple	1	1	1	1	1	1	2	2
Brownwood	2	3	3	4	5	6	7	9
Bryan/College Station	2	3	3	4	5	6	7	9
Corpus Christi	5	6	8	10	12	15	18	23
Kingsville	-	--	--	--	--	--	--	
San Antonio	7	9	11	14	17	21	26	32
Waco	2	3	3	4	5	6	7	9

As the transmission system will be digital, the actual circuits will come in DS-1 quantities (24 voice channels or equivalent). The following tables sum the backbone and access line quantities and express the results in DS-1 circuit requirements. The asterisk indicates DS-1 circuit requirements beyond the capacity of current 6 GHz digital radios in the operational fixed service. In these cases two radios will be required.

Table 4.4

DS-1 Circuit Requirements (Voice and Data)

IMT's	1982	1983	1984	1985	1986	1987	1988	1989
Austin-Abilene	8	9	9	10	11	12	12	13
Abilene-Lubbock	5	6	6	7	7	7	8	8
Austin-Dallas	12	13	14	14	15	16	17*	19
,ustin-Houston	10	11	12	12	13	14	15	15
Austin-Harlingen	5	5	5	5	6	6	6	6
Belton/Killeen/Temple	3	3	3	3	3	3	3	3
Brownwood	2	2	2	3	3	3	3	3
Bryan/College Station	5	6	6	7	7	8	8	8
Corpus Christi	5	6	6	6	7	7	8	8
Kingsville	2	2	2	2	2	2	2	2
San Antonio	9	10	11	12	12	13	14	15
Waco	5	5	5	5	6	6	7	7

After the DS-1 circuit requirements are determined for individual communities, the route segment-by-route segment circuit requirements can be determined. For the following table it has been assumed that the drop/insert points will utilize entire DS-1 channels (that is, the "left over" voice channels out of a 24-channel group cannot be utilized elsewhere in the system). The total circuit requirements are as follows:

Table 4.5

Total DS-1 Circuit Requirements

Total By Route Segment	1982	1983	1984	1985	1986	1987	1988	1989
Austin-Brownwood	8	9	9	10	11	12	12	13
Brownwood-Abilene	10	11	11	13	14	15	15	16
Abilene-Lubbock	5	6	6	7	7	7	8	8
Austin-Temple	15	16	17*	17*	18*	19*	20*	22*
Temple-Waco	12	13	14	14	15	16	17*	19*
Waco-Dallas	17*	18*	19*	19*	21*	22*	24*	26*
Austin-Bryan	15	17*	18*	19*	20*	22*	23*	23*
Bryan-Houston	10	11	12	12	13	14	15	15
Austin-San Antonio	14	15	16	17*	18*	19*	20*	21*
San Antonio-Corpus Christi	5	5	5	5	6	6	6	6
Corpus Christi-Kingsville	10	11	11	11	13	13	14	14
Kingsville-Harlingen	12	13	13	13	15	15	16	16

Airline distances between cities were calculated using the Vertical and Horizontal coordinates of the cities and the equation

$$\text{Airline Distance} = \frac{(V - V)\ (H - H)}{10}$$

For fiber optic facilities, route miles were coarsely approximated using a factor of 1.3 x Airline Distance. The following table shows V and H coordinates of the tandem candidate cities, while Table 4.7 shows the airline and broad-gauge terrestrial route mileages between nodes.

Table 4.6

Tandem Candidate Locations

	V	H
Abilene	8698	4513
Austin	9004	3997
Dallas	8432	4033
Harlingen	9819	3664
Houston	8938	3536
Lubbock	8598	4962

Table 4.7

Distances Between Locations

Routes	Airline Miles	Terrestrial Route Miles
Austin-Dallas	181.2	235.6
Austin-Houston	147.3	191.5
Austin-Abilene	189.7	246.6
Austin-Harlingen	278.4	361.9
Abilene-Lubbock	145.5	189.1

4.1.3 Terrestrial Transmission Facilities

A first-order economic comparison was made between the microwave and fiber optic transmission systems. In this analysis two major routes (Austin-San Antonio and Austin-Dallas), with large circuit requirements, were selected for this comparison. Of the possible routes, these two routes have the greatest potential for optic systems because of their large trunk sizes and (for Austin-San Antonio) short distance.

(1) Austin-San Antonio: 17 DS-1 circuits (1985).

(2) Austin-Dallas: 19 DS-1 circuits (Waco-Dallas segment).

In general, fiber optic systems prove in for large bandwidth and short distance routes, because:

(1) The cost of the fiber-optic system is relatively insensitive to bandwidth requirements.

(2) The maximum repeaterless span for a fiber optic system (about 15.5 miles for a 45 Mbps system) is shorter than that for a 6 GHz microwave system (25-30 miles). Single-mode fiber systems, which are expected to be commercially available from several vendors by the end of 1984, will increase the repeaterless span to approximately 22 miles while requiring more expensive (during the first year or two) fiber cable ($1.368K/cable-mile) than the current fiber cable ($.805K/cable-mile). From the economic viewpoint, the single-mode fiber optic systems will be more expensive than the current multimode fiber optic systems in the 1984-1986 time frame for the routes in the backbone network.

(3) One of the major cost components of the fiber optic system is the cable installation, which is very sensitive to distance and terrain ($1.25/ft for direct burial under ideal conditions, and $6/ft when a road must be crossed using a boring technique).

Common assumptions were made for both the microwave and the fiber optic systems to provide a reasonable basis for cost comparison purposes:

(1) At a repeater location: repeater, backup power, alarm, hut, land, and site work.

(2) At the end-office: terminal, multiplexer(s), additional backup power, alarm and office work.

The following parameters were assumed for fiber optic systems:

(1) A 1:1 protected terminal configuration is used in the end office.

(2) Four-fiber graded index cables are used in a route.

(3) The fiber optic cable installation includes cable splicing every 1.9 miles; on average, 98% direct burial and 2% requiring boring (i.e., approximately 100 feet for every mile requires boring).

(4) A factor of 1.3 was used to convert airline mileage to fiber optic cable mileage.

The cost components for the two types of the transmission systems are:

Table 4.8

First-Order Cost Components for Fiber and Microwave Systems (1982 Dollars)

System		End Office	Repeater	Repeaterless Span	Cable
Fiber-I	45Mbps	$ 44K	$ 54K	15.5 miles	$10.854K/mile
Fiber-II	90Mbps	$ 67K	$ 54K	13.7 miles	$10.854K/mile
Microwave-I	45Mbps	$219K	$350K	25 miles	-
Microwave-II	90Mbps	$405K	$613K	25 miles	-

The first-order cost comparisons for the fiber optic and microwave systems using ideal repeater spacing are as follows:

Table 4.9

First Cost Comparisons
for Fiber and Microwave Systems
(1982 Dollars)

Route	Air Miles	Fiber-I	Microwave-I	Fiber-II	Microwave-II
Austin-San Antonio	73	$1,442K	$1,137K	$1,488K	$2,035K
Austin-Dallas	181	$3,452K	$2,888K	$3,606K	$4,485K

For the 45 Mbps systems (672 circuits), the fiber optic system is 27% and 36% more expensive than the microwave system for the Austin-San Antonio and Austin-Dallas routes, respectively. From the traffic study conducted in this report, it is not expected that either of these routes will exceed the 45 Mbps system capacity by the year 2000 for both voice and data traffic. Any unexpected traffic growth may come from extensive video applications. Should heavy video traffic develop, there are other choices to carry such traffic, e.g., satellite.

In addition, the microwave system has finer modular growth (16 channels) than the fiber optic system (28 channels). This makes it attractive to thinner routes, such as Austin-Houston. The single medium, microwave systems, for the owned transmission facilities allows the same maintenance and operations equipment and procedures to be used for all facilities. This reduces the operating expense in contrast to the multimedia environment, such as mixed fiber optic and microwave systems.

As will be described in the Digital Microwave section, the number of hops predicted by a preliminary frequency and terrain study suggest that the repeater spacing for the State microwave system may be less than the 25-mile spacing projected above. In this case the fiber optic system on its face will be somewhat less expensive at a DS-3 rate (45 Mbps). However, fairly conservative assumptions were made in this frequency study. If similarly conservative assumptions were made for the fiber optic system, such as more difficult terrain, shorter repeater spacing, etc., the cost comparison is expected to remain substantially the same. As the two routes that were studied were the most attractive for optic systems, it is clear that microwave is the preferred medium for a State-owned transmission system, based on economic and traffic considerations.

4.2 Digital Microwave

The following sections will evaluate the capital cost of a digital microwave system in greater detail. This section describes a cost model used to estimate the first and continuing costs (in 1982 dollars) of a State-owned microwave system. The cost estimates that follow can be considered to be conservative, as single quantity prices were used. The potential "system discounts" that might possibly arise in a bidding situation are very difficult, if not impossible, to estimate, and as a result are not considered for this analysis. The single quantity costs should also be considered to be average prices, with some vendors charging higher prices and some lower. Finally, special circumstances, such as particularly difficult terrain, severe frequency congestion, etc., may cause the price of some of the repeater sites to exceed the estimate below. For the majority of sites, we would expect that the actual price will be lower than these estimates.

4.2.1 Microwave Repeater Cost Model

A microwave radio system has two major types of facilities: end terminals and repeater sites. The repeater sites can resemble end terminals when they are used to drop and insert traffic from nearby communities. The only real difference is that a terminal has a tandem switch associated with it. As a result, two slightly different cost models for repeaters will be developed.

A terminal or drop-and-insert repeater will typically contain channel bank equipment to convert incoming analog voice signals to the appropriate number of DS-1 (T-1) bit streams. If, in the case of a terminal, the associated tandem switch is digital, this A/D conversion and multiplexing will already have occurred before the signal reaches the radio. The tandem switch in this case must be capable of interfacing to DS-1 facilities directly. The signals from the individual DS-1 lines are then combined into a single high speed bit stream by a digital multiplexer-demultiplexer (muldem). This device can be integrated into the digital radio or it can be a stand-alone device. The output of the muldem is fed into the digital radio, which in turn is connected to the antenna using a waveguide transmission line. In a "through" repeater, where no drop or insert function is performed, channel banks and muldems are not needed.

To insure a high degree of reliability, space diversity receivers and 1:1 hot standby transmitters are preferred, and are assumed in the calculations which follow (this provides for both equipment and path protection). Typical configurations and planning level pricing of the various elements of a digital microwave system are presented in the following subsections.

4.2.1.1 Land

Each terminal or repeater will require a parcel of land on which to locate the tower and antenna, as well as a shelter to house the electronic equipment. In the case of a terminal, existing State buildings will most likely be used, with the antenna and associated tower located adjacent to the building or on the roof of the building, if it can support it. For some repeaters, existing State property and buildings could also be used. For the remaining repeaters, land will have to be acquired by the State. If 200-foot guyed towers are used, a bit less than two acres of land will be required for each repeater site (guyed towers can be designed to require less land, at a higher cost).

The average cost of these two-acre plots was estimated to be about $5,000. The median price for rural agricultural land in Texas is currently just over $900 an acre. As the desired land parcels are small and will ideally have some highway frontage, a higher cost per acre will likely result.

4.2.1.2 Shelter

A permanent shelter will be required at each of the repeater sites to house the radio equipment and associated power supplies, batteries, etc. For planning purposes a 14- by 8-foot shelter was selected as being sufficient to house the necessary equipment (the actual building size will be somewhat vendor dependent, as similar equipment can have different space requirements). A fiberglass shelter, including basic internal electrical wiring, costs about $9,100 F.O.B. the vendor's factory. In some areas where vandalism may be a problem, these shelters can be constructed with a more durable skin that resists damage from small caliber bullets and buckshot. Although the equipment will generate some heat during operation, a small electrical strip heater may be needed in some locations. All shelters will require a small air conditioning unit and an exhaust fan to maintain the equipment temperatures at a reasonable level during the summer. The heating and cooling requirements will add less than $1,000 to the cost of the building. Thus, the total cost for the shelter should total about $10,000, with the only remaining shelter cost being transportation to the repeater site, as the shelter is simply offloaded from a truck onto a level site (some shelters may require a concrete pad). Electrical power and local phone service (if desired) are then connected, and the building is ready for equipment installation. Some shelter manufacturers offer a service in which they will install most of the radio equipment in the shelter before shipment, minimizing on-site time.

4.2.1.3 Site Preparation

Depending on terrain, the cost of site preparation can vary a great deal. In most situations where the land is fairly flat, has few trees, and where local power is easily obtained, site preparation will be relatively simple. Each site will require a soil test performed by a soil testing lab to determine soil characteristics that might affect tower installation. Some excavation and leveling work will also be needed for the tower and building foundation (depending on the building, all that may be required is a level spot). A dirt or gravel road will be required to link the site to the nearest public road. Finally, local utility service will need to be brought to the site. Soil testing will cost around $1,500 a site; a gravel road about $5,000. The foundation for a 200-foot guyed tower will cost $4,100. Getting local utility service to the site can vary in cost a great deal, from a simple installation fee to large aid to construction charges which can run in the thousands of dollars (fees accessed by a utility to provide service where distribution plant does not exist). For a site without special terrain or power problems, site preparation should total around $11,000.

4.2.1.4 Tower

For planning purposes, 200 feet was assumed to be the average tower height for any of the repeater sites. The actual height of the tower will be determined primarily by the path length and intervening terrain for each individual hop. The tower price will vary depending on a wide variety of factors, including the height of the tower, the number and size of the antennas on the tower, the number and length of the waveguide runs, and the maximum severe wind and ice conditions under which the tower is designed to operate.

There are two major classes of towers: self supporting and guyed. Self supporting towers are more expensive at this height, but they require very little land. Guyed towers, as a result, are preferred on economic grounds if relatively inexpensive land is available. EIA RS-222-C (Structural Standards for Steel Antenna Towers and Antenna Supporting Structures) defines wind loading zones for various regions of the U.S. The relevant areas of Texas are in Windloading Zones A and B, with the majority being in Zone A. Some areas along the gulf coast, where high winds can be encountered, are classified as Zone B, which means that a stronger tower would be required. Relevant Zone B areas to a State-owned microwave system include the greater Houston area and all Gulf Coast counties between Kingsville and Harlingen (Corpus Christi is in Zone A; however, for this study Wind Zone B towers were assumed).

For Windloading Zone A, a 200-foot tower which could withstand 86 mph winds with 1/2 inch of ice while remaining in service (the tower could survive up to 111 mph winds) would cost $27,400 installed (the tower foundation is included in site preparation cost). It would cost an additional $6,600 to install four runs of waveguide and the four antennas that would be mounted on a typical tower. Thus a 200-foot guyed tower would cost $34,000 installed. This price includes the required painting and lighting for the tower, as a 200-foot tower must have airplane lights (for more information on lighting requirements, see Part 17 of the FCC Rules and Regulations) A self supporting tower of similar height would cost at least $7,500 more than a guyed tower.

For Windloading Zone B a guyed tower would cost an additional $3,000 over the cost of a Zone A tower for the tower itself. Stronger foundations might also be required. A self supporting tower in Zone B would cost an additional $5,500 over the cost of a Zone A self supporting tower, with a stronger foundation costing an additional $2,000.

It is important to note that any tower for a repeater site should be capable of supporting more than four antennas if long term traffic growth projections indicate that additional antennas may be required at some later date. Re-engineering a tower to carry a higher than anticipated load can be expensive (and often not even practical).

4.2.1.5 Fencing

To protect the tower, shelter and associated components from vandals, fencing is usually installed around the tower base and shelter. Fencing or guard posts can also be placed around guy anchor points to prevent damage from mowers, farm equipment and large farm animals (which may rub against the guy wires). For a typical site, fencing should cost about $2,500 (not including guard posts or fencing around guy anchor points).

4.2.1.6 Radios (6 and 12 GHz)

Planning level costs were determined for digital microwave radios in two frequency bands of the Private Operational Fixed Microwave Service as defined in Part 94 of the Federal Communication Commission's rules and regulations. The Operational Fixed Service is designed for use by private companies, individuals, and State and local governments. As most of the users utilize fewer channels than a typical common carrier, the maximum allowable bandwidth on any one of the frequency bands assigned to this service is generally less than the comparable Common Carrier Band. For example, in the 6 GHz Common Carrier Band a microwave channel can have a maximum bandwidth of 30 MHz, while in the comparable Operational Fixed Service Band the maximum bandwidth is 10 MHz. As a result, radios in the Operational Fixed Service tend to be more expensive on a per channel basis, when compared to fully equipped radios for the Common

Carrier Band, as several radios are required to match the capacity of a single Common Carrier Band radio (there are also fewer radios being made for these bands when compared to the Common Carrier Bands).

The two bands occupy 6.525 to 6.875 and 12.2 to 12.7 GHz parts of the radio spectrum. The 6 GHz band has a maximum allowed channel bandwidth of 10 MHz while the 12 GHz band has a maximum allowable bandwidth of 20 MHz. Current digital radio equipment for these bands have maximum capacities of 384 and 672 voice channels respectively (26.7 Mb/s or 45 Mb/s). A few manufacturers are in the very early planning stages for a higher capacity radio in the 6 GHz band (around 576 voice channels). Whether such a higher capacity radio is built will depend on demand in the marketplace.

For a straight repeater the radios will cost approximately $97,750 for a set of radios in the 6 GHz band or $105,000 in the 12 GHz band (space diversity, 1:1 hot standby transmitters). If drop and insert functions are performed at the repeaters the cost rises to $123,750 plus $4,100 per four DS-1 lines for the 6 GHz radios, as the radios contain their own muldems. All currently available 12 GHz radios utilize separate muldems; as a result the cost remains the same for the radios themselves. If more than one channel is needed for the path in question, the cost for radios will rise in increments of the above amount. It should be noted that there is only one vendor that currently manufactures a digital radio for the 6 GHz band; however, at least one other vendor should have a similar radio available by the time the State goes out for bid.

4.2.1.7 Muldems

A muldem combines DS-1 signals into some higher data rate, such as DS-3. Current digital 6 GHz radios have these devices built into the radios themselves, while most, if not all, 12 GHz radios require a separate muldem to combine up to 28 DS-1 lines into the one DS-3 line needed by the radio. The cost of a muldem can vary somewhat, depending on the manufacturer and the degree of redundancy required for reliability. The price can range from below $25,000 to a high of over $30,000 for a fully equipped muldem (28 DS-1 lines). For planning purposes a cost of $14,000 for the muldem, plus $1,800 for each group of 4 DS-1 lines, was used (a fully equipped muldem would then cost $26,600).

For a repeater site two muldems will be required, one to bring the "incoming" signal down to the DS-1 level and one to return the signal to the DS-3 level for transmission onward. Thus the total cost will be $28,000 plus $3,600 per four DS-1 channels for which the path is equipped. If a small number of DS-1 channels are need to be dropped or inserted, there are special drop/insert multiplex units (called extraction multiplexers) that can drop and insert up to four DS-1 signals from DS-3 through traffic for a much lower cost. These devices can be purchased for less than $10,000 (only one is needed).

4.2.1.8 Channel Banks

In many of the intermediate drop and insert points, where access line traffic is brought onto the STS backbone network, the incoming lines from the various State agencies will not be digital (DS-1 rate or higher), at least in the near term. In these situations the incoming analog signals will need to be converted to a DS-1 bit stream by a channel bank. Channel banks will also be needed for much of the data traffic, to derive lower speed channels out of the DS-1 channels (1.544 Mbps). Channel banks will cost about $1,100 each, plus $100 per tie line or $150 per FX line. Installation will cost an additional $500. Thus a fully equipped channel bank for 24 voice channels would cost $4,000, if tie lines were connected. For data traffic the cost of the channel bank rises by $550, and each data port costs $550 per line up to 9.6 Kbps and $650 per line for 56 Kbps lines.

4.2.1.9 Transmission Line

To connect the radios to the appropriate antenna, some form of waveguide is typically used. In most situations the State is likely to encounter, elliptical waveguide would seem to be the preferred medium. Unlike circular or rectangular waveguides, which are rigid, elliptical waveguide is flexible and can tolerate gentle bends. It is also considerably lower in cost and easier to install. The elliptical waveguide itself costs about $10.50 a foot for the 6 GHz band or $8.50 a foot for the 12 GHz band

Two connectors costing about $150 each will be needed for every cable run, while other necessary hardware will run about $700. If a lower voltage standing wave ratio (VSWR) is needed, the cable will cost about $1 per foot more. For planning purposes the antennas were assumed to be placed at 195 and 185 feet. Adding an additional 20 feet to these runs to allow for connection to the radios in the shelter yielded 215 and 205 feet for the total waveguide run. The resulting costs are $3,250 and $3,150, respectively. Each repeater will also require a dehydrator to pressurize the waveguide with dry air. A dehydrator will cost about $2,000 including a pressurization monitor (which will trip an alarm upon a system malfunction) and the appropriate connection hardware. Thus, for a 6 GHz repeater site serving one radio channel, the transmission line cost totals $14,800.

4.2.1.10 Antennas

For planning purposes eight-foot antennas were utilized (the actual size antenna needed at each repeater site will depend on the engineering criteria for the path in question). For most locations standard dual polarized antennas with radomes will be used. The use of a dual polarized antenna, even when current needs require only one radio channel, allow for easy growth. In some situations where frequency congestion is a problem, a higher performance antenna may be required to provide added side and back lobe radiation suppression.

An eight-foot standard dual polarized antenna will cost about $2,300; the appropriate radome will cost $950; and the mount will cost about $500, yielding a total cost of $3,750. An eight-foot dual-polarized high performance antenna will cost $8,900, with a radome and antenna mount adding an additional $500, for a total of $9,400 per antenna for the 6 GHz band or $8,400 for the 12 GHz band. It will be assumed, for the purposes of this planning study, that repeater and terminal sites in major metropolitan areas, where frequency congestion could be a problem, will require high performance antennas (i.e., Austin, Dallas, Houston, San Antonio, Corpus Christi).

4.2.1.11 Power

Most of the equipment described above requires DC power at either 24 or 48 volts and is typically powered by a battery supply. The power requirements at 48 volts should total less than 50 amps for a typical repeater site. A 100-amp power board, two 50-amp power supplies, and a set of 400-ampere-hour batteries should be sufficient for the power needs of a typical site. The two 50-amp power supplies provide redundancy in case of a failure of one of the supplies. The batteries are sized such that the repeater's radios, muldems, channel banks, alarm and control system, and other vital components will remain powered for up to eight hours without benefit of local commercial power. The power system should include a low voltage disconnect feature that disconnects the load from the batteries when the voltage starts to fall (at the end of eight hours), preventing damage to the battery plant. After discussions with the State of Texas, it was determined that standby generators at each repeater site, to provide power after the batteries discharged, were not required. Instead, a manual power transfer switch and an appropriate power plug on the side of the repeater shelter could be used to allow attachment of a portable generator. Portable generators could then be stored at various locations throughout the State, possibly being located near the tandem switching sites or network maintenance facilities.

A 100-amp power board will cost about $2,400 including circuit breakers and alarm relays. The 50-amp power supplies will cost approximately $2,400. A 400-amp-hour 48-volt battery plant will cost $4,900 for the batteries and $350 for a seven-foot battery rack. Finally, the manual transfer switch will cost about $500. Thus the power system for each repeater will cost approximately $12,950.

A portable generator (that could be towed by a pickup truck) costs approximately $13,500 for a 12KW diesel generator, mounted on a trailer. This cost includes a fuel tank containing enough fuel for over 24 hours of continuous operation, a weatherproof housing for the generator, and standard instrumentation. The actual size of a portable generator will depend on the power requirements of the largest repeater site. For sites with up to two radios, a generator of about this size should be sufficient.

It should be noted that if local power is lost at a repeater site, any system at the site which cannot be powered by 48-volt batteries will be inoperative. The major items in this category include the tower airplane lights, the air conditioner and heater, interior and exterior lighting for the shelter, and anything else powered off the power company AC lines. Thus a provision for emergency lighting in the shelter may be appropriate, as well as a DC-driven ventilation fan. If a power failure occurs during the evening hours, the FAA must be notified within half an hour, as a power failure will result in a loss of tower lighting (for more details on this requirement see Part 17 of the Federal Communication Commission's rules and regulations). As the alarm and control circuitry would be powered by the batteries, the network control center should know if such a failure takes place.

4.2.1.12 Alarm and Control

An alarm and control system allows each repeater site to be monitored and controlled remotely. Typical alarm points might include all the failure alarms on each piece of equipment at the repeater site, as well as intrusion and fire alarms and equipment status alarms. These would include the status of the tower lights; designation of which transmitters were functioning in a hot standby mode; whether the channel banks were functioning; whether local power was available, etc. Control points might include turning the radios on and off, turning the tower lights on, selecting a single receiver manually (overriding the space diversity function), powering a fire extinguisher, etc.

A microprocessor- or very small minicomputer-based system, which utilizes CRT's and printers displaying plain language text at the network control center, is the preferred reporting system. This type of system typically will display status on all of the system's repeater sites on request and will classify alarm conditions into several categories, such as major, minor and critical. Each alarm condition will generally have a different treatment by the system, with the most critical outages receiving an audible alarm in the network control center.

A microprocessor-based system will cost about $1,600 for each repeater site and $25,000 for the network control center. This includes local alarm displays and alarm memory features for each repeater site. Alarm memory provides for the noting of intermittent alarm conditions which may be missed by the alarm system when the system is polled (the condition could occur when some other unit is being polled). The master or control unit located at the network control center includes three CRT's and a printer.

With these systems the provision of a dial-in port could be valuable. A maintenance technician, equipped with an inexpensive portable terminal, could then access the alarm and control system while s/he was troubleshooting at the site. Careful consideration will have to be given to the amount of command and control capability, if any, that will be allowed from this type of terminal.

4.2.1.13 Installation

Installation includes shipping of the equipment to the repeater site and the wiring and installation of that equipment. For planning purposes installation was estimated at 12% of all other repeater costs.

4.2.1.14 Repeater Cost -- 6 GHz

Using the above costs it is possible to estimate the cost of a 6 GHz repeater. For a one-channel repeater the cost is:

Table 4.10

6 GHz Repeater Site Cost (One Radio Channel)
(1982 Dollars)

Item	Cost
Land	$5,000
Site Preparation	$11,000
Shelter	$10,000
Tower	$34,000
Fencing	$2,500
Radios	$97,750
Transmission Line	$14,800
Antennas	$15,000
Power	$12,950
Alarm and Control	$1,600
Installation	$24,550

Totaling the above costs yields a total repeater cost of $229,150 per site. If drop and insert functions are added to the site the cost rises to $258,100 plus $4,600 for every four DS-1 lines used on the route, and $4,000 for each channel bank required for the dropped and inserted voice traffic, including installation.

If two radio channels are required (up to 768 voice channels or equivalent) the costs for components of the system are as follows:

Table 4.11

<u>6 GHz Repeater Site Costs (Two Radio Channels)</u>
(1982 Dollars)

Equipment	Cost	
Land	$5,000	
Site Preparation	$11,000	
Shelter	$11,000	(slightly larger building)
Tower	$38,900	(eight waveguide runs)
Fencing	$2,500	
Radios	$195,500	(four radios)
Transmission Line	$27,600	(eight waveguide runs)
Antennas	$15,000	(unchanged)
Power	$17,800	(800AH batteries, 2-100A power supplies, 200A power board)
Alarm and Control	$1,600	
Installation	$39,100	

Totaling the above costs yields a repeater cost of $365,000 per site. If drop and insert functions are added the cost rises to $422,900, plus $4,600 for every four DS-1 lines used on the route and $4,000 for each channel bank required, including installation.

4.2.1.15 Repeater Cost 12 GHz

If 12 GHz radio gear were substituted for the 6 GHz radios the cost of a through repeater site drops by $11,650 to $217,500. If drop and insert functions are performed the cost rises by another $31,400 for the muldems, bringing the total to $248,900, plus $2,000 for every four DS-1 lines dropped or inserted and $4,000 for each line that is passed through, including installation. If a small number of lines are inserted or dropped a $10,000 extraction multiplexer can be used instead of the muldems, yielding a total cost of $227,500.

It should be noted that the 12 GHz radio equipment provides for 672 channels instead of the 384 provided for the 6 GHz radio. The per-repeater cost is lower, because 12 GHz radio systems rarely utilize space diversity antennas, due to the short path lengths usually encountered in 12 GHz systems. Due to these short paths, 12 GHz systems are generally more expensive than 6 GHz systems in the circuit quantities needed by the State. It should also be noted that the current 12 GHz Industrial Band may be reassigned to the Direct Broadcast Satellite service; thus radios in this band should be tunable from 12.2 to 13.250 GHz. For this reason, the use of 12 GHz radios is not recommended unless 6 GHz frequencies are not available, which may be the case in some metropolitan areas.

4.2.2 Other Repeater Configurations

In addition to the costs just derived which apply to the majority of the repeater sites, several other configurations will be needed less frequently in a State microwave system.

In some situations, where near term growth in circuit demand will result in the addition of a radio channel in a few years, it is appropriate to install some of the necessary common equipment when the repeater is first installed. The power supply, building and tower should be sized to accommodate the demands placed on them by the addition of a radio channel. This avoids having to modify these aspects of the repeater (at a greater cost) when the additional radio is put in. For a one-radio channel through repeater the cost rises from $229,150 to $235,700. In some situations two radio channels will only be needed for part of a path. This situation can arise when drop and insert traffic (which is carried for only part of the path) is present on a route. In these situations some of the drop-and-insert repeaters will require three radio's, one serving the light density part of the path while the other two serve the higher denisty portion (the added traffic originating at the repeater). The cost of such a drop/insert repeater (prepared for eventual expansion to four radios) is $345,200

In some cases, due to frequency congestion, 12 GHz radios may have to be used in urban areas. In these cases, the first repeater outside of the city will usually contain 12 and 6 GHz radios, so that 6 GHz can be used for the remainder of the path. These repeater sites will cost approximately $349,900 if one 12 GHz radio and two 6 GHz radios are used, or $272,200 if only one 6 GHz radio is needed.

As mentioned previously, high performance antennas may be needed in some urban areas due to frequency congestion. In these areas the cost of a repeater will rise by $6,325 per 6 GHz antenna or $5,210 per 12 GHz antenna, including installation costs.

Finally, in those areas which experience high wind conditions, and thus are classified as Wind Zone B, an additional $3,350 per repeater is needed to cover the cost of a stronger tower, including supporting structures and installation.

4.2.3 Compucon Results

Compucon Inc., a Telecommunications Research and Consulting firm, which has expertise in the frequency engineering area, was subcontracted to perform a preliminary frequency analysis of some key aspects of a potential State-owned microwave system. The analysis consisted of a preliminary frequency engineering study of some of the tandem switch locations that could be served by a State microwave system and are located in areas where frequency congestion is known to be a problem (Austin, Dallas, Houston, San Antonio). This analysis was performed by constructing hypothetical paths to the chosen locations, assuming typical equipment parameters for the industrial bands. The analysis also examined the probable number of hops that would be necessary for each of the four paths. This analysis assumed that the typical hop would be between 15 and 25 miles for the 6 GHz band. A preliminary examination of terrain availability was also utilized to determine the number of hops. These estimates have an expected variance of plus or minus two hops for each of the four paths. This is due to terrain variations which may appear when doing more detailed final site selection, and to avoid high-low frequency violations (see Part 94 FCC rules and regulations). The subsections which follow describe the results of this analysis.

4.2.3.1 Austin-Abilene-Lubbock Path

For this path, the only city that was examined for the availability of frequencies was Austin. The analysis revealed that one paired frequency is available in the 6 GHz band (in the Abilene-Lubbock direction) as well as some unpaired frequencies. The path will require approximately nine hops from Austin to Brownwood (a potential drop/insert point), three hops from Brownwood to Abilene, and seven hops from Abilene to Lubbock, for a total of 19 hops. The use of Abilene and Brownwood as potential drop points does not add to the number of hops between Austin and Lubbock.

4.2.3.2 Austin-Dallas Path

For this path, two cities were examined for the availability of frequencies (Austin and Dallas). The analysis revealed that at least two paired frequencies are available in the 6 GHz band from the site in Dallas. Frequencies out of Austin towards Dallas are a problem, however. No paired frequencies were available (although some unpaired frequencies were available). It may be possible to clear some additional frequencies when a more detailed analysis is performed. An alternative would be to utilize the 12 GHz band. The path will require approximately four hops from Austin to Temple (a potential drop/insert point), two hops from Temple to Waco and five hops from Waco to

Dallas for a total of 11 hops. The use of Temple and Waco as potential drop/insert points does not add to the number of hops between Austin and Dallas. Belton could be substituted for Temple with no effect on the number of hops.

4.2.3.3 Austin-Harlingen Path

For this path, two cities were examined for the availability of frequencies (Austin and San Antonio). Frequencies out of Austin towards San Antonio are a problem. As with the Austin-Dallas path, no paired frequencies were available (although some unpaired frequencies were available). Again, it may be possible to clear some additional frequencies when a more detailed analysis is performed. As with the Austin to Dallas path, an alternative would be to utilize the 12 GHz band. From San Antonio towards Austin one pair of frequencies was found to be available, while in the Harlingen direction two paired frequencies were available (horizontal polarization only).

The path will require approximately five hops from Austin to San Antonio, eight hops from San Antonio to Corpus Christi, one hop from Corpus Christi to Kingsville, and five hops from Kingsville to Harlingen, for a total of 19 hops. The use of Kingsville as a drop/insert point will not affect the number of hops in the system.

4.2.3.4 Austin-Houston Path

For this path, two cities were also examined for the availability of frequencies (Austin and Houston). The analysis revealed that two paired frequencies are available in the 6 GHz band from the Austin site in the Houston direction. Frequencies out of Houston towards Austin are a problem. No available frequencies were found in the 6 GHz band. The use of high performance horn antennas may make the use of 6 GHz possible. This can only be determined when a more detailed analysis is performed. The likely solution would be to utilize the 12 GHz band for the first hop out of Houston.

The path will require approximately six hops from Austin to Bryan and five hops from Bryan to Houston for a total of 11 hops. If Bryan is eliminated as a drop/insert point the number of hops declines to nine. This assumes that 12 GHz is used for the first hop out of Houston and that one 12 GHz repeater will be needed before the path can utilize 6 GHz.

4.2.4 Terminal Costs

The costs for equipment at an end terminal site are quite similar to those for a repeater. To avoid potentially harmful interactions between the radio and tandem switching gear through a common power supply, BNR recommends that the 48-volt power supplies for the radio equipment be kept separate from the tandem switching equipment supply, unless a power engineer who is very familiar with the specific switching and radio equipment purchased by the State designs a common system. The calculations which follow assume a separate power system is installed for the radio equipment, although they may share an emergency generator. It is also important that the tandem switches selected be able to function in an RF environment. The terminal sites fall into three categories: the Austin terminal, which involves four microwave paths converging on a single point; the Lubbock, Dallas and Harlingen terminals, which involve a single 6 GHz path; and the Houston terminal, which involves a 12 GHz path due to frequency congestion. The calculations which follow assume that the tandem switch selected by the State will be digital and that it will have the capability of direct interface to the muldems at the DS-1 level. For dedicated data lines, modems and channel banks will most likely be needed, at least in the near term, to interface the analog public network facilities with the digital transmission system. The calculations also assume that a suitable building and land are available at each site (for no additional cost to the State).

4.2.4.1 Austin Terminal

The Austin terminal, as mentioned above, potentially could involve the use of two frequency bands. For the purposes of this analysis the worst case will be assumed; thus, for two of the paths (Austin-San Antonio and Austin-Dallas), the use of 12 GHz equipment (without space diversity) is assumed for the first hop. Equipment pricing for this location is as follows:

Table 4.12

Austin Terminal Radio Costs
(1982 Dollars)

Equipment	Cost	Comments
Land	$0	(located on existing State land)
Site Preparation	$6,000	(gravel road unnecessary)
Shelter	$0	(use existing building)
Tower	$40,300	(Six waveguide runs, six antennas)
Fencing	$1,600	(just around base of tower)
Radios (6 GHz)	$123,600	(two radios)
Radios (12 GHz)	$104,000	(two radios)
Muldems (12 GHz)	$28,000	(two muldems)
Transmission Line	$20,450	(six waveguide runs)
Antennas	$54,400	(six high performance dual polarized)
Power	$17,800	(340 AH battery, 2-100A power supplies, 200A power board)
Alarm and Control	$1,600	
Installation	$47,750	

Totaling the above items yields a terminal cost of $445,500, plus $4,600 per four DS-1 6 GHz radio channels, or $2,000 per four DS-1 12 GHz radio channels, installed.

4.2.4.2 Dallas Terminal

This terminal will need two 6 GHz radios to accommodate initial circuit demand. Budgetary pricing for this terminal is as follows:

Table 4.13

Dallas Terminal Radio Costs
(1982 Dollars)

Equipment	Cost	Comments
Land	$0	(located on existing State land)
Site Preparation	$6,000	(gravel road unnecessary)
Shelter	$0	(use existing building)
Tower	$33,300	(four waveguide runs, two antennas)
Fencing	$1,600	(just around base of tower)
Radios (6 GHz)	$123,600	(two radios)
Transmission Line	$14,800	(four Waveguide runs)
Antennas	$18,800	(two high performance dual polarized)
Power	$12,950	(400 AH battery, 2-50A power supplies, 100A power board)
Alarm and Control	$1,600	
Installation	$25,500	
Total	$238,150	

4.2.4.3 Lubbock, Harlingen Terminals

These terminals require a single 6 Ghz radio to accommodate initial circuit demand. The capital cost for these terminals is a follows:

Table 4.14

Lubbock, Harlingen Terminal Radio Costs
(1982 Dollars)

Equipment	Cost	Comments
Land	$0	(located on existing State land)
Site Preparation	$6,000	(gravel road unnecessary)
Shelter	$0	(use existing building)
Tower	$30,700	(two waveguide runs, two antennas)
Fencing	$1,600	(just around base of tower)
Radio (6 GHz)	$61,800	(one radio)
Transmission Line	$8,400	(two waveguide runs)
Antennas	$7,500	(two, dual polarized)
Power	$12,950	(400 AH battery, 2-50A power supplies, 100A power board)
Alarm and Control	$1,600	
Installation	$15,650	

Totaling the above items yields a cost of $146,200 for the Lubbock terminal. The cost of the Harlingen terminal is $3,350 higher (including installation) for a total of $149,550. This is due to the need for a stronger tower in wind zone B areas.

4.2.4.4 Houston Terminal

Due to the unavailability of 6 GHz frequencies, 12 GHz will have to be used. The cost for a 12 GHz single channel terminal are as follows (one radio channel can carry 672 voice channels or equivalent):

Table 4.15

Houston Terminal Radio Costs
(1982 Dollars)

Equipment	Cost	Comments
Land	$0	(located on existing State land)
Site Preparation	$6,000	(gravel road unnecessary)
Shelter	$0	(use existing building)
Tower	$32,050	(one waveguide run, one antenna, wind zone B)
Fencing	$1,600	(just around base of tower)
Radio (12 GHz)	$52,000	(one radio)
Muldem	$14,000	(one muldem)
Transmission Line	$4,800	(one waveguide run)
Antenna	$8,400	(one high performance dual polarized)
Power	$12,950	(400 AH battery, 2-100A power supplies, 200A power board)
Alarm and Control	$1,600	
Installation	$16,000	

Totaling the above costs yields a total capital cost of $149,400.

4.2.5 Total First Cost by Path

The following sections will develop the total first cost for the proposed microwave system by path, as well as a first-order economic evaluation of these facilities compared against leased private line facilities (using the private line tariff) between the same locations.

This pathwise comparison of leased facilities against owned microwave radio is not an entirely accurate one. Some leased IMT costs (e.g., Houston-Abilene) are considered, in this comparison, to be comprised of leased segments in both the

Houston-Austin and Austin-Abilene paths, while in reality the leased line costs would be determined by the direct airline distance between Houston and Abilene. Thus these figures will tend to overstate any cost advantage of owned over leased facilities for the entire system. Unfortunately it is not a simple matter to correct for this problem on a route-by-route basis. As a result, following the path-by-path analysis of first costs, a comparison is made between the total system cost and leased facilities taking this overstatement of leased costs into account.

To arrive at a per path cost allocation for the Austin Terminal, the total cost of the terminal was simply divided by the number of paths (four) leaving Austin. One should note that if any of the paths were eliminated, the cost for the other paths would rise, as some of the common costs would not change if one or more of the radios and associated equipment were eliminated. As was mentioned in Section 4.2.1.10, the use of high performance antennas has been assumed for repeater or terminal sites located in Austin, Corpus Christi, Dallas, Houston, and San Antonio due to frequency congestion in these areas. Finally the per path costs for any year are based on the following year's circuit requirements. Thus the initial system will accommodate 1986 circuit requirements, while the additional capital expenditure in 1986 will accommodate 1987 circuit demand and so forth.

4.2.5.1 Austin-Abilene-Lubbock Path

This path, which comprises 19 hops of 6 GHz radio, will cost approximately $4,596,500. The path will require 16 through repeaters, two drop/insert repeaters (in Brownwood and Abilene) and two terminals (Austin and Lubbock), all utilizing the 6 GHz band. Over the planning period (1984 to 1988), one radio channel (384 voice channels) will be sufficient to accommodate anticipated circuit demand. The $4,596,500 figure consists of $4,440,200 for radio equipment, $92,000 for DS-1 interface cards and $64,300 for channel banks. The channel banks would be used to provide 56 Kbps channels for the data network and to provide A/D conversion for the access line traffic from Brownwood. It was assumed that all access line traffic would need a channel bank and that all channel banks were purchased fully equipped for voice traffic. Thus, all 24 line cards would be purchased when the channel bank is originally purchased. For data line cards it was assumed that the line cards would be purchased as needed, due to their higher cost. Additions were assumed to cover the next year's circuit demand; thus additions in 1986 would cover 1987 circuit demand and so on. Year-by-year capital costs for this path are as follows:

Table 4.16

Austin-Lubbock Path Costs
(1982 Dollars)

Year	Total Cost
Initial Construction	$4,596,500
1986	$7,000
1987	$8,000
1988	$20,200

If leased circuits were used instead of a State microwave system, the yearly cost would be $1,211,300 in 1985, using the 1982 private line tariff. The initial capital cost would be paid back in in under four years, assuming no growth. This also does not consider the lease cost for data circuits that would be carried on the microwave system, the operational costs of the system or the time value of money. If a simple comparison takeing the time value of money into acccount is performed, the system pays back in just under four years. This analysis assumes a cost of money of 12% and inflation rates of eight percent for the radio equipment and nine percent for the leased circuits. It assumes that the capitol expenditure for the radio occurs in 1985 and is not complete until the beginning of 1986. Thus the lease circuit costs will be avoided starting in 1986. If this inflated stream of payments is discounted back to the year of installation of the microwave, 1985, it results in a total discounted cash flow of $5,859,500, for the first four years of operation. This compares with an (inflated) initial capitol cost of $5,790,200. As with the other analysis this analysis does not consider growth, operational costs (which are quite small in relation to the capitol costs), or the cost savings from data circuits. However, it does illustrate that substantial savings could result if this microwave path were built by the State. With growth and data circuits considered, radio costs are paid back more quickly.

4.2.5.2 Austin-Dallas Path

The Austin-Dallas path will require 11 hops of 6 and 12 GHz radio for a total cost of $4,025,700. The $4,025,700 consists of $3,815,500 for the radio repeaters and terminals, $158,000 for DS-1 interface cards, and $52,200 for channel bank equipment.

In order to accommodate circuit demand this path will need two 6 GHz radios for much of its length. Initially a single radio channel will be needed on the Temple-to-Waco section of the path. In 1987 this section of the path will need an additional radio channel to accommodate circuit growth expected in 1988. The other sections of the path will need two radio channels in order to accommodate initial circuit demand. Because of frequency congestion, it is assumed that the first hop out of Austin will utilize 12 GHz radio.

As a result, this path will need six 6 GHz through repeaters equipped for two radio channels. The path will also need two drop-and-insert repeaters at Temple and Waco. These repeaters will initially need two channels in one direction and one in the other until 1987 when an additional radio will be need to accommodate additional circuit demand between Dallas and Austin. This path will also require a single radio channel repeater (which will need an additional channel in 1987), a one-channel 12 GHz-to-two-channel 6 GHz repeater and two terminals (Austin and Dallas). Year-by-year capital costs for this path are as follows:

Table 4.17

Austin-Dallas Path Costs
(1982 Dollars)

Year	Total Cost
Initial Construction	$4,025,700
1986	$1,000
1987	$299,900
1988	$24,400

For this same time period, leased facilities from a common carrier for these circuits would cost $1,495,000 in 1985, without considering the cost of leasing data circuits. In this case the savings will equal the initial capital investment in under three years. This calculation does not take into account the operational costs of the system, the time value of money or the added lease cost savings from the data circuits carried by the microwave system.

4.2.5.3 Austin-Harlingen Path

This 19-hop path will require two radios for the Austin-to-San Antonio section of the path and one radio channel for the remainder of the path. The first hop of the path will most likely be at 12 GHz, as the 6 GHz band appears to be congested at Austin in the San Antonio direction. The path between Corpus Christi and Harlingen will require Wind Zone B towers to meet the windy conditions encountered in this area of the

State.

This path requires three 6 GHz through repeaters equipped for two radio channels, a 12-to-6 GHz repeater (as 6 GHz frequencies may be a problem out of Austin in this direction), 11 one-channel 6 GHz through repeaters (four of which should have Wind Zone B towers), two single channel drop-and-insert repeaters (also having Zone B towers), one drop-and-insert repeater equipped for one radio channel in one direction and two in the other, and the two terminals. Of the total $5,439,800 cost of the system, $5,158,600 is for the repeaters and terminals, $158,000 is for the DS-1 interfaces, and $123,200 is for the channel banks. Year-by-year capital costs for this path are as follows:

Table 4.18

Austin-Harlingen Path Costs
(1982 Dollars)

Year	Total Cost
Initial Construction	$5,439,800
1986	$11,000
1987	$21,000
1988	$28,200

If leased facilities were used instead of microwave, the lease cost would be $1,397,000 in 1985, without considering the cost of leasing data circuits. Thus, in a similar manner to the previous calculations, savings due to ownership equal the initial capital investment in under four years.

It should be noted that a secondary tandem in San Antonio may be attractive to switch voice traffic onto the State microwave system, just from the San Antonio metropolitan area. The attractiveness of this will depend on the nature of the potential additional traffic sources in the San Antonio metropolitan area. If the second radio channel can be eliminated, the capital cost of the radio repeaters and terminals could be reduced by $1,259,800. If the number of repeaters needed for the Austin-to-San Antonio path turns out to be less than originally estimated after a full path survey is performed (a distinct possibility, as Compucon utilized conservative assumptions), the cost of a second radio channel would be reduced accordingly. For example, if two fewer repeaters were needed, the cost difference would be reduced to $988,100. A discussion of the issues involved with inefficient access line groups is presented below in Section 4.3.2, "Access Line Efficiency".

4.2.5.4 Austin-Houston Path

This path consists of 11 hops, for a total initial capital cost of $3,535,700. The $3,535,700 consists of $3,398,800 for the terminals and repeaters, $98,800 for the DS-1 interfaces and $38,100 for the channel banks. This path will require the use of 12 GHz radio in the Houston metropolitan area due to frequency congestion. Also the Houston terminal and two of the repeater sites will have to utilize Wind Zone B towers, most likely. The path will need five two-radio-channel through repeaters, two one-radio-channel through repeaters (prepared for eventual expansion to two channels), one 12 GHz repeater and one one-radio-channel 12-to-6 GHz repeater (again the 6 GHz section should be prepared for eventual expansion to two channels). The path will also require one drop/insert repeater at Bryan/College Station equipped for two radio channels in the Austin direction and one in the Houston direction (but with common equipment sized for two channels) as well as the two terminals (Austin and Houston). Year-by-year capital costs for this path are as follows:

Table 4.19

Austin-Houston Path Costs
(1982 Dollars)

Year	Total Cost
Initial Construction	$3,535,700
1986	$14,200
1987	$1,000
1988	$2,000

In a similar manner to the previous path capital cost derivations, if leased circuits were substituted for this path the total lease cost would be $1,297,000 in 1985, without considering data circuits. Thus, savings in lease costs would equal the initial capital cost in under three years.

4.2.6 Total System Cost

The sum of the above costs yields an initial capital investment of $17,597,700 for the microwave system. There are two additional common costs which should be added to this total.

First, a detailed path survey and related activities must be performed. This consists of a detailed analysis of the available frequencies and terrain to determine the actual physical locations of repeaters. Once the desired locations are determined, the State must negotiate for the land. Once these two steps are complete, the final specifications for the RFQ can be completed and sent out to potential bidders. After the radio vendor is selected, the necessary FCC forms must be completed and sent to the FCC to obtain a construction permit, allowing the system to be built. To perform these tasks the State will require the assistance of a telecommunications engineering firm which specializes in microwave path studies and FCC microwave applications. For a network the size of the State of Texas, this should cost around $141,000 for the path survey, help in preparing the RFQ, and help in preparing the FCC license application.

Second, once the contract is awarded to the vendor or vendors, the State will require assistance in overseeing the installation of the network. It would be preferable to have an outside consultant assist the State in overseeing the vendor's installation of the system. This project management assistance for the digital microwave system would run about $125,000. Ideally the firm providing project management services for the microwave system would also provide similar services for the tandem switch and network management installation.

If these two costs are added to the capital costs, the new total first cost for the 60-hop digital microwave transmission system is $17,863,700. The total year-by-year capital costs are as follows:

Table 4.20

Total STS Microwave System Costs
(1982 Dollars)

Year	Total Cost
Initial Construction	$17,863,700
1986	$33,200
1987	$329,900
1988	$74,800

If leased facilities were used instead of this transmission system the annual charge would be $2,255,400 for 1982 circuit requirements, and $2,851,000 for 1985 circuit requirements. If the circuit requirements did not increase after 1985, the savings in leased circuit costs would equal the initial capital investment in just over six years, without considering the cost of leased data circuits or access lines, that would be carried by the system. If the lease cost savings in access line facilities is taken into account, the savings will equal the capital cost in just over three and one half years, using the 1985 savings of $2,029,000. Thus it is clear that an owned microwave system is an attractive transmission system for the State.

4.2.7 Service Lives of Equipment

A good measure of the expected life of a piece of telecommunications equipment is its expected life for regulatory purposes, since (at least in theory) the life for regulatory purposes should match the actual service life of the equipment. After consulting the Texas Public Utility Commission and the Federal Communications Commission as to recent expected equipment lives for regulatory purposes, it was determined that the regulatory lives of microwave equipment currently range from about 14 years to over 18 years, depending on the common carrier and jurisdiction. As a result, a life of 15 years was selected as being a reasonable life expectancy for this equipment.

4.2.8 Future Growth

If the expected growth rates continue beyond 1989, several of the paths will require additional radio channels in the 1990's. In approximately 1990 a second radio channel may be needed between Bryan/College Station and Houston. In 1989 or 1990 a second radio channel may be needed between Kingsville and Harlingen. This would be caused primarily by growth in circuit demand between Corpus Christi and Harlingen. The need for an additional radio channel could be eliminated or delayed by several techniques. If a secondary tandem were placed in Corpus Christi the greater trunking efficiency would eliminate the need for the additional channel. Another technique would be to rehome some of the access lines from agencies in Corpus Christi to Austin, utilizing the spare transmission capacity on the Corpus Christi-to-Austin section of the route. If the agencies which have a high community of interest with Austin were treated in this manner the need for an additional radio channel would also be eliminated. Finally, a second radio may be needed in the Brownwood-to-Abilene section of the Austin-to-Lubbock path in 1990 or 1991.

4.2.9 Sensitivity to Growth

As mentioned at the outset of this chapter, one of the major advantages of a microwave system is its fine modular growth. As a result, major changes in voice channel demand can be accommodated by the addition of a radio channel over the route in question. If the growth in demand for voice channels is less than anticipated in the current growth forecast, the addition of a radio channel can be delayed, freeing the State's capital for other uses. As long as the repeater sites and towers can accommodate additional equipment, growth can be accommodated gracefully without a costly reworking of the transmission system.

A major difference in the demand for data circuits is of much less concern, as the backbone facility will be digital. On the route with the largest data bandwidth requirement (Austin-Dallas), the total 1989 data requirements are equivalent to less than 30 voice channels (although for convenience two DS-1 facilities would be used). On this same route voice circuit growth alone will equal this bandwidth requirement in a year and a half. An error of 100% in 1989 data bandwidth requirements would only require the addition of one DS-1 facility on this route. Thus, it can be seen that a large change in the required bandwidth for data will not have a major impact on the radio system.

A future demand for broadcast quality video would have a major effect on bandwidth requirements. The transmission system cannot easily accommodate this type of video signal. Compressed full motion video requiring one or a few DS-1 channels could easily be accommodated by this system, however. There are several products currently on the market or planned during the next two years that provide compressed full motion video, for teleconferencing, using a single DS-1 channel.

In order to provide for broadcast quality video, a separate 12 GHz radio would be required, as the bandwidth available in the 6 GHz band of the Operational Fixed Service is insufficient to handle this type of video signal.

A digitally encoded video signal would require 45 Mbps of bandwidth, the entire capacity of current 12 GHz digital radios in the Operational Fixed Service. As a result, separate 12 GHz radios would be required for the video signal. Even if analog radios were used, only one video channel could be accommodated per radio.

Analog radios (which are currently less expensive than digital radios in this application) would cost $26,000 per repeater for duplex (two way) operation or $13,000 for simplex operation. This assumes hot standby or other equipment failure protection features are not used. If these items are added the system cost would be greater. These radios could share the microwave system's power supply and tower, but would require a separate antenna in most cases. The power supply, tower, shelter and other repeater site equipment would have to be sized to handle the additional load of the radio.

It is also important to note that additional repeaters would be required for the microwave system, as the maximum permissible path length is lower for 12 GHz systems (generally under 15 miles). This can be accomplished either by adding additional repeaters when needed just for the video part of the system, or reducing the maximum permissible hop length for the entire system. Which one of these two alternatives is preferable can only be determined by a detailed path survey, when the actual path lengths for the 6 GHz system become known as well as the time frame when demand for this type of video service would arise (if ever). In either case, this will add considerably to the system cost.

As a result it appears that other alternatives, such as satellite transmission or fiber optics, will be preferable to the use of terrestrial microwave for this application, if it ever arises on a wide scale.

If demand for this type of transmission is small and/or from a single agency or organization owning the transmission facilities does not seem to be justified, unless a single agency were willing to underwrite the addition of broadband facilities to the network for eventual use by several agencies. In the near term, leased facilities would seem to be the prefered solution. Many vendors can supply time on a satellite transponder on an "as needed" basis, if adequate advance notice is given. If the demand is sporadic, portable earth stations can be leased when required, instead of purchasing the necessary earth stations. An alternative would be to lease time on an existing earth station. For example, some PBS stations have begun to offer time on their earth station facilities for teleconference applications. In this case, studio facilities have also been provided. Thus for less than full time usage, there are several attractive satellite based leasing alternatives.

4.2.10 Additional Paths

As was demonstrated in the sections above, substantial cost savings can accrue to the State if large groups of access line traffic are carried by a State-owned transmission system. As a result, the State may want to examine the use of spur microwave routes to pick up some large concentrations of access line traffic. Some areas which merit further investigation include Fort Worth, Galveston and several other large communities that are within several microwave hops of the backbone microwave network. Short microwave paths to pick up this additional traffic may prove to be economically attractive to the State, as well as State-owned transmission systems within a metropolitan area to avoid local loop charges.

4.3 Other Considerations

4.3.1 Voice Compression

Time Assignment Speech Interpolation (TASI) was first used on transoceanic cables as a means of increasing the number of voice conversations carried by an undersea cable. This was accomplished by assigning a transmission facility to a call only when speech was present, as the average voice use of a typical line circuit is no more than 40%. In the past several years TASI systems have been available for use on private networks. Typical systems can compress as few as nine trunks onto six facilities. If larger trunk groups are used, efficiencies of better than 2:1 can be achieved. A typical system that might be used by the State of Texas would provide 48 trunks over 24 facilities.

The use of these systems can result in dramatic cost savings. A system which can accommodate 48 trunks over 24 facilities would cost $47,000 for the basic hardware plus $900 per port (there are 72 ports at each end -- 48 for the trunks and 24 for the facilities). This results in a total system cost of $176,600. A maintenance contract for this system would cost about $500 per month. Using current Southwestern Bell private line tariffs this system would save over $10,000 a month on a 300 mile circuit, including the $500 per month maintenance charge. Thus this system would pay back in under a year and a half (without considering the time value of money). On shorter routes the payback is equally impressive.

TASI systems could be attractive to the State before the implementation of the new network. For example, if this system were used for the current El Paso-to-Abilene circuits, 15 facilities would be required to provide for the 30 trunks (both access lines and ONAL's). This system would cost $39,000 for the common equipment and $81,000 for the 90 ports, yielding a total of $120,000 for the system, installed. The airline distance between El Paso and Abilene is 399 miles, using the AB tariff yields a cost per circuit of $787.60, ignoring termination charges. This yields a total cost of $11,814 for the 15 circuits eliminated by the TASI system. Total termination charges for the TASI system will be somewhat higher than those for the existing facilities, and there will be some additional charges for local private line facilities to connect the Access Lines and ONALS to the TASI hardware. These charges consist of the additional set of terminations at each end to connect to the TASI system. The current charge would be replaced by 30 short private lines from the individual PBX, key system or FX facility to the TASI system; 15 facilities between the El Paso end of the TASI system and Abilene; and 30 private lines between the Abilene end of the TASI system and the Abilene switch. As long as these charges do not exceed $1,314 per month and the TASI system maintenance cost is $500 per month, the equipment will pay back in 12 months. Thus the economics of these systems can be very attractive to the State.

The cost savings in facilities is not without its price. The user will experience a condition known as freeze-out (speech loss) during heavy load conditions. When the system is heavily loaded, a facility may not be available every time that speech is present on a particular trunk. In this case the beginning of words may be clipped as the system attempts (and fails) to immediately find a facility. This problem can be lessened by the use of digital speech storage (the cost model above included this feature). These systems utilize RAM storage to momentarily store speech bursts until a facility becomes available. This still results in some impairment (delay) of the speech signal but generally is not as objectionable as a freeze-out condition.

Data calls can present a serious problem for this type of system. In fact some systems may not be designed to handle a data call at all. If the TASI system can accommodate a data call, a facility must be assigned for the duration of the call. The dedication of a facility for a data call reduces the pool of facilities available for the other trunks, resulting in a degradation in the transmission quality of the voice calls. Thus, these systems do not function well if a high percentage of the calls over the system are dial-up data. One typical system is capable of accommodating up to ten percent data calling, with some loss in efficiency. The number of facilities required to carry 48 trunks rises from 22 to 24 when ten percent of the calls are dial-up data.

A recommended approach to voice compression equipment is to try it on a limited scale first, as a means of reducing costs on routes where owned transmission facilities are not economic and the distances are great (such as El Paso).

Another use would be to delay the addition of microwave radio channels on existing transmission facilities. Thus the traffic over the Dallas-to-Austin route could be accommodated over a single radio channel if TASI were used. Eventually the traffic level would be high enough that it would be less expensive to add the radio channel, instead of using the TASI system. The basic decision that must be made is whether the added complexity and potential degradation of transmission quality are acceptable, to gain the cost savings.

4.3.2 Access Line Efficiency

Currently the STS network has many small access line groups. These groups connect smaller State offices to the STS network. Unfortunately, these access lines are not as efficient as larger access line groups. For example at a P.02 grade of service, two access lines can accommodate 8.06 CCS of traffic or 4.03 CCS per line in the busy hour (using Erlang-B tables). At the same grade of service, a ten-line group could accommodate 183.02 CCS or 18.3 CCS per line in the group. Put another way, five two-circuit access line groups can accommodate 40.3 CCS of traffic while a similar number of circuits in a single group can accommodate 183 CCS of traffic; over four and one half times as much traffic.

As a real world example, San Antonio currently requires 171 access and FX (ONAL) lines to provide a P.02 grade of service during the busy hour. If all the agencies could be served by a single trunk group 77 lines would be needed. In like manner Kingsville would require 22 access and FX lines to provide P.02 service, but if a single trunk group could be used the total lines required would drop to 18. As Kingsville has only two trunk groups (one access line group and one FX group) which are relatively large, the difference is not as dramatic as with San Antonio.

These calculations are based on STS report 133-B and 133-C for March 1982. The circuit requirements were derived using the average busy hour traffic in CCS for the agency in question and the Erlang-B blocking formula. No attempt was made to correct the busy hour traffic figure to offered traffic; if such a correction were made the circuit differences would be even more dramatic.

4.3.2.1 Secondary Tandems

There are several methods to eliminate some of the inefficiencies of small trunk groups. In some situations the addition of a secondary tandem serves the function of gathering traffic from a region and placing it on a large, "efficient" trunk group as well as providing for intra-region communications. This is what would occur at the Harlingen secondary tandem.

A simpler method is to dispense with intra-region communications and have the tandem just serve as a concentrator. In this situation a PBX in a city or region might have the nearby PBX's homed on it, and they would jointly share a common trunk group from the PBX to the nearest tandem. This is similar to what presently occurs in El Paso for STS network access.

These techniques are not without their costs, however. Unless a suitable PBX already exists which can be used as a concentration point, a separate and expensive tandem switch will be needed (this would make it economically unfeasible in many cases). An existing PBX would require additional hardware in the form of trunk (or tie line) cards to handle the additional terminations. The switch might require a modification of its software to provide this networking function. Finally, the ultimate capacity of the switch will be lower for its original function as the switch capacity is utilized for these other functions. This would accelerate the expansion of the switch's common equipment and may also accelerate the replacement of the switch as it's ultimate capacity is reached.

Besides the economic cost of these methods, the transmission quality of a telephone call on the system will suffer somewhat, as another switch is involved. If the switch is digital and interfaces with digital transmission facilities directly (digitally) this problem is not very significant. If the switch is digital and must interface with analog facilities, some signal degradation will occur as A/D and D/A conversions are added.

4.3.2.2 OCC-Like Access

Another alternative is to mimic the access method utilized by the so-called Other Common Carriers (OCCs). In this method a group of FX lines would serve the small users. These users would dial the local number of the FX, outpulse a five- or six-digit identification code, and finally the number they desired to reach. The tandem would contain the necessary hardware and software to process this information, to allow for authorization and billback of these calls. As with an OCC, the user would be forced to dial 22 or 23 digits for an off-net call. This method could bring the advantages of the previous two methods without the added hardware costs.

This plan could be implemented in several ways. The simplest and most efficient plan (from a trunking perspective) would be to eliminate all dedicated access lines for those cities where this type of connection was provided. In this case, the FX group that would be used to serve off-net locations in the community would be combined with the circuits required to provide service to the State offices. These would then be two-way trunk groups. All callers would then have to use the public network to access the STS FX lines. If the user was served by a PBX which could dial the extra digits automatically, the user would notice no difference in his or her dialing procedure. All other users would be "forced" to dial the extra digits (Auto Dialers or a speed call function on a PBX would make this easier on the user). PBX's and key systems which did not have DTMF signaling (Touch Tone) would have to convert to DTMF service or purchase auto dialers or key pads to provide the necessary signaling to the STS network (at present a central office will not pass rotary dialed information of this type to a PBX trunk).

Transmission quality would also suffer somewhat, as the transit through the local central office at one or both ends would degrade the quality somewhat. This could be compensated for, to some degree, by maintaining a high transmission quality on the network itself. If this type of arrangement were implemented the initial design and preventive maintenance (especially transmission testing) become even more important. Thus, there are two potential user acceptance problems: dialing additional digits and lower transmission quality.

This type of system also imposes some additional administrative costs. The identification numbers will have to be assigned and changed periodically (to prevent abuse). The billing back may also be a bit more difficult, as an agency may decide to utilize multiple authorization codes to assist the agency in its own internal accounting for telecommunications costs.

One way of lessening the impact of these problems, while still capturing some of the potential economies, would be to provide some dedicated access lines to large users whose access line groups are of sufficient size to be reasonably efficient. An alternative would be to allow agencies to have dedicated access lines for an additional fee. Thus those agencies who had small, inefficient trunk groups could have a dedicated access line if they wanted to pay for it. This could be especially important for agencies who provide emergency services, such as the Department of Public Safety and the Highway Department, as a central office can be "tied up" during an emergency situation (as the general public attempts to make more phone calls than the central office was designed to accommodate). In these situations a dedicated access line would provide access to the network. For larger users the added cost would be offset, to some degree, by eliminating the added local access lines that would be required to allow access to the FX lines (as well as avoiding message unit charges if they become part of the local exchange tariff). Ideally, the charge would be such that the "optimum" solution, as far as the State as a whole is concerned, would occur.

This method of access would have several side benefits. By allowing access onto the network without requiring dedicated access lines, small State offices which, on their own, could not justify an access line, could be provided service. The combination of traffic from several small State offices in a small community might make it economic to provide an access facility. By having this system in place, off- to on-net access would be greatly simplified, as a State employee could access the network from a non-State location in an identical manner to that used by the employee at a State office. As the system would be automated, the need for an operator to manually record the call data necessary for billing would be eliminated. This type of system could be supplemented by interstate and intrastate 800 Service facilities, to provide access to the network in those areas that do not have dedicated access lines.

Using Kingsville and San Antonio again as examples, the savings that can be achieved by utilizing these techniques can be illustrated. In the case of San Antonio, if all access lines are replaced with one large FX group, 94 circuits are eliminated, saving approximately $14,000 per month. There are also some potential savings in the number of line cards required, both at the Agencies' PBX's or key systems and at the tandem. All of these savings are offset somewhat by additions to local access line groups to accommodate the additional traffic, along with the higher cost of the FX lines when compared to an access line.

If one assumes that for every former dedicated access line a local access line must take its place (a very conservative assumption), these access lines will cost approximately $4,500 per month. For simplicity, it was assumed that PBX trunks and Centrex trunks are identical; thus 95 PBX and 45 key system trunks were assumed for this calculation. Obviously, each of the State locations in San Antonio already has existing local trunks; thus the additional local trunks required to handle this traffic will be much lower than the number of dedicated access lines this system would replace. An optimistic assumption would be to assume that the additional trunks required would be identical to the change in the number of FX lines. Thus, 46 local trunks would be required, for a tariffed charge of approximately $1,500 per month (assuming that the ratio of PBX to key system trunks remains the same). The actual number required will, of course, be somewhere in between these two assumptions (46 and 140 trunks).

For the additional 46 FX lines the added net cost of an FX termination (compared to the average dedicated access line termination charge) reduces the "savings" by approximately $1,450 per month. Thus the net savings could be as low as $8,050 or as high as $11,050 when these costs are taken into account. This monthly savings must then be weighed against user inconvenience (which may lead to increased bypass of the network), potentially lower transmission quality, and increased administration costs.

One method of lessening these problems, while still retaining some of the savings, would be to allow dedicated access lines for large users. Thus, only the most inefficient access line groups would be replaced by this access technique. If only users who would require four or fewer dedicated access lines were "forced" to use the OCC form of access the number of circuits required changes to 119, saving 52 access lines or approximately $7,800 per month. In this case, the additional local access lines total $1,800 per month, if one is needed for each former dedicated access line, or $350 per month, if just one is needed for each additional FX line. The added termination charges for the 12 new FX lines total $375. Thus, the net savings could range from $7,025 to $5,625 depending on which assumption is made about local access lines.

If a similar analysis is performed for Kingsville the results are not as dramatic. Saving four access lines results in a savings of about $1,200 per month (18 instead of 22 lines). If the same assumptions that were used for the San Antonio example are utilized, the added cost of local access lines reduce the savings by $325 to $425, depending on whether the optimistic or pessimistic assumption is used, respectively. In this case, the "optimistic" $325 figure is probably more accurate, as there is only one State agency in Kingsville receiving service from the STS network (this user requires 15-line dedicated access lines for a P.02 grade of service).

The added net increase in cost for 11 additional FX terminations reduces the savings by approximately $275. Thus the net savings would range from $500 to $600 per month. This illustrates that for users with large, and thus efficient, trunk groups the savings are not very dramatic. In this case the 15 line dedicated access line group and the 7-line FX group could be reduced to a total of 18 FX lines, saving just 4 lines. Thus, in this type of situation, this access technique is less attractive.

5 SWITCHING ARRANGEMENTS

5.1 Introduction

The following sections document BNR's study work in the area of determining the appropriate switching system arrangement to serve the STS voice communications requirements. A detailed description of the switching arrangements required at each location is provided along with a discussion of the methodology employed to arrive at these recommendations. Several alternative plans for meeting the switching requirements are presented and the economic factors that form the basis for the selection of the recommended arrangement are also described. The requirements for both tandem trunk and local PBX switching have been evaluated by BNR as part of these activities.

5.2 Single vs. Multi-Vendor Issues

Uniform control and functionality of the STS tandem backbone network is a critical element that will assure the successful operation of the network as an integrated system. To achieve this end BNR strongly recommends that a single vendor of switching equipment be considered for the tandem nodes. Dialing patterns, routing arrangements, maintenance, administration, signalling, data collection, and a myriad of other requirements must be integrated at the detail level in order for the six nodes to act as an integrated system. BNR's experience indicates that this can best be accomplished by the deployment of tandem switches that are designed and supplied from a single vendor.

This is not as essential with PBX switches however, since they are designed to operate "outboard" of the tandems, and historical standards for interconnection of PBX's to a centralized network (previously the DDD network) are in place and have been understood by North American switch suppliers for some time. The possibility of implementing a combined PBX/ tandem at one or more STS locations does suggest that in those cases the vendor for all of the tandem nodes and the combined PBX/tandems (if any) should be the same, so that integration of the tandem network can be assured. BNR does not believe that stand-alone PBX's need be selected from the same vendor(s).

5.3 Switching Requirements

5.3.1 Tandem Switching

5.3.1.1 Functional Requirements of Tandem Switches

(1) Uniform Dialing: A primary function of the tandem switch is to provide a cost effective means for connecting authorized STS users to on-net and off-net facilities in a manner that is transparent to the user. The dialing plan should be as uniform as possible for all users regardless of the calling location or the route that the call will take. After dialing the STS network access code (1 or 2 digits at the local PBX), it is desirable to utilize a seven-digit code to reach the called on-net party. The first three digits would represent a particular on-net destination location, while the remaining four digits would represent the particular station or extension number of the called party. The use of authorization codes to validate access to the STS network is an optional requirement for STS's consideration. Off-net destinations should be reached by dialing the cutomary 7- or 10-digit DDD telephone number. Prefix requirements of the DDD network and/or OCC's should be applied by the system as required.

(2) Routing: The tandem switch must be capable of determining the desired final location and automatically selecting the appropriate route to reach that destination, whether it be off-net or on-net. The process should include selection of the least-cost route from among the choices available, and also provide digit translation(s) as required. On-net destinations that are dialed by the use of off-net telephone numbers should be recognized by the tandem and routed over STS facilities to the on-net location. Digit translations may be required.

(3) Satelite circuits:Special precautions should be provided to prevent 2 satellite hops in order to avoid untenable transmission delays.

(4) Four-wire: The equivalent of switched four-wire circuit paths are desired to ensure quality "toll" transmission through the tandem. Most digital switches provide this capability.

(5) Stored program control: It is recommended that STS only consider switching systems that utilize a stored program control system for call set-up, routing, data gathering, diagnostics, etc. It is also recommended that fully redundant processor arrangements be provided so that reliability can be assured.

(6) Man-machine interface: The switching system must provide a user-friendly method of allowing authorized personnel access to the status information and to facilitate maintenance and administration of the network. A CRT and a printer to provide hardcopy are desired at each switching node. The ability to connect additional I/O devices both at the switch site and at remote locations is required. The requirements for a centralized network management center are discussed in Section 6.

5.3.1.2 Location and Sizing of Tandems

The facility design and optimization process forms the primary input to the switching designer. The locations of the switches were selected to coincide with the sites where the NTINDS design tool indicated that the switching and facility costs would be minimal. The sizes of the tandem switches are determined by the summation of all the facility requirements at each location. These facilities include:

(1) Inter-Machine Trunks (IMTs): required to carry traffic between STS tandems.

(2) Access Lines: required to serve both local and distant State PBXs.

(3) Off-Net Access Lines: required to provide access to and from the public networks.

(4) WATS: Off-Net WATS-like circuits provided on a reduced-rate basis.

Section 3.1 concluded by recommending a six-switch tandem network, with five primary tandems in Abilene, Austin, Dallas, Houston and Lubbock, and a secondary tandem in Harlingen. The size of each of the six tandem switches is shown in Table 5.1 which follows. These quantities reflect the facilities required to provide a P.02 grade of service, which would be a significant improvement over the present service levels. In addition to these six sites, potential economic benefits may be acheived by the provisioning of a small tandem switch at San Antonio. This subject is discussed further in the section devoted to the consideration of alternative plans.

Table 5.1

Location and Size of Tandem Switches

	1984	1985	1986	1987	1988	1989
ABILENE						
Acc Lns	267	286	305	324	343	362
Off Net	56	60	64	68	72	76
WATS	10	11	12	13	14	15
Sub-Tot	333	357	381	405	429	453
IMTs	99	111	123	135	147	159
TOT TERM	432	468	504	540	576	612
AUSTIN						
Acc Lns	1415	1512	1609	1706	1803	1900
Off Net	250	267	284	301	318	335
WATS	49	53	57	61	65	69
Sub-Tot	1714	1832	1950	2068	2186	2304
IMTs	517	554	591	628	665	702
TOT TERM	2231	2386	2541	2696	2851	3006
DALLAS						
Acc Lns	970	1048	1126	1204	1282	1360
Off Net	321	347	373	399	425	451
WATS	38	41	44	47	50	53
Sub-Tot	1329	1436	1543	1650	1757	1864
IMTs	274	296	318	340	362	384
TOT TERM	1603	1732	1861	1990	2119	2248
HARLINGEN						
Acc Lns	291	307	323	339	355	371
Off Net	101	106	111	116	121	126
WATS	11	12	13	14	15	16
Sub-Tot	403	425	447	469	491	513
IMTs	87	93	99	105	111	117
TOT TERM	490	518	546	574	602	630
HOUSTON						
Acc Lns	859	922	985	1048	1111	1174
Off Net	290	309	328	347	366	385
WATS	32	34	36	38	40	42
Sub-Tot	1181	1265	1349	1433	1517	1601
IMTs	243	260	277	294	311	328
TOT TERM	1424	1525	1626	1727	1828	1929

LUBBOCK						
Acc Lns	292	312	332	352	372	392
Off Net	98	105	112	119	126	133
WATS	11	12	13	14	15	16
Sub-Tot	401	429	457	485	513	541
IMTs	108	114	120	126	132	138
TOT TERM	509	543	577	611	645	679

5.3.2 PBX Switching

5.3.2.1 Location and Sizing of PBX Switches

The existing Centrex, PBX and central office service provided by Southwestern Bell Telephone in the six principal STS cities has been utilized as the baseline for consideration of PBX alternatives. The locations and sizes of the PBX line requirements for the study period are shown in Table 5.2 which follows.

Table 5.2

Location and Size of PBX Switches

	1984	1985	1986	1987	1988	1989
ABILENE						
PBX LNS	350	375	400	425	450	475
AUSTIN						
PBX LNS	5218	5577	5936	6295	6654	7013
DALLAS						
PBX LNS	2978	3217	3456	3696	3934	4173
HARLINGEN						
PBX LNS	448	472	496	520	544	568
HOUSTON						
PBX LNS	6886	7329	7772	8215	8658	9101
LUBBOCK						
PBX LNS	8130	8695	9260	9825	10390	10955

The following assumptions form the basis for the line quantities shown above:

(1) 1982 base: As described in correspondence from A.F.Glavan to J.Morrison, dated November 4, 1982.

(2) Line growth rates: Directly related to the access line growth rates as determined by the NTINDS network design process, which included PBX generated traffic as an input. It is assumed that the line quantities will follow the traffic growth rates.

5.3.3 STS Network Alternatives

5.3.3.1 Present Method of Operation

Trunk switching is presently provided by four CCSA tandem switches which are leased from Southwestern Bell. These switches are located in Abilene, Austin, Dallas and Houston. Telephone service is provided by a combination of Centrex, PBX, key systems and central office arrangements, also leased from the telephone company. In some cases, telephone service is provided by equipment that is owned by the State agencies that are directly involved. In this study we are examining alternatives for the leased arrangements only; the existing owned PBX systems are not considered as candidates for replacement at this time.

5.3.3.2 Plan A: Tandem-Only Network

This plan consists of the contruction of a tandem-only backbone network to replace the existing CCSA arrangement leased from the telephone company. The six tandem switches would be owned and operated by STS and would be placed into service in 1985. The telephone station requirements would continue to be served from telephone company supplied equipment as presently.

5.3.3.3 Plan B: Separate Tandem and PBX Switches

This plan consists of the construction of a new switching network to replace the existing Centrex, PBX, key system, and CCSA arrangements that are being leased from the telephone company. The tandem and telephone station requirements would be provided by separate tandem and PBX switches owned and operated by STS. The tandems and PBXs would be placed into service in 1985 and 1986 repectively.

5.3.3.4 Plan C: Combined Tandem and PBX Switches

This plan consists of the construction of a new switching network to replace the existing Centrex, PBX, key system, and CCSA arrangements that are being leased from the telephone company. The tandem and telephone station requirements would be provided by a single switch in each of the six cities, which would be owned and operated by STS. The switches would be placed into service in 1985 to meet the tandem demand, while the PBX capability would be cutover in 1986.

5.3.4 Austin Switching Node Alternatives

The various alternatives for the provisioning of telephone service in the Austin area have also been examined apart from the alternatives for STS as a whole. This is in part due to the special nature of the Austin area, in that unlike other locations, STS has responsibility for the telephone station demand in addition to the backbone network.

5.3.4.1 Plan 1-Present Method of Operation: Austin

The present method of providing telephone service for most of the Capitol Complex in Austin is the leasing of Centrex lines from Southwestern Bell Telephone. The switching system is located on telephone company premises in a centralized location and provides service to approximately 4500 stations for almost 100 agencies and departments in the Capitol area. A telephone company leased CCSA arrangement provides for the tandem switching function.

5.3.4.2 Plan 2-Tandem Only: Austin

This plan consists of the construction of a new tandem to serve the Austin trunk switching requirements, while the existing leased Centrex system would be retained.

5.3.4.3 Plan 3-Stand-Alone PBX Switching: Austin

This plan consists of the construction of a new tandem to serve the Austin trunk switching requirements. The Austin telephone requirements would be provided by the construction of a separate PBX switching system, also to be owned and operated by STS. The tandem and PBX switches would be placed into service in 1985 and 1986, respectively.

5.3.4.4 Plan 4-Combined PBX/Tandem Switching: Austin

This plan consists of the construction of a new switching system designed to provide both tandem and PBX switching from a single switch. The tandem function would cut into service in 1985, while the PBX function would be placed into service in 1986. The system would be owned and operated by STS.

5.4 Discussion of Alternatives

In this subsection the major factors that impact each of the alternative plans are discussed, and the significant items of sensitivity are identified and quantified where possible. The pricing methodology utilized by BNR to determine the relative costs of the plans is also detailed.

5.4.1 Switch Pricing Methodology

5.4.1.1 Price Estimating for a Network

BNR has utilized a pricing profile for the switches described in the various alternative plans that is considered to be representative of the types of products that are available in the marketplace and are suitable for STS's requirements. This price "predictor" is used for generic planning purposes only and is not intended to be used or documented as being a firm price for a specific application. The actual prices that STS might experience in response to a Request For Quotation (RFQ) will vary from vendor to vendor and will reflect the market conditions at the specific point in time that the equipment delivery is required.

It also should be noted that the prices for switching systems are sensitive to the architectural scale of the specific products involved and how the products "map" onto the size of the applications. The STS tandems, for example, range in size from 540 to 3,000 terminations in size. It is essential for operational reasons that a single vendor be utilized for the six tandem switches, and therefore BNR has priced out the entire STS network accordingly. Occasionally a vendor will present a "family" of switching products to meet a network design such as STS's, and therefore a single pricing algorithm may not be appropriate. This is quite often true with PBX switches and is discussed in greater detail in the PBX alternatives section. We have taken these circumstances into consideration when performing the economic analysis presented in this study.

5.4.1.2 Elements of Price Sensitivity

Price sensitivity to the following parameters (where applicable) is customary, and has been considered in BNR's cost modeling.

(1) Getting Started (GS) cost: this usually includes processor, basic I/O devices, basic memory, generic software, and other common equipment costs.

(2) Trunk terminations: includes IMT's, PBX access lines, off-net lines (including C.O. trunks), etc.

(3) Traffic (in terms of system CCS or Erlangs). This is usually not relevant with digital tandem switches, which are normally non-blocking by design and therefore are not sensitive to traffic load. It is an important element in PBX switches, however, since almost all PBX switch design incorporates some concentration in the "front end" where the lines terminate. This concentration is perfectly acceptable and is useful in keeping costs under control; however it does present an opportunity for potential blocking of calls if the system is not engineered properly. The customary approach to assuring that adequate capacity is provided to meet the traffic demand, is for the PBX line capacity to be rated at a particular traffic usage level, usually stated in terms of a range of Erlangs or Hundred Call Seconds (CCS) per station. The price per PBX line should be understood in relation to this traffic parameter. Generally the higher the average traffic per line, the more costly the system will be.

(4) Trunk facility type: analog or digital. There is considerable sensitivity to this parameter. A digital trunk terminating on a digital switch is significantly less expensive than an analog trunk termination. The reverse is true with analog switches.

(5) Line (telephone) terminations in PBX situations.

A typical pricing formula will take the form of:

$GS + $ per digital tandem termination
+ $ per analog tandem termination
+ $ per PBX line
+ $ per digital PBX trunk
+ $ per analog PBX trunk

and will be useful over a stated range of applications.

5.4.1.3 Switch Parameters

The following items shall be considered as being included in the total price. They may be prorated on a per line or trunk basis, loaded into the common cost or identified separately, but they are included.

(1) Switching system, including hardware and software

(2) Installation, including all required cabling to a facility demarcation point.

(3) System operational test in the field.

(4) Regular power (DC and AC equipment required to make system functional)

(5) Man-machine I/O device for switch maintenance and administration.

(6) Telephone sets (where applicable) that include a mix of: 90% 2500 (or equiv), 10% electronic (multifunctional).

(7) Customer training

(8) System documentation

(9) Engineering

(10) Delivery and warranty

5.4.2 STS Tandem Network Alternatives

The cost of the tandem function, as outlined in each of the alternative plans, will vary from plan to plan due to significant differences in the recommended equipment arrangements. The initial costs associated with each of the plans are presented below. The lease costs shown in the PMO plan represent what STS is presently paying to Southwestern Bell for the CCSA network and have been increased to reflect annual growth in the access line and other trunk terminations. The quantity of terminations that are required for a P.02 grade of service are also shown so that a comparison with the other plans can be made. The expenditures shown in Plans A through C, have been determined by applying BNR's planning price methodology to the tandem arrangements shown in Table 5.1.

Table 5.3

STS Tandem Switch Capital/Lease Costs
(1982 Dollars)

		1984	1985	1986
PMO	CCSA @ P.07:	$2,265K	$2,431K	$2,598K
	" " P.02:	$2,265K	$2,884K	$3,562K
Plan A	Tandem ntwrk only:	$3,611K	$7,453K	$ 0
Plan B	Separate tandems:	$3,611K	$7,453K	$ 0
Plan C	Combined PBX/Tdm: (tdm $ only)	$3,984K	$11,318K	$ 0

Plan A, which provides for the construction of an STS-owned tandem backbone network only, requires the identical level of capital expenditures for tandem equipment as Plan B, since the tandem portion of the equipment arrangements are the same. Plan C however, provides for the tandem and PBX functions to be served from a single switch in each city, and therefore significantly larger expenditures are required initially in 1984 and 1985 to provide the larger processor capacity needed to support the PBX lines in addition to the tandem function. The PBX line charges are excluded.

These one-time capital expenditures compare favorably with the recurring annual lease expenditures associated with the PMO plan. The full economic implications associated with each of these plans are presented in Chapter 7, this chapter includes an analysis of operational issues as well.

5.4.3 PBX Alternatives

The cost of the PBX function, as outlined in each of the alternative plans, will also vary from plan to plan due to significant differences in the recommended equipment arrangements. An overview of the initial costs associated with each of the plans is presented below, along with a view of the recurring charges associated with the leasing of the existing telephone company arrangements. These costs represent the expenditures for the PBX function only and were derived from the equipment arrangements shown in Table 5.2. They exclude tandem-related expenditures.

Table 5.4

STS End Office Capital/Lease Costs
(1982 Dollars)

		1986	1987	1988
PMO	Centrex-PBX : (Telco lease)	$16,895K	$17,918K	$18,942K
Plan A	Tandem ntwrk only: (Telco lease continues)	$16,895K	$17,918K	$18,942K
Plan B	Separate PBXs :	$42,162K	$ 2,904K	$ 4,668K
Plan C	Combined PBX/Tdm: (PBX $ only)	$41,112K	$ 2,904K	$ 4,513K

The PMO and Plan A both provide for the continuance of the present method of operation for the telephone line functions;

therefore the PBX cost components are identical. Plan B provides for an initial capital expenditure in 1986 of $32,357,000 which represents the costs associated with the installation of several PBXs as shown in Table 5.5. The initial line size represents the number of working lines in 1988, since PBX equipment should be engineered to meet the anticipated demand for a two year period. In 1988, additions to the PBX's are assumed which would then provide sufficient capacity to meet all growth in demand that year. This is chosen artificially, instead of a job providing two years of growth, in order to make all plans consistent (caring for growth through the end of 1988).

Table 5.5

PBX Requirements for Plan B

	Initial Lines	1990 Lines	Quantity of PBXs
Abilene	450	500	1
Austin	6,650	7,400	3
Dallas	3,900	4,400	2
Harlingen	550	600	1
Houston	8,650	9,600	3
Lubbock	10,400	11,500	3
TOTAL	30,600	34,000	13

An analysis of the details of Southwestern Bell's Centrex charges indicates that approximately 75% of the Centrex stations are classified as off-premise at Austin. Both Plans B and C include expenditures for outside plant cabling between the PBX's and associated off-premise telephone stations. Using Austin as a model for the assumptions regarding the mix of off-premise and local telephones, and assuming an average off-premise station circuit is 5,000 feet in length with a cost of $140 per circuit, the associated cabling costs are as follows:

Plan B $1,188K

Plan C $3,556K

These costs are included in the figures for the alternatives presented above and occur only in 1986, since it is recommended that sufficient cabling for the entire project requirements be placed initially.

BNR has modeled the deployment of multiple PBX units to serve the user communities in Austin, Dallas, Houston and Lubbock, since it represents the most cost effective solution. Almost all vendors' PBX systems are optimized for a particular range of line sizes, with the processor being a major difference between the small, medium and large systems. Generally a larger processor complex is significantly more costly than the smaller versions. Although the cost for incremental line and trunk terminations in the larger systems are usually lower due to the "economies of scale", the specific applications under study for the State of Texas do not appear to be large enough to offset current pricing for getting started with a large PBX.

Other considerations that impact the decision regarding distributed (multiple) vs. centralized (single) PBX's include the effects upon outside plant cabling (for off-premise extensions) and access line requirements at the tandem. These issues have been considered in the overall economic analysis and are presented in detail in the discussion of the alternatives for serving the Capitol Complex Centrex.

Plan C, which provides for the implementation of a single switch for both the PBX and tandem functions, ameliorates the economic penalty associated with the startup cost for the large switch, since the single processor can fill both needs. BNR's analysis indicates that when both the tandem and PBX requirements are considered there is only a slight difference in costs between Plan B and Plan C. There is, however, a significant economic difference between the PMO Plan and the total (line + tandem) purchase approaches (Plans B and C) which suggests that in all cases the State of Texas would benefit from ownership of its own switching network.

5.4.4 Austin Telephone Service Alternatives

The two alternatives to the present method of providing telephone service in the Austin area are represented by Plans 3 & 4, which provide for the installation of multiple and centralized PBX's respectively. Plan 2 assumes continuation of the existing Centrex arrangements, but does include replacement of the CCSA tandem with an STS-owned system. The annual expenditures for these four plans are presented in the following table and have been derived from the equipment requirements presented in Tables 5.1 and 5.2.

Table 5.6

AUSTIN SWITCHING ALTERNATIVE PLANS

Initial Capital Investments and Annual Lease Costs
(1982, $000)

	1984	1985	1986	1987	1988
PLAN 1 PMO					
CCSA	823	1,074	1,351	1,433	1,516
Centrex	3,243	3,466	3,689	3,912	4,135
Total...........	4,066	4,540	5,040	5,345	5,651
PLAN 2 Tdm Only					
CCSA	823	440	0	0	0
Centrex	3,243	3,466	3,689	3,912	4,135
Tandem	1,011	1,011	0	145	0
Total...........	5,077	4,917	3,689	4,057	4,135
PLAN 3 Tdm+PBX (separated)					
CCSA	823	440	0	0	0
CTX/PBX Telco Chgs.	3,243	3,466	2,140	631	675
Tandem	1,011	1,011	0	145	0
PBX Switch	0	0	6,848	0	340
PBX Cabling	0	0	258	0	0
Total...........	5,077	4,917	9,246	776	1,015
PLAN 4 Tdm+PBX (combined)					
CCSA	823	440	0	0	0
Centrex	3,243	3,466	2,140	631	675
Tandem }	1,472	1,472	0	81	0
PBX Switch}	0	0	5,706	0	609
PBX Cabling	0	0	774	0	0
Facil Saving	0	0	(137)	0	0
Total...........	5,538	5,378	8,483	712	1,284

5.4.4.1 Austin Tandem

A comparison of Plans 1 and 2 presents a clear view of the first-order economics associated with the decision as to continue the CCSA arrangement or purchase a tandem switch for STS ownership and operation. The ownership alternative (Plan 2) requires an initial additional expenditure of approximately $1,000,000 1984 and an incremental expenditure of almost $400,000 in 1985. These additional costs will almost be completely offset in 1986 by the elimination of the CCSA lease charges. In fact, the payback period would appear to be less than two years. A more complete understanding of the relative economics is presented in section 7.1, where other factors such as operating costs can be evaluated.

5.4.4.2 Austin PBX

A comparison of Plans 3 and 2 presents a clear view of the first-order economics leading to a decision whether to continue the existing leased Centrex-based telephone arrangement or to purchase PBX equipment that will be owned and operated by either other State organizations or by STS on behalf of the various State agencies. The ownership alternative (Plan 3) requires an initial incremental expenditure of approximately $5.6 million in 1986. These additional costs are offset in the next two years by $6.4 million in savings from the cessation of lease charges for the Centrex system. The incremental savings in 1988 and thereafter are greater than $3 million annually.

The outside plant (cabling) costs in Plan 3 are estimated at $258,000, assuming that 25 percent of the stations are off-premise. This is significantly lower than the $774,000 estimated for Plan 4 (assuming 75% off-premise stations), since Plan 3 provides for the deployment of multiple PBX's, thus reducing the quantity of off-premise stations. The implementation of a single PBX, as modeled in Plan 4, will allow some some trunk savings due to the economies of scale in its trunk groups. These facilities savings are estimated to be $137,000 and are shown as a credit to Plan 4.

The differences between Plans 3 and 4 are very slight, which suggest that the decision regarding the implementation of a separate vs. a combined PBX/tandem arrangement is not a clear economic choice. Other factors, including operational needs, vendor pricing strategies, product reliability, etc. may influence the final selection of the appropriate PBX switching arrangement.

5.5 Attendant Service

With the installation of the new network, operator services should be centralized in Austin. These operators will be responsible for providing directory assistance as well as the recording of billing information for some off-to-on network calls.

5.5.1 Directory Assistance

If few changes are made in current procedures, the demand for directory assistance services with the new network should be quite similar to those for the existing network (with normal growth). The demand for these services can be reduced, by adopting a strategy of further encouraging printed directory use. This can be accomplished by charging back to the agencies a fee for directory services, based on usage. In this way the agencies which utilize directory services would pay for these services in proportion to their usage.

This should be accompanied by the ready availability of current printed directories. This could be accomplished by building the cost of directories into the basic charges for STS service instead of providing a separate charge for them. They could then be distributed to the various State agencies at no additional charge to these agencies. These two steps would eliminate the temptation to rely on directory services instead of a less costly printed directory.

5.5.2 Off-to-On Calls

Currently Off-to-On calls on the STS network are handled manually by the STS operator, who gathers the necessary billing information and completes the call. With a new network a large proportion of this procedure can be automated, eliminating the need for operator intervention in most cases. This can be accomplished through the use of Direct Inward Station Access (DISA). This would allow a user to dial into the network, with network security and billing provided through the use of authorization numbers.

Care must be excercised to prevent abuse of these authorization numbers. This can be accomplished in a number of ways. The authorization numbers should be long enough to reduce the probability that a valid authorization number will be discovered by random dialing. The numbers should be changed periodically, to prevent unauthorized users (such as former employee, etc.). from utilizing the network using an "old" number Finally, most callers should be allowed to make only off-to-on calls. By restricting off-to-off calling to a few selected users, the abuse of the system becomes much less attractive.

Signaling of the required information would be accomplished through the use of Dual Tone Multi Frequency (DTMF) tones. If the user was utilizing a rotary dial phone, a portable DTMF pad could provide the necessary signaling. There still will be situations where a means of DTMF signaling is not available, however. In these situations operator intervention will be required in most cases (there are some voice recognition systems which could be used in this instance).

5.5.3 In WATS

The use of the network for off-to-on calling could be encouraged if the State were to implement 800 service. This service would supplement the existing FX circuits, providing coverage to areas of the State that do not have sufficient calling volumes to justify an FX line. Ideally, the users would call the local FX lines, whenever one could be reached without resulting in toll charges, and would use the 800 number in all other situations. This behavior could be encouraged if a higher charge were made when the 800 service facilities were used, reflecting their higher cost. The State could also publish a wallet-sized card with the off-to-on numbers on it to encourage the use of the preferred numbers by traveling employees.

The actual number of 800 service facilities that would be needed is very difficult to determine. This is due to the lack of comprehensive data on present calls which might be carried by such a service. As a result the State will of necessity have to place an arbitrary number of these circuits in service and closely monitor the traffic on these facilities. Frequent adjustments in the number of these facilities will be needed until a steady state condition is reached.

5.5.4 Operator Requirements

When the new network is first brought into service an initial surge in demand for directory services is expected, as users become familiar with changes in the numbering plan, and the new network in general. After this initial period has elapsed, this demand should decline until it arrives at a steady state condition.

There will also be an initial increase in demand for operator services if the State encourages the use of the network for off-to-on calling (including the implementation of an 800 Service to supplement the existing FX facilities). This will also decline as users become familiar with the use of the authorization numbers and the DISA system.

As a result of the expected initial high demand for operator services, temporary personnel will be needed to supplement the long term operator requirements for the new network. If the current operator services were centralized, approximately eight operators would be needed in Austin. As a starting point, 12 operator positions should accommodate the initial demand for services, as the users become familiar with the network. Because of the many factors which cannot be quantified, this number is very approximate. As the network will be implemented in stages, the demand for operator services should be monitored closely, so that adjustments in the number of operator positions can be made as the network is implemented.

Of these 12 operator positions, at least half should initially be staffed by temporary personnel. This is due to the expected initial peak in demand for operator services, which should be short lived as users become familiar with the operation of the network. As the demand for these services reaches a steady state condition, some of the temporary operators could be hired on a permanent basis, while the remainder are let go (as the demand for operator services declines).

To transition to this arrangement, the agencies supplying operators in Abilene, Dallas and Houston should be notified that operator services will no longer be required from these locations after 1985. This will enable the agencies in question to plan appropriatly. These agencies could then gradually decrease the size of their operator staffs through attrition, or plan to utilize these employees for other job functions.

6 NETWORK MANAGEMENT

6.1 Introduction

This section first details the network management functional requirements in operating the STS network. Based on these functional requirements and the STS network configuration, network managment equipment configurations and costs are then estimated based on the generic prices of the existing products. The staffing organization, salaries and overhead costs in operating the network are also derived based on pay scales for the independent telephone industry. In addition, the spare parts and repair expenditures are estimated.

6.2 Functional Requirements

To manage the complexity of the private STS network, a well structured network management organization with the assistance of a sophisticated network management system is required. The major network management functions are providing adequate day-to-day communication services for the network's customers, and the state agencies, including:

(1) maintenance: ensure the smooth day-to-day operations of the network and remedy problems in the network before they become severe.

(2) traffic control: ensure that the network provides adequate traffic carrying capacity. With the appropriate network design as specified in this report, no network topology redesign will be required for a long period of time (until 1989).

(3) administration: provide an appropriate mechanism for equipment/facility procurement and inventory, station changes/moves, and on-line directory.

(4) accounting: provide equitable chargeback to the individual agency for its network usage. This can reduce abuse of the network resource through improved accountability.

In addition, there should be a long range network planning program. At the risk of sounding self-serving, it is recommended that this program be performed with outside consultant assistance.

It is recommended to deploy a centralized organization with a centralized Network Managment Center (NMC) to perform the above-stated objectives. The key reasons for centralization are:

(1) coordination and control: Some activities in a single network subsystem, a network node (tandem switch) or a transmission facility, may have an impact on the total network or require coordination between two locations. For example, to take a network node out of service or to repair a transmission facility which spans two nodes requires cooperation among the affected locations. The best way to achieve this is through a centralized organization.

(2) cost effectiveness: With a centralized component of the organization, a few highly skilled personnel can be located at the central site. This allows maximal productivity from the personnel. In addition, with today's technology, it will not be economic to have a sophisticated network managment system, which is minicomputer based, in each network node location. There may be some microprocessor based processing at the network node locations.

The NMC should be a passive system complex so that its failure will not interrupt the network's operation. The NMC should be located in a central site (most probably in Austin) and may consist of several systems. For example, one for transmission facility maintenance and another for network switch maintenance, transmission quality testing, administration and accounting. Each system will have remote monitor, test and control capabilities, i.e., there is remote site equipment associated with each system. Depending on the systems available on the market and their costs, further division of the system may be required.

The network management organization consists of staff at the central site and at regional sites where the network nodes reside. The central site staff has ultimate responsiblity for network-wide maintenance, administration, and control. The regional site staff has responsibility for maintenance and administration of the tandem switch and transmission facilities under the domain of the region. (For example, the Dallas and Houston regions will each have responsibility for part of the transmission facility between Dallas and Houston.) Any activity requiring staff from more than one region will be coordinated through the central site staff.

6.2.1 Maintenance

Each network node and each transmission facility should be able to:

(1) self test,

(2) remove faulty units from service,

(3) switch in a hot standby unit if available,

(4) provide alarms locally and send the maintenance information to the NMC.

The network operator will be alerted of any major network subsystem outage so that he/she can take immediate actions, such as removing a faulty network subsystem from service and reconfiguring the network so that the network can be operated with maximal efficiency under such conditions. The NMC shall also keep a maintenance history data base to assist the network operator in diagnosing and isolating faulty units, so that he/she can coördinate repairs to be performed by the regional site staff.

6.2.1.1 Testing and Subsystem Maintenance

Both switch and transmission facilities should have adequate testing capabilities, either run autonomously or initiated from the NMC. They can switch in a hot standby unit autonomously or upon manual request. The network operator can remotely request testing and switch in a hot standby unit.

6.2.1.1.1 Switch Maintenance Capabilities

No single fault should be able to take a tandem switch down except catastrophic events such as fire. The tests required for a tandem switch which have impacts on the network are:

(1) switch processor complex: The switch should have appropriate tests to detect the failure of a processor. Failure of a processor will trigger an automatic switchover to the redundant processor. This is considered to be a major failure. If the switch processor complex fails, it is considered to be a critical failure.

(2) circuit assurance: The switch should provide reports identifying IMT and PBX access line circuits with excessively long or short holding times. These reports can be used as a source to assist in localization of a problem.

    In addition, the switch will perform tests on other access lines and on its own internal links.

6.2.1.1.2 Transmission Facility Maintenance Capabilities

In addition to the above stated circuit assurance tests from the switch, an automatic transmission quality test system is required to provide quantitative measurements of transmission quality, such as insertion loss and noise. The automatic transmission quality test system will cause the seizure of IMT/PBX access line circuits in a switch and the appropriate test equipment (e.g., test lines and responders) to be connected to each end of the seized circuits. Measurements performed on the circuits by the test equipment will be sent to the NMC. Appropriate reports will be generated in the NMC as follows:

(1) circuits exceeding a preset maintenance threshold, prompting the network operator to initiate the maintenance activities on them.

(2) circuits not tested and the reasons, such as busy.

The transmission facility system should have adequate maintenance capabilities including:

(1) Detect the status of equipment on each transmission site, including repeaters, relays, power, and others. Display status locally and send the status information to the NMC. In addition, physical conditions of the transmission site will be monitored, such as door alarms in the unattended location, fire, and others.

(2) Measure digital signals, such as bit error rate, and analog signals, such as voltage, and send the measurement data to the NMC.

(3) Switch in hot standby units, either autonomously or upon (remote) manual request.

(4) There should be an emergency power supply. Batteries can be used for short-term (four to eight hours) backup, with either portable or fixed emergency generators available for service well within that time.

The circuit tests on transmission quality and the stated facility maintenance capabilities, coupled with overall preventive maintenance procedures, will ensure transmission quality and up time comparable to the public network.

6.2.1.2 Monitor/Alarm

As discussed above, all maintenance information will be sent to the NMC. The NMC will generate alarms for any critical network subsystem outage. A critical alarm will indicate a network subsystem outage, the network node or facility at which the outage occurred and the reason, i.e., switch process complex failure or building on fire. In addition, any intermittent failure exceeding a preset frequency threshold for the type of failure will trigger an alarm condition. Those critical alarms should be displayed and have associated audio alarming to attract the operator's attention so that he/she can take immediate action. Each regional site will have the alarms of its own tandem switch. In addition, a work station in a regional site may display the status of the transmission facility under its domain of maintenance.

Other maintenance information (not as severe as a major alarm condition) will also be handled by the NMC to provide timely information to the operator. A maintenance history data base will be kept and major alarms such as failure of a trunk group or minor alarms such as failure of a trunk circuit will be reported to the operator. The operator can quickly identify the status of the various network subsystems by interrogating the data base (e.g., by switch, time period and maintenance trouble type).

This centralized monitoring feature requires the NMC location to be manned 24 hours a day, while the regional sites need to be manned only 8 hours a day.

6.2.1.3 Removal of Network Subsystems From Service

Based on monitor and alarm information, the network operator can remove network subsystems from service:

(1) Remove a tandem switch: The network operator can remove a faulty tandem switch from service by updating the routing table. The NMC will download the updated routing table to the affected (adjacent) tandem switches (this procedure may be initiated automatically).

(2) Remove a link: The network operator can remove a faulty transmission link from service by updating the routing table as stated above. The operator may also remove a link to perform routine tests on the transmission facility in the evening.

(3) Remove an IMT group or circuit: Based on data from automatic transmission tests, the operator can remove a faulty IMT group or circuit from service. The NMC will download this information to the affected switches.

6.2.1.4 Diagnosis and Maintenance Management

The network operator may be able to isolate a faulty unit based on monitor information. He can also use diagnostic tools to request a specific test on switch or transmission facilities.

The NMC will provide a trouble ticketing mechanism * so that the network operator and the network manager can track maintenance/repair activities. The system will assist the network operator in recording troubleshooting activities, the responsible repair personnel, and the status of the repair. A trouble ticket summary report will be generated for the network manager periodically or upon request.

In addition, an alarm history and summary report can be generated periodically or upon request. This provides a history of network status and time of recovery of various alarms.

6.2.2 Traffic Control

An individual tandem switch will measure the traffic load on individual links connected to it. It will report those measurements to the NMC. The network engineer in the central site can then rearrange the IMT circuits based on traffic data. In addition, the network operator may reconfigure the routing tables in emergency situations, such as natural disasters, or when a link between two tandem switches fails.

6.2.2.1 Traffic Measurement

Each tandem switch measures traffic parameters on a per link basis, including:

(1) call attempts (per hour).

(2) call completions or overflow (per hour).

(3) traffic load (CCS).

Those measurements will be sent to the NMC. The NMC will consolidate these measurements and provide a traffic measurement data base.

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* Mechanized trouble ticketing for a private network is not available in current major products. A mechanized trouble ticketing system will be very useful in providing effective network maintenance control. In the future, some network management systems may provide such a feature. Even if it is not offered, the STS may build a microcomputer based system to perform this function. It is estimated that a 16-bit microcomputer system with 256K memory, dual floppy disks, a 10 Mbyte hard disk, and a printer will cost about $10K, and the software development will cost about $15K.

6.2.2.2 Traffic Analysis

The NMC reports periodically on the network grade of service (end-to-end blocking) based on measured traffic parameters and network design objectives. This report may include recommendations on IMT circuit additions/deletions to satisfy the objectives. The NMC may also provide a load simulation capability * to report to the network engineer about an expected grade of service based on potential IMT circuit rearrangements entered by him/her.

6.2.2.3 Traffic Reconfiguration

A major cause for a network traffic overload is the occurrence of a natural disaster. In this situation, not only the STS network but also the DDD network (which serves as the overflow from the STS network) will be overloaded. The network operator may change routing tables so that the only users that can access the STS network are those with the appropriate Class of Service (COS), e.g., Department of Public Safety. The NMC will download this change of routing tables to the affected switches.

Another cause for STS network traffic overloads is when a link between two switches is down. With an Automatic Route Selection (ARS) feature in the affected tandem switches, the traffic will be overflowed to an alternate link. The operator can update the routing tables of the distant switches to prevent their traffic from entering the affected region when those distant switches have other alternate routing capabilities, such as off-net routing.

6.2.3 Administration

The NMC provides a centralized point for many administrative tasks associated with the network, although some of these tasks will be properly carried out at each regional site. The NMC provides the following centralized data bases:

(1) Equipment data base, including an inventory of access lines and IMT transmission facilities, and the routing table of each tandem switch.

(2) Directory data base: allowing the network operator to retrieve the following user information on-line:

o directory number

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* Load simulation is not available in current products.

- o COS
- o location
- o switch port
- o organization

It also provides a periodic printout of the network directory.

The staff at the central site will be responsible for:

(1) IMT circuit rearrangement: addition or deletion of IMT circuits.

(2) Access line rearrangement: addition or deletion of access lines.

(3) Routing table changes: updating the routing table in each tandem switch.

(4) Authorization code administration: addition to or deletion from the list of authorization codes that can be used on the network.

(5) COS modification: redefining an existing COS or addition of a new COS.

The updated data will be downloaded to each affected switch.

The staff at each regional site will be responsible for the maintenance and installation of equipment at the node and may update the directory for those users being served by his/her location. The update is performed through the centralized NMC or is performed locally and reported to the NMC so that it can keep a current version of the directory. In addition, the regional site staff performs administration activities which only impact the served location, including:

(1) station moves and changes -- associated directory updates will also be performed.

(2) switch hardware rearrangements, including additions or deletions of switch hardware.

6.2.4 Accounting

The NMC provides a billing facility to charge back the network resource usage to individual agencies. To provide equitable accounting, the NMC has to collect Call Detail Recording (CDR) data from each network node. The CDR data will then be processed off-line to generate billing data. The bill will be partitioned into network, DDD, WATS and local call charges, plus fixed charges. Each category will have its own chargeback algorithm and parameters to allocate costs equitably. The major parameters are call time (e.g., day, evening, night), call duration, calling and called areas, and markup.

CDR data can also be used at a later date for long range network planning, by providing point-to-point patterns and volumes.

On-line CDR data access * will be required to perform call traces to identify the paths of calls which encountered trouble (indicated by users or the automatic transmission quality test system).

The CDR reports include:

- Station Activity Detail Report
- Location Activity Detail Report
- Location Summary, by Cost Center
- Cost Center Summary, by Department
- Network Summary, by Agency
- Exceptional Cost and Duration Report
- Incomplete Record Report
- Point-to-Point Report.

6.3 Equipment Requirements

6.3.1 Methodology

Generic network managment equipment to perform the stated functional requirements are detailed. Some stated functional requirements are not available in the market, including load simulation, mechanized trouble ticketing, and on-line CDR access; however, they may become available when the State of Texas starts to implement the network. All planning price models discussed will not include these features.

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* On-line CDR access is not available in the current major products.

(1) Switch Network Management Center

Different vendors provide different facilities to act as network managment centers. Two typical approaches are:

(a) Some Network Management Functions Provided by the Switch: It provides a centralized monitoring display. It collects and transfers CDR and traffic data to magnetic tapes at the central site. Software is provided to generate CDR and traffic reports, using the customer's own mainframe computer (e.g., IBM). The managment functions and the software packages are included in the switch price. This approach is typically provided by the tandem-only products.

(b) Stand-alone Minicomputer-Based Network Managment Center: In addition to the functions as stated above, it provides CDR processing, traffic analysis and directory assistance. Furthermore, it usually provides a better user interface in the monitoring display and in maintenance data retrieval. This approach is typically provided by the combined tandem and PBX products.

The planning price for a large stand-alone system is approximately $500,000.

(2) Transmission Quality Test Equipment

(a) Patch Panel: Provides patching fields and a transmission test set for manual testing on voice grade, conditioned and program circuits. The planning price is:

$3,500 + $50/circuit.

(b) Automatic Transmission Quality Test System(s): This system tests the access lines at each tandem node. It tests transmission losses and levels, and also noise. Based on industry experience, inadequate transmission facility quality may exist for up to 20% of the total circuits in a network. It is recommended that every PBX access line be tested once each week. In general, these tests should be done routinely in the off-hours, for example 2 am to 5 am. In general, it takes about 30 seconds to test a circuit, and a circuit should be tested twice in the same test period to ensure correct test results. There will be 60 circuits tested per hour. A test system can thus handle:

60 circuits/hr x 3 hrs/day x 7 days/week =
1260 circuits/week.

A typical planning price is:

$40,000 per 1260 circuits for a micro-based system and a transmission test set;

$500 per "PBX" location for a test station.

The automatic transmission quality test system will be located at strategic nodes for a network as large as the STS. A configuration guideline is to locate one at a tandem node if it has a sufficient number of circuits (on the order of 700 circuits). If a location does not have a sufficient number of circuits, it can use the system located at an adjacent node. In addition, if the number of circuits just exceeds the requirement for frequency of tests, then requirements may be relaxed such that all circuits are tested in an 8-day period, thus deferring the placement of a new system.

Some systems have an automatic IMT transmission test feature, measuring losses and levels, but not noise, on daily basis. To measure IMT noise, one can configure a transmission quality test system to test some pre-selected PBX access line on an adjacent tandem switch. Based on the known access line quality, one can estimate the quality of the IMT. This test will have little impact the automatic transmission quality test system capacity.

(3) Transmission Facility Maintenance

The central transmission facility alarm and control center located at the central site costs approximately $25,000.

The transmission test equipment at each location costs approximately $10,000 (per network node).

6.3.2 Cost Derivation

The first cost investment for network management equipment are shown in the following table.

Table 6.1 Stand-Alone Network Management Center (Austin) Cost (1982 Dollars)

	1985	1986	1987	1988	1988
$ TOTAL	500,000	-	-	-	-

Table 6.2 Transmission Facility Maintenance Equipment Cost (1982 Dollars)

	1985	1986	1987	1988	1988
Abilene					
$ Test Equipment	10,000	-	-	-	-
Austin					
$ Alarm/Control	25,000	-	-	-	-
$ Test Equipment	10,000	-	-	-	-
$ Subtotal	35,000	-	-	-	-
Dallas					
$ Test Equipment	10,000	-	-	-	-
Harlingen					
$ Test Equipment	10,000	-	-	-	-
Houston					
$ Test Equipment	10,000	-	-	-	-
Lubbock					
$ Test Equipment	10,000	-	-	-	-
$ TOTAL	85,000	-	-	-	-

Table 6.3 Transmission Quality Test Equipment Cost (1982 Dollars)

	1985	1986	1987	1988	1988
Abilene					
$ Patch Panel	26,900	1,800	1,800	1,800	1,800
$ Auto Test Sys (Lubbock & Abilene)	40,000	-	-	-	-
$ Test Sta	13,000	-	-	-	-
$ Subtotal	79,900	1,800	1,800	1,800	1,800
Austin					
$ Patch Panel	122,800	7,750	7,750	7,750	7,750
$ Auto Test Sys (Austin & Harlingen)	80,000	-	-	-	-
$ Test Sta	31,500	-	-	-	-
$ Subtotal	234,300	7,750	7,750	7,750	7,750
Dallas					
$ Patch Panel	90,100	6,450	6,450	6,450	6,450
$ Auto Test Sys	40,000	-	-	-	-
$ Test Sta	35,000	-	-	-	-
$ Subtotal	165,100	6,450	6,450	6,450	6,450
Harlingen					
$ Patch Panel	19,400	1,400	1,400	1,400	1,400
$ Test Sta	14,000	-	-	-	-
$ Subtotal	33,400	1,400	1,400	1,400	1,400
Houston					
$ Patch Panel	79,750	5,050	5,050	5,050	5,050
$ Auto Test Sys	40,000	-	-	-	-
$ Test Sta	27,000	-	-	-	-
$ Subtotal	146,750	5,050	5,050	5,050	5,050
Lubbock					
$ Patch Panel	30,650	1,700	1,700	1,700	1,700
$ Test Sta	11,000	-	-	-	-
$ Subtotal	41,650	1,700	1,700	1,7001	1,700
$ TOTAL	701,100	24,150	24,150	24,150	24,150

6.4 Staffing Requirements

6.4.1 Staffing Organization

A guiding principle in setting up an organization to run the STS network is that coordination of network activities will be centralized. The current Operations Department has to be restructured to perform day-to-day operation of the network. The current staff can be the core of this new organization. The proposed new organization is shown in Figure 6.1. The skill levels and number of staff members are as described in the pages following Figure 6.1.

```
                          +------------------+
                          |Telecommunications|
                          |    Director      |
                          +------------------+
                                   |
                                   |
                          +------------------+
                          |   Operations     |
                          |    Manager       |
                          +------------------+
                                   |
                                   |
                    ----------------------------
                    |                          |
        ********************                   |
        *           |      *                   |
        * +--------------+ *       +------------------+
        * | System       | *       |Telecommunications|
        * | Administrator| *       |     Analyst      |
        * +--------------+ *       +------------------+
        *           |      *
 -------*------------------*------
 |      *           |      *     |
+---------+ * +------------+ * +--------+
| System  | * |   System   | * | System |
|Operators| * | Technicians| * | Clerk  |
+---------+ * +------------+ * +--------+
        *   at network     *
        *      nodes       *
        ********************
```

Note: The staff members within the box labelled by "*" are the additions to the current organization. All current members remain in the proposed new organization.

Figure 6.1 Proposed Operations Department

Job Title: Operations Manager

Job Description

- o Overall responsibility for operation and performance of network
- o Interface with system administrator
- o Establish and maintain standard operating procedures
- o Handle escalation with vendors and carriers
- o Provide management reports
- o Coordinate preventive maintenance schedules

Qualifications

Education: College degree

Experience

- o Three to five years in an Assistant Telecommunications Manager's position or equivalent with voice networking experience.
- o Experience in management of a complex communications system with particular emphasis on formulating the necessary procedures to achieve good operating efficiencies and control.
- o Experience in interfacing effectively with upper management in order to communicate goals, objectives and needs.
- o Experience in obtaining future growth trends from upper management, providing an orderly growth plan, and formulating system needs.

Employment Status: State employee (This position should not be a contract personnel.)

Job Title: System Administrator

Job Description

- o Supervise and coordinate activities of operators and technicians
- o Follow up special problem areas
- o Define operating procedures
- o Perform trend analysis, including system performance and trouble reports
- o Interface with vendors, carriers and station users as required

Qualifications

Education: High school graduate - some college preferred

Experience

- o Three to five years' first or second line supervisory experience in the telecommunications field.
- o Experience in dealing with vendors, carriers and users is required.
- o Three to five years' experience with a computerized switch desirable.
- o Three to five years' experience in voice network operations.
- o Good written and oral communications skills and ability to interface effectively with department heads and users.

Employment Status: State employee (This position should not be a contract personnel.)

Job Title: Telecommunications Analyst

Job Description

- o Analyze traffic reports
- o Perform ongoing circuit optimization analysis
- o Analyze rates and tariffs for current and new offerings
- o Make recommendations to management on new circuit configurations
- o Design and recommend associated routing tables
- o Perform savings analysis
- o Forecasting

Qualifications

Education: High school graduate

Experience

- o One to three years' Telecommunications Analyst experience.
- o Experience in working with rates and tariffs, assessing efficiency and effectiveness of telecommunications facilities, and making appropriate recommendations to correct deficiencies or respond to increased demand.
- o Mathematical, written and oral skills necessary.

Employment Status: State employee

Number of Positions: one at the central site

Job Title: System Operator I

Job Description

- o Database maintenance including add/change/removal of authorization codes, routing tables, ports, trunk groups, etc.

- o Maintain database activity logs

- o Load/update new programs

- o Maintain updated programs and database disks and tapes and the associated documentation

- o Monitor network status

Qualifications

Education: High school graduate

Experience

- o One to two years as a System Operator on any type of computer-based system with particular emphasis on database updating, new program loads, changing of log tapes and other computer related activities.

- o One to two years in telecommunications Field.

Employment Status: State employee

Number of Positions: one at the central site

Job Title: System Operator II

Job Description

- o Take trouble reports from users
- o Create Trouble Tickets
- o Retrieve Call Records
- o Perform first level trouble isolation
- o Dispatch technicians for repair
- o Follow up with the users
- o Log trouble tickets for follow-up
- o Interface and follow up with vendors and carriers
- o Cost justify access lines to the network
- o Backup System Operator I

Qualifications

Education: High school graduate

Experience

- o Two to three years of clerical and keyboard experience with some background in technical or telecommunications field.
- o Ability to communicate effectively with users.
- o Experience in working with rates and tariffs.

Employment Status: State employee

Number of Positions

- o 5 persons at the central site to provide 3 shifts/day and 7 days/week operations.

Job Title: System Technician (On-site)

Job Description

- o Preventive maintenance
- o Trouble isolation
- o Spare parts inventory maintenance
- o Transmission quality test
- o Transmission facility (digital radio) maintenance
- o Interface with carriers and vendors
- o Equipment installation
- o Maintain system hardware log
- o Station moves and changes (if combined PBX and tandem).

Qualifications

Education: High school graduate with two years of technical school (electronics) or equivalent

Experience

- o Two to four years in maintenance of minicomputers.
- o Some knowledge of data/voice communications and familiarity with use of oscilloscope, voltmeter and transmission test set.
- o FCC radiotelephone second class (first class preferred) license required for the technicians maintaining digital radio facilities.

Employment Status: State employee or on contract basis

Number of Positions

- o one at Austin for digital radio facility maintenance, covering four routes and ranging as far as Corpus Christi, to ensure visiting each repeater site at least once per month * .

- o two at Austin for tandem switch (over 1500 ports) maintenance.

- o two each at Dallas and Houston sites for tandem switch (over 1500 ports) maintenance and digital radio facility maintenance.

- o one each at Abilene, Harlingen, and Lubbock sites for tandem switch (500 to 1500 ports) maintenance and digital radio facility maintenance.

  At those sites where only a single technician is located, there are times when the site is not manned:

  (i) The technician spends one day every week visiting repeater sites.

  (ii) The technician is occasionally on vacation or sick.

  It is recommended that those locations be maintained using contract personnel. For this study, it is assumed that state employees are used, and the technician in Austin can provide backup. Furthermore, if there is a technician (after 1986) in each location for PBX maintenance, he can provide backup for the network maintenance technician and vice versa.

- o one per 750 stations at each "PBX" ** location operated by STS.

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* The digital radio facility maintenance policy is to visit every repeater site, within the territory of the node, at least once a month. The number of technicians for digital radio maintenance varies, depending on the accessibility of the sites because traveling time is the major component of time spent.

** As a conservative estimate, it is assumed that the staffing requirement for separate tandem and PBX switches, and for a combined system, will be the same.

Job Title: System Clerk

Job Description

- o Prepare telco circuit orders
- o Manage requests for authorization additions, changes or deletions
- o Coordinate authorization changes with personnel
- o Back-up system operators

Qualifications

Education: High school graduate with an aptitude for clerical duties in a technical field

Experience

- o One to two years in a Telecommunications setting such as interfacing with a telephone company business office or working in a telephone company business office.
- o Some typing or other keyboard experience.
- o Experience in communicating effectively with users.

Employment Status: State employee

Number of Positions: one at the central site

6.4.2 Salaries and Overhead Cost Derivation

The salary for each type of position can be derived from pay scales for the independent telephone industry. The data used in this study are based on the the report "Compensation and Benefits in the Independent Telephone Industry - 1982" published by the National Telephone Cooperative Association (NTCA). The pay scale is more sensitive to company size than to region. The average salaries for the companies with revenues over $5 Million * are used for this study, because they can reflect the pay scale for the STS network closer than the averages indicated by the South West Region.

Not surprisingly, the employees of Bell System carriers held a 24-percent average wage advantage over those of non-Bell carriers as revealed by a survey conducted by the U.S. Labor Department's Bureau of Labor Statistics. The wage advantage depends on the occupational category; statistics are only available for board job categories. For this study, the wage advantages of the Bell System employees are not included. Nevertheless the information, as shown in the report by the NTCA, provides a useful benchmark with which to gauge the relative salary positions of Bell System and independent telephone industry workers (i.e., what the competitive marketplace will be).

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* The STS total charges to the customers in the fiscal year 1981 were about $8.1 Million. It fell in the over $5 Million category.

Table 6.4 Staff Salary Estimates
(1982 Dollars)

Job Title	Telco Classification	NTCA average salary '82 $2 - $5 M Companies
Operations Manager	Assistant Manager	$39,757
System Administrator	Plant Superintendent	$32,620
Telecomm. Analyst	Computer Programmer	$22,302
System Operator I	Computer Programmer	$22,302
System Operator II	Plant Record Clerk	$15,695
Technician	Electronic Technician	$22,637
System Clerk	Commercial Clerk	$13,690

The following table estimated Staff salaries assuming all network personnel are available in 1985 and PBX personnel are available in 1986. The subtotals are for network operations only, and the total includes PBX staffs, who are all provided by the STS.

Table 6.5 Operations Department Staffing and Salaries (1982 Dollars)

	1985	1986	1987	1988	1988
Abilene					
Techn. (network)	1	1	1	1	1
Techn. (PBX)	-	1	1	1	1
Austin					
Operations Mgr	1	1	1	1	1
System Adm	1	1	1	1	1
Telecomm Analyst	1	1	1	1	1
System Op. I	1	1	1	1	1
System Op. II	5	5	5	5	5
Techn. (network)	3	3	3	3	3
Techn. (PBX)	-	8	9	9	10
System Clerk	1	1	1	1	1
Dallas					
Techn. (network)	2	2	2	2	2
Techn. (PBX)	-	5	5	6	6
Harlingen					
Techn. (network)	1	1	1	1	1
Techn. (PBX)	-	1	1	1	1
Houston					
Techn. (network)	2	2	2	2	2
Techn. (PBX)	-	11	11	12	13
Lubbock					
Techn. (network)	1	1	1	1	1
Techn. (PBX)	-	13	14	14	15
TOTAL Operations Department					
Operations Mgr	1	1	1	1	1
System Adm	1	1	1	1	1
Telecomm Analyst	1	1	1	1	1
System Op. I	1	1	1	1	1
System Op. II	5	5	5	5	5
Techn. (network)	10	10	10	10	10
System Clerk	1	1	1	1	1
SubTOTAL	20	20	20	20	20
$SubTOTAL	435,516	435,516	435,516	435,516	435,516
Techn. (PBX)	-	39	41	43	46
TOTAL	20	59	61	63	66
$TOTAL	435,516	1,318,359	1,363,633	1,408,907	1,476,818

In addition, it is recommended that the STS monitor FCC radio applications, using an outside consulting service, to identify any potential interference from new applications (at an estimated cost of $1,500/year).

To derive a total Telecommunications Division overhead cost, the following assumptions are used:

(1) The ratio of overhead cost to salaries in the Operations Department for fiscal year 1982 (Sept 1981 - Aug 1982),

168,740/157,899 = 1.0687,

is used for the expected overhead cost for the new Operations Department. In addition, $1,500 for outside consulting is added to get a net overhead cost for the department.

(2) In addition to salaries, the state-paid benfits totaling 24% of salary are added.

(3) All other departments: Administration, Customer Services, and Data Processing, remain at present staffing levels.

The estimated Telecommunications Division overhead costs are shown in the following table.

Table 6.6 Telecommunications Division Overhead Costs (1982 Dollars)

	1985	1986	1987	1988	1989
Adm.					
Salary	52,556	52,556	52,556	52,556	52,556
Overhead	79,219	79,219	79,219	79,219	79,219
Customer Svc					
Salary	132,680	132,680	132,680	132,680	132,680
Overhead	244,851	244,851	244,851	244,851	244,851
Operations					
Network					
Salary	435,516	435,516	435,516	435,516	435,516
Overhead	571,460	571,460	571,460	571,460	571,460
Network and PBXs					
Salary	435,516	1,318,359	1,363,633	1,408,907	1,476,818
Overhead	571,460	1,726,837	1,786,087	1,845,337	1,934,212
Data Processing					
Salary	79,139	79,139	79,139	79,139	79,139
Overhead	139,545	139,545	139,545	139,545	139,545
TOTAL					
Network Only					
Salary	699,891	699,891	699,891	699,891	699,891
Overhead	1,035,075	1,035,075	1,035,075	1,035,075	1,035,075
Network and PBXs					
Salary	699,891	1,582,734	1,628,008	1,673,282	1,741,193
Overhead	1,035,075	2,190,452	2,249,702	2,308,952	1,397,827

For network operations, the number of staff personnel in the Operations Department will increase from nine positions currently to 20 positions when the private network is installed. The Telecommunications Division overhead costs will increase from $670,251 to $1,035,067 when the new network is installed.

If the STS operates all PBX's as specified in the switch configuration, 39 additional technicians are required in 1986.

6.5 Spare Parts and Emergency Equipment Cost

Appropriate spare parts should be stored strategically in each network node site and central site to ensure that parts are readily available for repair. The general policy on spare parts inventory is that

(1) Spares for the parts which have a relatively "high" failure rate and do not have hot-standbys in the system are stored at each network site.

(2) Spares for parts which rarely fail or have hot-standbys in the systems are stored at the central site.

The spare parts allocations for the tandem switching systems, totaling approximately $364,000, are:

(1) $64,000 at Austin (Central Site) for CPU, memory, power supply, disk drive, magnetic tape drive and other common control equipment;

(2) $50,000 at each network node for termination cards and other non-redundant parts.

In each network node, there is an emergency power supply * for the tandem switch and the radio equipment at the tandem site. In addition, the emergency power supply in Austin also covers the stand-alone network management center. The costs of the emergency power supplies, totaling $147,000, are:

(1) $21,000 each at Abilene, Harlingen, and Lubbock - 30 KW each;

(2) $32,000 at Austin - 75 KW;

(3) $26,000 each at Dallas and Houston - 55 KW each.

---

* The emergency power supply uses natural gas fuel and has automatic transfer switches to act as an automatic standby power system.

The spare parts allocations for the PBX equipment ** are derived based on industry experience:

(1) The number of spare cards at each PBX location is approximately 0.5% of lines.

(2) Approximately $1,300 per card.

(3) The vendors' service centers have stocks of the less frequently failed parts and the parts with hot standbys.

The PBX equipment spares costs, totaling approximately $197,600, are:

(1) $3,900 at Abilene (assuming 600 lines);

(2) $42,900 at Austin (assuming 6500 lines);

(3) $26,000 at Dallas (assuming 4000 lines);

(4) $3,900 at Harlingen (assuming 600 lines);

(5) $55,900 at Houston (assuming 8500 lines);

(6) $65,000 at Lubbock (assuming 10,000 lines).

The spare parts allocations for the digital radio systems, totaling approximately $75,000, are:

(1) $20,000 at Austin for two different types of radio (i.e., 12 GHz and 6 Ghz) and centralized rare failed parts;

(2) $15,000 at Houston for two different types of radio;

(3) $10,000 each at Abilene, Lubbock, Dallas, and Harlingen site for single type of radio (6 GHz).

In addition to the spare parts, portable emergency power generators, which are trailer mounted, are required in case of power failure at repeater sites. The total cost for seven of these is $94,500; and that cost is broken down as follows:

(1) $27,000 (two supplies at $13,500 per unit) at Austin;

(2) $13,500 (one supply) at each other node (total of five).

** As a conservative estimate, it is assumed that spare parts allocations for the combined tandem and PBX system are approximately equal to those for separate tandem and PBX.

It is recommended that maintenance contracts be used for the network management system, starting at the second year, because their installed first costs include first year service. Spare parts will be maintained by the vendors. This eliminates spare parts inventory costs.

Table 6.7 Annual Maintenance Charge for Network Management Equipment (1982 Dollars)

Equipment	Maintenance Charge $/year
Transmission Quality Test Equipment	
Patch Panels (@600 under 1000 ports @1200 over 1000 ports)	5,400
Auto Test Sys (@1800 per system)	9,000
Subtotal	14,400
Minicomputer Network Management System	26,000
TOTAL	40,400

The maintenance charges for the multiplexers are low:

(1) $56/month per basic unit plus four power units, and

(2) $2/month per card.

They are negligible for this panning study. In additional, the spare modem costs are also negligible.

The price of the digital radio alarm and control equipment includes spare parts. Several spare test stations at $500/station are required. Their prices are negligible for this planning study.

The above cost calculations did not include repair vehicles, which are required to carry spare equipment for repeater site visits.

6.6 Repair Expenditures

The major repair expenditures are for switching and digital radio systems. They will become effective after the first year, which is covered by equipment warranties.

Tandem switching systems repair expenditures are derived from industry experience:

- o number of cards returned for repair per year is approximately 5% of the terminations.
- o approximately $150 per card for repair can be assumed.

Table 6.8 Tandem Switching Systems Repair Expenditures (1982 Dollars)

	1985	1986	1987	1988	1988
Previous year Terminations		7,172	7,655	8,138	8,621
$ Repair	-	53,790	57,413	61,035	64,658

The PBX systems expenditures * are derived from industry experience:

- o number of cards returned for repair per year is approximately 5% of the terminations.
- o approximately $265 per card for repair can be assumed.

* As a conservative estimate, it is assumed that the repair expenditures for the combined tandem and PBX system are approximately equal to those for separate tandem and PBX.

Table 6.9 PBX Systems Repair Expenditures (1982 Dollars)

	1985	1986	1987	1988	1988
Previous year Lines			27,320	28,975	30,630
$ Repair	-	-	361,990	383,919	405,848

Digital radio repair and miscellaneous expenditures, including painting of towers, are estimated at approximately $56,000 annually.

7 SYSTEM-LEVEL EVALUATION

7.1 Scope

In this section the significant alternatives for each of the network components are presented and evaluated individually and collectively so that recommendations regarding a cohesive STS network can be made. A detailed ecomonic analysis of each alternative plan is presented and supplemented with a discussion of non-quantifiable issues that impact the decision process leading to selection of the recommended arrangements. Section 8 will then contain a synopsis of recommendations as a result of the conclusions that are drawn herein.

7.2 Economic Evaluation

7.2.1 Introduction

This section examines the economic impact of the various alternatives on the State of Texas. In any economic study certain assumptions about the future must be made. These assumptions are described and sensitivities to variations from the chosen assumptions are examined. The specific areas of concern are the choice of the length of the study period, the discount rate, the inflation rate, expected changes in the tariff structures and treatment of owned assets at the end of the study.

The alternatives examined in this section are:

(1) The PMO @ P.07;

(2) The PMO @ P.02/P.01;

(3) Plan A - Replace CCSA with owned tandems;

(4) Plan B - In addition to Plan A replace Centrex with PBX's which are separate from the tandem switches;

(5) Plan C - In addition to Plan A replace Centrex with PBX's which are combined with the tandem switches.

These alternatives are described in Section 2. In addition, the economics of replacing Centrex and CCSA in Austin are evaluated separately.

The basic method employed is a discounted cash flow analysis. The cash flows for each year are totaled. Since money has a time value, a discount rate is applied to each year's expenditures to convert them into their equivalent 1984 worth. These equivalent 1984 dollars are then added together to arrive at the total cost of the project in 1984 dollars. This value is called the PWE or Present Worth of Expenditures for the project.

7.2.1.1 Austin Comparison

The replacement of the CCSA network by an owned tandem switch will provide significant savings in Austin. The PWE with an owned tandem is about $45.0M while the PWE when continuing with CCSA is about $55.4M.

Replacement of Centrex service with an owned PBX is also a clear cut winner. PBX ownership has a PWE of about $27M while the PWE with Centrex is more than $45.0M. For an investment of roughly $7M in 1986, annual charges of nearly $2.8M are eliminated for the remainder of the study period.

The economics for the separated PBX/Tandem and the combined PBX/Tandem are indistinguishable within the accuracy of the evaluation method.

It is clear from the economics that both the CCSA and Centrex tariffs should be replaced in Austin with owned systems.

7.2.2 General Considerations

7.2.2.1 Study Period

An important item in any economic analysis is the choice of the length of the study period. Too long a study period will favor ownership over a lease or tariff. Ownership requires a capital expenditure in the early years of the study and eliminates or reduces lease or tariff payments over the remainder of the study. Thus, the longer the study period the greater the savings will appear. Conversely, too short a study period will favor lease or tariff because the capital asset does not have enough time to recover its savings. The key to an accurate study is to choose a study period appropriate to the expected service lives of the major capital assets involved. In this analysis a ten-year study period was decided upon. There is a five-year growth period followed by a five-year complementary period in which no growth is considered. This approach enables all assets to be in use for at least five years before the study terminates and their remaining value must be assessed. During the complementary period annual charges are held constant, excluding inflation, and no capital additions are made.

The asset lives assumed for this study are as follows:

Table 7.1

Expected Equipment Service Lives

Asset	Expected Svc. Life (Yrs.)
Spare Parts	0
Modems	5
PBX Switch	7
Multiplexers	7
Test Equipment	10
Tandem Switch	10
Management Center	10
Radio System	15
Emergency Power Gen.	25

7.2.2.2 End-Of-Study Valuation

All of the above items are assumed to have a useful life of at least ten years. Thus, a modem placed in 1985 will not need to be replaced in 1990. The service lives above reflect the impact of changing technology. A piece of equipment may be replaced before it fails simply because equipment using more modern technology provides additional savings. Thus, the service life is only used to determine the value of the equipment at the end of the study period.

To determine the value of assets at the end of the study, an in-place value was arrived at. This assumes that the equipment remains in place for the remainder of its service life rather than being salvaged. The approach used was to linearly decrease the value of the asset from its full value to zero over the service life. Thus, at the end of five years a ten year asset will be valued at half of its value in terms of purchase year dollars. This amount will then be inflated by five years of inflation to determine its end-of-study value. This amount is then reflected in the PWE reduced by the discount factor.

The item which retains the most significant end of study value is the radio facility. To see how this is treated examine Table I.19 of Appendix I, STS Ownership of the Network (Plan A). Facilities are placed in 1984 through 1988. The total expenditure, in 1982 dollars, is $18,301,550. The inflated cost is $22,596,230. At the end of the study this has a remaining value of $8,208,900 in 1982 dollars, which after inflation becomes $19,140,180. This is reflected in the PWE using 0.3606 as the discount factor, see Table I.4, Alternative Plan A. Thus, the contribution to the PWE is ($6,901,949).

7.2.2.3 Discount Rate

Another item of debate in an economic analysis is what discount rate to use. This number, which is also called the cost of capital or the cost of money, represents the time value of money to the organization for which the study is being done. It is usually reflective of the organization's cost of borrowing, or its opportunities to use the money in other ventures which will yield a return. Although the State of Texas raises money through taxes and does not borrow, it should still consider the time value of money in any study. The State should work to minimize the burden on the taxpayer, who does have a cost of money. In this study a discount rate of 12% is used. This is consistent with figures presently used in industry and represents the expected long term cost of money.

A high cost of money will tend to favor lease and tariff charges over ownership. This occurs because a higher discount rate will cause future payments to have a lower present worth. Since the lease and tariff plans have more charges in later years they are help by a high discount rate.

Sensitivity to variations in the discount rate were examined. Tables I.7-I.11 and I.12-I.16 depict the various plans at discount rates of 14% and 10%, respectively.

The results are as follows:

Table 7.2

Discount Rate Sensitivities

Discount Rate:	10%	12%	14%
PMO (P.07)	$505.1M	$464.0M	$427.9M
PMO (P.02/P.01)	$562.5M	$516.2M	$475.6M
Plan A	$420.3M	$390.3M	$363.9M
Plan B	$341.4M	$321.5M	$303.8M
Plan C	$342.2M	$322.6M	$305.1M

Examination of the above table shows that although the magnitude of the savings is reduced at the higher discount rate, Plans A, B, and C still provide large savings over the PMO.

7.2.2.4 Inflation Rates

Another item similar to the discount rate is inflation. The use of a low inflation rate will tend to favor the tariff situation. Purchase has, as part of its appeal, the fact the major costs are fixed at the time of purchase, thus enabling the State to avoid lease cost increases due to inflation.

The inflation rates assumed for this study are as follows:

Table 7.3

Study Inflation Rates

Item	Rate
All assets	8%
Tariffs	9%
Labor	10%

Decreasing the inflation rate has an effect similar to increasing the discount rate.

7.2.2.5 Timing Of Payments

The assumption of annual payments is in fact an approximation. Lease and tariff payments are generally made monthly at the beginning of the month and capital expenditures may be made throughout the year. For ease of analysis this evaluation assumed that all payments are made at the beginning of the year. This assumption results in a higher PWE than would be obtained if a monthly analysis were run. However, as long as all plans have relatively evenly distributed payments over each year, each plan will be affected equally. As a comparison of a beginning-of-year assumption versus an end-of-year assumption, see Tables I.1 and I.2. Table I.1 assumes beginning-of-year payments and shows a PWE of $464.0M. Table I.2 assumes end-of-year payments and shows a PWE of $414.3M. A monthly analysis would most likely show a PWE of about $440M. Unless the monthly expenditures are strongly skewed to either the beginning or end of the year the actual PWE should be within $5M of this figure.

7.2.2.6 Tax Effects

Tax considerations are normally part of an economic study; however, since the State government is exempt from paying taxes this is not considered. Once the decision to purchase a piece of equipment has been made, the means of financing the acquisition should be examined. It is possible that leasing as an alternate means of financing may have tax advantages to the vendor which could be then passed to the State as lower lease rates. In general, however, the IRS disallows any agreements which have no purpose other than tax avoidance.

7.2.3 Analysis

7.2.3.1 PMO (P.07)

The cash flow analysis for the PMO @ P.07 grade of service is shown in Table I.1. The table which shows supporting details for those cash flows is shown in Table I.17. As with the other support sheets all expenditures are shown first in 1982 dollars. These figures are then inflated based on the year of occurrence to arrive at the figure used in the cash flow analysis. Examining Table I.17, the sources of the data are as follows:

The tandem switch costs were calculated from the CCSA tariff. How this is determined is shown in Appendix H.

The initial IMT charges through half of 1986 are based on a number provided by STS [reference telephone conversation with

A. F. Glavan]. Midway through 1986 it is assumed that the TELPAK tariff will be gone and private line charges will apply. Determination of the cost of the IMT's charged at private line rates is carried out in Appendix H.

Other facility costs include access lines, tie lines, ONALs, LONALs and data. These figures are arrived at in Appendix H.

The initial WATS charges through half of 1986 are based on a TSD-provided figure [reference telephone conversation with A. F. Glavan]. In mid-1986 it is assumed that WATS will jump to a higher rate. The charges at the higher rate are determined in Appendix H.

Centrex/PBX costs are the costs for all the State agencies. This is based on the existing tariff charges for the Austin Centrex which was provided by STS [ref. Capitol Centrex - Comparison of Current SWB Rates versus Rates Filed Jun 21, 1982]. These rates were then applied to Abilene, Dallas, Harlingen, Houston and Lubboc based on line size as shown in Table 5.2.

The determination of system administration costs is carried out in Chapter 6.

The cash flow analysis is shown in Table I.1. The cumulative cash flow for the PMO @ P.07 is $824,407,240. The discount factor is:

$$\frac{1}{(1+ \text{Cost of Capital})^{n}}$$

where n is the number of years from the start of the planning period to the year of placement.

The cumulative discounted cash flow in 1993 is the present worth of the annual expenditures (PWE). For the PMO @ P.07 the figure is $464,023,410.

7.2.3.2 PMO (P.02/P.01)

The cash flow for this plan is given in Table I.3, and the source information is in Table I.18.

The only difference here from the previous analysis is that in mid-1985 the figures for the tandem (CCSA), the IMT's and the other facilities increase to provide for a better grade of service. These figures are derived in Appendix H.

The PWE for this plan is $516,198,830. Thus a $52M PWE increase is required to provide the level of blocking which would be achieved on the owned network.

7.2.3.3 Plan A

The cash flow for this plan is given in Table I.4, and the source information is in Table I.19.

This plan replaces the CCSA network with owned tandem switches. The CCSA charges through mid-1985 are the same as with the PMO. From the latter half of 1985 to the end of the plan they disappear. Tandem switch costs are derived in Section 5.

This plan also replaces the IMT facilities with an owned radio system. IMT charges through mid-1985 are also the same as the PMO, and then they also disappear.

Due to the use of the radio facilities, the cost of other leased facilities drops from the PMO in mid-85. These figures are described in Appendix H.

Cost figures for the radio facilities come from Section 4.

Ownership of the tandem network requires expenditures for maintenance equipment and additional labor costs. These are derived in Section 6.

For this plan the PWE is $390,318,280. This is a PWE savings of $73.7M over the PMO @ P.07 and a savings of $125.9M over the PMO expanded to the same grade of service.

7.2.3.4 Plan B

The cash flow for this plan is given in Table I.5, and the source information is in Table I.20.

In this plan Centrex is replaced by owned PBX's at all State agencies. Only one half the Centrex tariff is applied in 1986 as the PBX systems are turned up. The bulk of the PBX costs occur in 1986, as described in Chapter 5. Only one half of the cost of the 1988 addition is used in the analysis, because it is a two-year addition.

Additional system administration costs are included to account for PBX maintenance.

The PWE of this plan is $321,544,730. This represents a $68.8M PWE saving over Plan A, indicating that Centrex replacement is clearly advantageous, given the assumed prices and rates.

7.2.3.5 Plan C

The cash flow for this plan is given in Table I.6, and the source information is in Table I.21.

In this plan the PBX functions are combined with those of the tandems. It differs from Plan B in the tandem and PBX costs, in the charges for access lines, and in the additional costs for a management center.

The PWE for this plan is $322,572,380 which, within the accuracy of this analysis, is equivalent to the PWE of Plan B.

7.2.3.6 Austin Comparison

The cash flow analysis sheets for the Austin comparison are given in Appendix J. The source data is in Chapter 5. From Table J.1 the PWE for the PMO is $55,408,180. Table J.2 shows that the PWE when CCSA is replaced by an owned tandem is $44,985,160, yielding a savings of about $10.4M over retaining the CCSA. Tables J.3 and J.4 show that owned PBX's replacing the Centrex save an additional $17.9M. There is no economic difference between the separate tandem/PBX and the combined tandem/PBX alternatives.

7.2.4 Conclusions

7.2.4.1 Network Plans

In looking at Plan A versus the PMO, it is clear that ownership of the tandems and radio facilities yields significant savings. Plan A has a PWE of a little over $390M. The PMO with the present grade of service has a PWE of about $464M. While increasing the grade of service on the PMO to match that provided by the radio system would produce a PWE of more than $516M. Thus, ownership of the tandems and radio facilities will save at least $74M in 1984 dollars while providing a significantly better grade of service.

Plans B and C consider the replacement of all Centrex and leased PBXs at State agencies with owned PBXs. In Plan B the PBX is separate from the tandem switch and in Plan C the PBX is an integral part of the tandem switch. The economic analysis shows virtually no difference between Plans B and C. However, either plan yields an additional PWE savings of more than $67M over Plan A.

It is clear that the State of Texas should own its tandem network and the PBXs providing service to the State's agencies. Network ownership saves at least $74M and PBX ownership another $67M for a total PWE savings of at least $141M over the life of the study.

7.3 Intangibles

7.3.1 Switching

From the economic analysis it is clear that significant reductions in communications costs for the various State agencies that now subscribe to Southwestern Bell's CCSA and Centrex services will be achieved with the purchase of private tandem and PBX switching systems. BNR strongly recommends that Texas proceed in that direction. It is not clear, however, what the best choice is between the combined and separate PBX/tandem alternatives. Both alternatives offer similar economic benefits; technology benefits are identical; and there are no significant differential implications associated with dependent plans.

There are some aspects of the two alternatives that bear further discussion, however. Universal implementation of the combined PBX/tandem solution at all (or nearly all) six tandem sites would require that STS (or some single agency) take on the operational responsibility for both functions. This is required, because it is not feasible to separate the maintenance or administration of the PBX portion from that for the tandem. The combined processor has a single complement of operating software for both functions and could only be accessed by a single technician for diagnostic or translation update purposes at a given moment in time. This would reduce the quantity of I/O devices somewhat, but the economic effects are trivial. The single operating agency would be responsible for dealing with all system troubles and the possibility of introducing a centralized system for the direct reporting and clearing of user troubles would exist. This could produce some improved levels of responsiveness, and user perceptions of service might improve slightly. If STS were to assume the responsibility for all six sites and they were served by combined PBX/tandem switches, the STS staff requirements for operational support would increase as follows:

Table 7.4

Staffing Requirements

Existing	9 people
Tandem network only	20 people
Tandem network+Austin PBX	28 people
Combined PBX/tandems	59 people

This excludes the 16 people presently required for administration, customer service and data processing.

There would be some unquantifiable maintenance benefit associated with the combined arrangement, since the processor complement would be reduced. However, the bulk of the personnel are required to service the demand generated by the switch terminations, not the common control; therefore, the benefits are relatively insignificant. Since PBX's are volatile in comparison to the tandems (due to the high level of station moves and changes), there is some additional element of higher risk to the stability of the tandem network when the functions are combined. When a PBX failure occurs it affects the local user community only; when a tandem fails, the effects are more far reaching. The arguments for and against the combined vs. the separate approach are not strong enough to suggest that one arrangement is clearly preferable to the other overall; therefore, BNR cannot recommend a specific arrangement at this time. The results of competitive bidding in the marketplace may reveal some economic difference that is presently not known.

7.3.2 Operations

To some observers, ownership of a private switching network and associated facilities could be a burden and might result in a lowering of service. The implementation of a centralized network management arrangement as described in this study could actually result in an improvement in the perceived level of service for several reasons. BNR's experience has shown that many of today's telephone company-based "private" network arrangements do not provide levels of transmission and call completion performance that are comparable to those of the public telephone network. This is primarily a result of the inadequacy of the operational procedures employed by the telephone companies for private network management. These private arrangements are not similar to the operational centers and capabilities available for the public network, even though the same organization operates both.

In recent years, vendors of private switching systems and facilities have introduced operational control systems that actually place more control in the hands of the private network owner than the telephone companies provide for their CCSA and PBX customers. This is especially true in the area of transmission performance monitoring and testing. Presently, the testing of private line circuits that are leased and maintained by the telephone company (or other common carriers) are on a link-by-link basis, usually accomplished once a month. No complete end-to-end circuit testing is ever accomplished unless there is a reported trouble which cannot be cleared through the normal sectionalized maintenance process. In contrast to this, BNR is recommending the installation of a network management center that includes the automatic performance testing of STS's circuits on a programmed basis, resulting in the testing of each circuit on a weekly basis. These transmission tests are conducted on an end-to-end basis, that is, from the test center to a telephone line termination at each and every local switch in the STS network, whether owned or leased from the telephone company. In this manner, STS should be able to detect and correct transmission troubles before user complaints (and dissatisfaction) build up.

7.4 Conclusions

As documented and discussed in each of the technology sections and finally as weighed by the detailed economic analysis included in this section, it is clear that STS will achieve significant economic benefits from ending it's lease arrangements with the telephone companies, for both network and local telephone switching systems, in favor of direct ownership. It also has been demonstrated that significant economic benefits are associated with ownership of much of the private line facilities serving the STS network. These benefits are obtainable with payback of the capital investments in approximately two years of operation. The full costs of maintenance and administration of the network and facilities have been included in these evaluations.

When the alternatives are considered in toto, the economic benefits of the ownership plans are dramatic in terms of absolute savings. Depicted in the chart below are the aggregate savings for the total STS and PBX arrangement.

Table 7.5

PWE Savings Summary

Plan	PWE	PWE Savings (P.02)		PWE Savings (P.07)	
PMO (P.02)	$516M	-		-	
(P.07)	$464M	-		-	
A (radio+tdm)	$390M	$126M	24%	$ 74M	16%
B (radio+tdm+PBX)	$322M	$194M	38%	$142M	31%
C (radio+tdm/PBX)	$323M	$193M	37%	$141M	30%

From the summary shown above it appears that more than 60% of the economic savings are derived from the network and the remaining 40% from the end-office segments.

It is BNR's recommendation that STS should proceed with a plan to obtain ownership of the tandems and facilities that comprise the STS network. Additionally, either STS or some combination of other agencies should begin the process to migrate away from the various Centrex and other leased telephone arrangements and obtain ownership of their own PBX's.

8 RECOMMENDED PLAN

8.1 Overview

Two plans are recommended, depending on whether STS operates the PBX's in all network node locations (Plan C) or not (Plan B), as discussed in Section 7. This section details implementation plans including equipment, staffing, and capital and expense requirements. In addition, floor space requirements are specified.

8.2 Implementation Plan

8.2.1 Equipment Requirements

The implementation schedules are broken into three parts: radio, tandem switching/network management and PBX. They are coordinated to provide a smoothly phased service transition.

The important considerations for the radio installations are:

- o One aspect of path survey activity includes land acquisition. Any delay in land acquisition will cause total project delay.
- o The FCC permit process may be sped up, through the use of a communication lawyer.
- o Radio installation requires multiple crews. Installation activity needs to be coordinated.
- o Firm frequencies need to be sent to the vendor three months, at most, after the contract is granted. Specific frequencies may be changed during the licensing processing.
- o Be familiar with Part 94 of FCC rules and regulations: Private Operational-Fixed Microwave Service. Subpart E is particularly relevant in dealing with the licensing process.

The important considerations for the switch/management center installations are:

- o Separate regular power plants for switches and radio are recommended. Note the fixed emergency power can be shared.
- o Transmission facilities must be in place and operational two months before switch cutover.

- PBX activity starts after all tandems are cut over.
- Customer (STS) PBX translation data needs to be sent to the vendor six months before cutover.
- Floor loading should be verified (vendor-dependent).
- Fire codes regarding batteries, engine alternators and fuel storage are location-dependent.
- Coordination of RF emissions and susceptibility between switches and radio is required.
- Verify air circulation and/or conditioning for switches and radio vs. building capabilities.

```
             1983          |              1984          |              1985
J F M A M J J A S O N D|J F M A M J J A S O N D|J F M A M J J A S O N

v-------v
radio path
  survey

        v-v
        prepare RFQ

          v-----------v
         RFQ         award

                     v-v
                     prepare appl. to FCC

                       v---------v
                       appl.     FCC
                       FCC       permit

                              Build Radio Site
                      v----v-------v----------v-------v-------v
                         firm    1st ship      cut     cut     cut
                        frequencies            1st grp 2nd     3rd
```

First Group:

Austin-San Antonio

Austin-Abilene

Second Group:

Austin-Dallas

Lubbock-Abilene

Third Group:

Austin-Houston

Harlingen-San Antonio

Figure 8.1 Radio Installation Schedule

```
       1983             |        1984             |        1985
J F M A M J J A S O N D|J F M A M J J A S O N D|J F M A M J J A S O N

          v------------------v-----------v-------v-------v-------v
          RFQ              switch       1st     cut     cut     cut
                           award        ship  1st grp   2nd     3rd
```

First Group:

Austin Tandem	(Local A.L. + San Antonio + Network Management)
Abilene	(Local A.L. + Brownwood)

Second Group:

Dallas	(Local A.L. + Waco)
Lubbock	(Local A.L.)
Austin	(Temple + Belton + Killeen)

Third Group

Houston	(Local A.L.)
Harlingen	(Local A.L. + Corpus Christi + Kingsville)
Austin	(Bryan)

Figure 8.2 Tandem and Network Management Installation Schedule

```
          1985                        1986
J F M A M J J A S O N D|J F M A M J J A S O N D

v-------------v----------v--------v-------v
RFQ          1st        cut      cut     cut
             ship     1st grp    2nd     3rd
```

First Group:

Austin

Abilene

Second Group:

Dallas

Lubbock

Third Group

Houston

Harlingen

Figure 8.3 PBX Installation Schedule

8.2.2 Staffing Requirements

Staffing requirements for administration/customer service/data processing, network operations and PBX operations are shown in Table 8.1. The key position is that of system administrator who ensures proper operation of the network.

Table 8.1 Staffing Requirements
(number of persons)

	1984	1985	1986	1987	1988
Adm/Cust Svc/DP	16	16	16	16	16
Ntwk Op.	9	20	20	20	20
Total (Ntwk Only)	25	36	36	36	36
PBX Op.					
Abilene	-	-	1	1	1
Austin	-	-	8	9	9
Dallas	-	-	5	5	6
Harlingen	-	-	1	1	1
Houston	-	-	11	11	12
Lubbock	-	-	13	14	14
Subtotal	-	-	39	41	43
Total (Ntwk+PBX)	25	36	75	77	79

8.2.3 Capital and Expense Requirements

This section summarizes the capital and expense requirements for the recommended plans (Plans B and C). The tables which follow describe the year-by-year planning level costs for the two alternatives in nominal (inflated) dollars. In the case of a stand-alone tandem, the operation of the PBX's at each of the tandem locations might or might not be the responsibility of

STS. This alternative's requirements are as follows:

Table 8.2

Capital and Expense Requirements, Stand-Alone Tandems
($000)

	1984	1985	1986	1987	1988
Capital					
Tandem	$1,569	$7,858	$0	$683	$0
PBX	$0	$258	$44,022	$0	$2,481
Radio, Modems, Multiplex	$8,631	$15,429	$647	$1,239	$1,184
Network Mgmt	$0	$1,948	$35	$38	$42
Subtotal	$10,200	$25,493	$44,704	$1,960	$3,707
Expense					
Leased Facilities	$15,472	$16,742	$19,346	$22,707	$27,242
Leased PBX/Centrex	$17,641	$20,554	$13,841	$4,468	$5,206
Leased Tandems	$2,692	$1,574	$0	$0	$0
Operations (Network)	$811	$1,378	$1,697	$1,873	$2,067
Operations (PBX)	$0	$0	$1,692	$2,539	$2,937
Subtotal	$36,616	$40,248	$36,576	$31,587	$37,452
TOTAL	$46,816	$65,741	$81,280	$33,547	$41,159

After the initial installation period, between 1984 and 1986, all added capital costs are primarily for line cards and related items. The radio system does have one expansion during the study period, taking place in 1987, to accommodate anticipated growth in circuit demand.

In the case of a combined PBX/tandem, STS would own and operate all of the PBX's that were being used as tandems. In this case there is a small facilities saving in that some local access lines would be eliminated. This alternative's requirements are as follows:

Table 8.3

Capital and Expense Requirements, Combined PBX/Tandems
($000)

	1984	1985	1986	1987	1988
Capital					
Tandem	$2,004	$12,726	$0	$431	$0
PBX	$0	$258	$42,593	$0	$2,236
Radio, Modems, Multiplex	$8,631	$15,429	$647	$1,239	$1,184
Network Mgmt	$0	$2,601	$35	$38	$42
Subtotal	$10,635	$31,014	$43,275	$1708	$3,462
Expense					
Leased Facilities	$15,472	$16,403	$19,020	$22,328	$26,802
Leased PBX/Centrexs	$17,641	$20,554	$13,841	$4,468	$5,206
Leased Tandems	$2,692	$1,574	$0	$0	$0
Operations (Network)	$811	$1,378	$1,735	$1,915	$2,133
Operations (PBX)	$0	$0	$1,692	$2,539	$2,937
Subtotal	$36,616	$39,909	$36,288	$31,250	$37,058
TOTAL	$47,251	$70,923	$79,563	$32,958	$40,520

An examination of the capital and lease costs for Austin illustrates some of the differences in capital requirements between the two alternatives. It should be noted that operational costs, which are identical in both alternatives, are not listed.

Table 8.4

Capital and Lease Requirements, Austin Only
Separate PBX ($000)

	1984	1985	1986	1987	1988
Capital					
Tandem	$1,179	$1,274	$0	$213	$0
PBX	$0	$0	$9,668	$0	$540
Lease					
Centrex	$3,853	$4,488	$3,020	$971	$1,132
Leased Tandem	$978	$570	$0	$0	$0
TOTAL	$6,010	$6,332	$12,688	$1,184	$1,672

Table 8.5

Capital and Lease Requirements, Austin Only
Combined PBX/Tandem ($000)

	1984	1985	1986	1987	1988
Capital					
Tandem	$1,716	$1,854	$0	$119	$0
PBX	$0	$0	$8,630	$0	$483
Lease					
Centrex	$3,853	$4,488	$3,020	$971	$1,132
Leased Tandem	$978	$570	$0	$0	$0
Facility Savings	$0	$0	($97)	($225)	($261)
TOTAL	$6,547	$6,912	$11,553	$865	$1,354

8.2.4 Other Considerations

The floor space requirements are shown in Table 8.6. They include equipment, power, walkway, and working space requirements. Space for spare parts is not included.

Table 8.6 Floor Space Requirements (square feet)

	Tandem	PBX	Radio	Patch Panel	Ntwk Center	TOTAL
Abilene	300	660	120	20	-	1,100
Austin	850	910	150	80	30	2,020
Dallas	750	860	120	60	-	1,790
Harlingen	300	660	120	20	-	1,100
Houston	700	1060	120	50	-	1,930
Lubbock	300	1160	120	20	-	1,600

MAJOR USERS OF THE STS NETWORK

APPENDIX A

1 MAJOR USERS OF THE STS NETWORK

This appendix describes some of the major users of the STS network. These descriptions are the result of numerous interviews with State employees responsible for these agencies' communications.

1.1 University of Texas System

1.1.1 Organization

The University of Texas System is composed of the University's seven general academic institutions, four health sciences facilities, two specialized hospitals, one observatory, two marine science bases, and the Museum of Texan Cultures in San Antonio. The four health science facilities serve one or more of the following functions: medical school, graduate school of medical science, and school of nursing.

The general academic campuses of UT are located in Austin, El Paso, San Antonio, Tyler, Dallas, Arlington and Odessa. The health institutions are located in Galveston, Dallas, San Antonio and Houston. There are approximately 115,000 students in the UT System, in addition to System employees.

In addition to UT, there are 33 other State-supported colleges and 70 junior colleges, including the University of Houston, Texas Tech and Texas A&M. Each of these institutions have their own data processing and communications systems. A description of the existing situation at Texas Tech is included later in this chapter.

1.1.2 Voice

UT Austin is currently served by a Centrex system. All outgoing long distance calls pass thru a Watsbox, which provides for user authorization, least cost routing and call detail recording. STS access is currently provided via the Watsbox. The Centrex is in the process of being replaced by a Northern Telecom SL-100 PBX. In fiscal 1981 UT Austin expended $145,000 on STS voice services for over 1.5 million minutes of use, while the entire system expended approximately $820,000 for over 8.96 million minutes of use.

1.1.3 Data

For the most part, the academic campuses do not have major data traffic between them. However, there is a shared development of computer programs for business applications under way currently. The package is being develcped for the Dallas, San Antonio and El Paso campuses by a vendor. This project is sponsored by the UT System but will not be used immediately on all the campuses. In the future, the program may be centralized and made available for use by all the campuses. The applications include student records, financial aid, admissions and an accounting package.

The Marine Science bases (2 locations--both on the coast), and the Observatory have communications requirements between each other. They presently do not transmit data electronically, however, but fly it between locations.

UT Austin, and possibly other UT campuses, participate in a nationwide library network called the Amigos network. It is funded by both public and private institutions and is an on-line library cataloging system developed by the Ohio College Library Center. This system saves $1 per volume in cataloguing costs. Similar library networks exist around the country, and there is reportedly a movement at the national level to integrate several of these activities.

At UT Dallas there are IBM 4300 series computers running both business and research applications as well as a microwave data transmission facility

There are small "office automation" trials in many locations. The top administrative officials at UT San Antonio have terminals. The Dallas Health Science center has over 100 Displaywriters.

One campus has an IBM 5520 system. Another 5520 is located in the building where the meeting was held in Austin, with experimental links to all 14 establishments of the UT System. Austin has three separate Ethernet pilots; this is also a collaborative effort with Xerox on a beta-test basis.

1.1.4 Video

In general it was said that the demand for video is not great today, but is foreseen as "strong on the horizon." Clearly the future use of video by the UT system is seen as quite important. The topic of video applications and the feasibility of video transmission on the new state network came up repeatedly during the interview.

The University currently uses video for a variety of applications. For example, the South Texas Medical Center has a closed circuit TV system using coaxial cable. There is a TV application developing as part of medical training, wherein a TV camera follows a doctor on his rounds through a hospital and is remotely viewed by students. In general, the medical professions have a requirement for continuing education. Relicensing in the State depends on passing an examination, and TV could be used for these update medical courses.

There is also a network among many of the educational institutions and classrooms located at area businesses in the Dallas-Fort Worth area. This microwave network, known as the Tager system, carries one-way television and two-way voice communications. The university uses a microwave transmission system between Austin and San Antonio to provide TV-based courses on engineering subjects at both locations. There are currently plans to expand this system via coaxial cable.

A subcommittee of the Dean's Council at UT Austin is investigating the need for video (applications and transmission facilities) statewide. The College of Engineering would like to offer educational video in business locations around the State. A discussion is taking place currently between the University and the local cable company in Austin.

1.2 Texas Tech University

1.2.1 Organization

Texas Tech consists of two organizations: Texas Tech University and Texas Tech University Health Science Center (the medical school), which are separate and distinct entities. Although these two organizations are separate, the same individuals are on both boards, and the President of the University is also the President of the Health Science Center.

1.2.1.1 Texas Tech University

Enrollment totals 23,000 at the university, with the vast majority of the students at the main campus in Lubbock. The university also operates the Texas Tech University Center at Amarillo and the Texas Tech University Center at Junction, as well as an agricultural field laboratory in Lubbock County and an agricultural research and teaching facility in Terry County. University enrollment is expected to remain stable or drop slightly over the next five years, due to the declining birth rate.

1.2.1.2 The Health Science Center

The Health Science Center's main facility is on the Texas Tech campus in Lubbock. This facility consists of classrooms and offices for the medical school and a Hospital that is associated with the medical school (Lubbock General Hospital). The medical school has clinics (with associated medical education facilities) in Amarillo, El Paso, and Odessa. The medical school also has clinics in Claude, Shallowater, Wilson, Crosbyton, Dallas, Ft Worth and San Benito.

Medical students typically spend their first two years in Lubbock and then go to one of the outlying clinics (Amarillo, El Paso or Odessa). In Amarillo the Health Science Center runs an Academic Center, a family practice and an ambulatory care clinic, and it utilizes an associated teaching hospital (the county hospital). The facilities in El Paso are similar, with an academic center, a family practice, orthopedic and psychiatric clinics, as well as an associated teaching hospital (again a county hospital). The Medical School is currently setting up similar facilities in Odessa and is in the process of building a permanent facility (no medical students yet). The emphasis on medical education at several locations is due to the shortage of doctors in the rural areas of West Texas. Currently There are approximately 20 counties in West Texas that do not have a single doctor.

The Health Science Center future plans include establishing schools of Pharmacy and Veterinary Medicine (both of which have been approved and await funding). With the University student enrollment leveling off or possibly declining in the future, the Health Science Center is the only area of the University likely to see major growth.

1.2.2 Voice

The University's facilities are served by two Centrexs, both of which are implemented on the same 1A ESS with Generic 6 software (the two function as one for access codes and intercom functions). One of the Centrexs handles Texas Tech traffic, while the other is used for the Health Science Center. This was done to provide separate attendant consoles, both of which are maintained 24 hours a day. The Health Science Center has approximately 250 stations, of which 150 are in patient rooms, while Texas Tech has 8,000 stations, of which 4,000 are in student rooms. The Centrex is also used as an access point to STS by nearby State agencies. A total of 25 to 30 STS access lines connect the Centrex to the Abilene switch. The Office of Communications Services, which is responsible for university telecommunications services, is currently using CICS and several 3270 series terminals to provide directory assistance. The university utilizes Dimension 400 switches in Amarillo and El Paso to serve the Health Science Centers in these cities (these systems each have approximately 200 stations). The Amarillo facility has access to STS via West Texas State (Canyon,TX), while the El Paso facility has access via UT El Paso. Each of these facilities has 4 STS access lines and 3 dial tie lines to the Lubbock Centrex. When the Odessa facility is completed, it is expected to have similar facilities. Other outlying university facilities are served by business lines and key sets. Dimension users have access to the Lubbock Centrex's WATS and STS facilities using the dial tie lines. These users, as well as traveling university employees using In-WATS, access these facilities using a system called Tech-Net (a trade mark of Texas Tech). This system is accessed by using a special trunk code off the Centrex. The system verifies that the user is authorized by using a 5-digit identification code and then provides a CDR function collecting the data necessary to bill back the call. The Lubbock Centrex is likely to remain for the near term due to the high cost of rewiring the campus, which is quite spread out. The use of an ETN network to connect the Dimensions to the Centrex is being explored, but the economics of this option are unclear at present. In fiscal 1981 Texas Tech expended over $117,000 on STS voice services for 752,000 minutes of use for the University and 528,000 for the Health Science Center.

1.2.3 Data

Texas Tech is currently served by an IBM plug-compatible ITEL computer (now National Advanced Systems), and a Burroughs minicomputer, while the Health Science Center is served by an older IBM mainframe. Texas Tech currently has about 200 terminals, of which half are used by students and half are for administrative purposes. Currently 150 local data lines connect these terminals to the mainframes.

The volume of data communication between the campus and outlying locations is quite limited at this time. It consists of some traffic to public data bases (primarily library use, although the University Police access a Department of Motor Vehicles data base) and the transmission of accounting and client billing information from the clinics back to Lubbock. Four 2400 baud lines connect terminals located at the Amarillo and El Paso clinics to the Health Science Center computer (two lines for each clinic). An additional two 2400 baud data lines to Lubbock will be added when the Odessa clinic becomes fully operational (A local area network may be installed in the new clinic, possibly Datapoint's ARC).

The only near term expansion in inter-location data communications is the addition of the two data lines to Odessa. At present no other change in inter-location data traffic is anticipated.

1.2.4 Video

There is little demand for full motion video at present. Audio conferencing is used between the clinics and Lubbock, and the possibility of utilizing high resolution freeze frame video has been explored. A conferencing system is needed to connect Nurse Practitioners located in rural counties that lack doctors to the hospital in Lubbock. At this time FX circuits to Lubbock are the likely near term solution.

1.3 Texas Education Agency

1.3.1 Organization

TEA was created in 1948 by the Gilmer-Aikens Act. The CEO is appointed by the State Board of Education, and heads a 24-member board. There are 900 employees in the Agency, of which 850 work in Austin. This year, the Agency paid out $3.9 billion to the school districts, constituting 60% of school budgets for the year. The "big seven" school districts account for 30-40% of the children served. They are located in Austin, Dallas, Houston, San Antonio, El Paso, Fort Worth and Corpus Christi.

The entities involved in the Education Agency are: the districts where the schools are located; 20 Regional Service Centers which provide administrative services to clusters of districts; the Texas Education Agency; local Field Offices of the Agency; and the Board of Education. These are not exactly hierarchically arranged. The School Districts and the Service Centers report to the Board of Education. The agency Field Offices report to the Agency. The Agency reports to the Board.

1.3.1.1 School Districts

School districts are unique geographical divisions that do not correspond to other political or geographic units. They are autonomous, and their existence is guaranteed by the state constitution. They have their own taxing power. In addition to taxes, the districts also obtain revenues from oil lands. There is a permanent school fund with dividends of $3.9 million per year. In addition to the regular school districts, there are vocational schools and schools for the deaf and blind. The latter report directly to the Board of Education, while the vocational schools report to the TEA. The school districts comprise about 70% of the agencies activity and responsibility.

1.3.1.2 Service Centers

There are 20 Regional Service Centers which provide administrative services to clusters of school districts. Given the guaranteed existence of each school district, i.e., the fact that they cannot be forced to consolidate, the Service Centers provide an important mechanism for the maintenance of the smaller school districts, since they provide administrative functions that would otherwise be too costly for the individual districts to carry. At the other end of the size spectrum, some districts, such as those in the large urban areas, contain their own service center. A Service Center handles from 1 to 25 school districts.

The functions provided are administrative services, data processing, records, reporting, and communications. The Service

Centers are not controlled by the Education Agency, nor are the Service Center personnel on the Agency payroll. However, the Board of Education sets policy for the Centers.

The primary communications the Service Centers make are with the School Districts. There are frequent communications between the Agency and the Service Centers, because the Agency does not have its own computing equipment, and district information is reported to the Agency through the Service Centers.

1.3.1.3 Other

The TEA also supports small offices (two to three employees per office) in several locations throughout the state. Schools for the blind and deaf report directly to the Board of Education, and vocational education is also handled by the TEA.

There is an Audit Division of the TEA that manages accreditation of schools. Each school district is audited each year, remotely. Every five years each district is visited by an auditor. There are also accounting services. Accounting is said to be complex because of various sources of funding for the districts and the Agency. The Agencies budget is nearly 50% Federal. The Federal monies go to support Federal programs such as school lunches, bussing, and special education. Not all of the schools accept the Federal funding, in which case they don't have to comply with programs such as bussing. However, most do accept the funding and the programs.

The biggest Agency program dealing with outside individuals is the certification program for teachers. Apparently there is a high probability of error in filling out the certification forms. This concerns initial certification mainly. Apparently the books are quite out of date (they go back 100 years), and teachers long since dead are still certified and on the books. For the current certifications, applicants may be denied certification erroneously. Or applicants may call in to ask for assistance in filling out the forms. In either case, a good deal of phone traffic is generated.

Finally, there is a consulting staff that does research and advises on teaching methods and a legal staff that hears appeals from school districts or from citizens.

1.3.2 Current Equipment and Communications Costs

The STS service has been good, though they are currently experiencing a deterioration in the grade of service to certain large metropolitan areas such as Houston at the peak time (2 PM). They do not currently have DID, so all calls to the Agency go through a receptionist, which is inconvenient. Phone expenses in 1981 were: $183,000 on STS, $337,000 to Bell; Total = $520,000. For 1982 projected phone expenses are $190,000 on STS, $406,00 on Bell; Total = $596,000.

They have had three major reorganizations since 1979, which proved very expensive in moves and changes. This August the Agency will move 75% of its personnel to a new building; and in 1985 the entire Agency will move closer to the Capitol area.

The Service Centers use IBM 370's for the most part, though since each Center has its own purchasing authority for items under $10,000, there is some diversity of equipment. Communication paths for information between the Service Centers and the Agency were not defined in interviews with the TEA. For documentation, the centers were using magnetic card or tape typewriters. Negative experiences with these devices have caused this to be discontinued

1.3.3 Plans and Needs for the Future

The accounting system is complex due to the diversity of revenue sources and the variety of entities reporting to the Agency, and variety of entities the agency reports to. These accounting functions could be a future source of data communications traffic. Office automation is something they feel they need. However, the initiation of such technology is possibly set back by the bad experience with magnetic card and tape typewriters described above. At present there are no plans for video, and no specific plans for data communications.

1.4 Mental Health and Mental Retardation (MHMR)

MHMR is the largest State Agency. There are 25,000 employees serving 35,000 residential clients. Services are also delivered to 135,000 other citizens through outpatient facilities. The total budget is $500 million a year, approaching $1 billion for the legislative biennium.

There are 29 residential facilities, located throughout the State, principally in small towns. The two major categories of residential facility are hospitals for the mentally ill and schools for the mentally retarded.

There are four State Centers for Human Development, including a residence facility in Houston, an outdoor recreation site in Leander and a central headquarters in Austin.

MHMR works closely with 30 Community Mental Health and Mental Retardation Centers. These are city or county functions which deliver mental health services. The State supports 50% of the costs of communicating with these locations, and providing related equipment.

There are 540 geographically separate locations where outpatient services are provided. Some are small offices; some are parts of the hospitals mentioned above.

1.4.1 Current Communications

1.4.1.1 Voice

The larger locations are served by 28 PBX's, and a Centrex. Most of these local switches are Dimension PBX's, if in a Bell area. There are some ROLM CBX's in the areas served by GTE.

In addition to supporting communications for the agency itself, MHMR telecommunications also serve other State users in the areas where they are located. MHMR facilities are often the largest State agencies in the cities where they are located, so they feed other STS supported locations. One operator at each such location will be the STS operator. There are hundreds of phones at each of the larger sites (29 major). There is no SMDR in most locations due to cost.

Much of the traffic is between Austin and the facilities scattered throughout the state. The facilities also make calls to the families of clients. There are some out-of-state communications to Washington D.C. Most of the phones are restricted from DDD on the regular network, but DDD calls can be made on the STS network. Central headquarters places the Long Distance calls through a PBX operator to control use. In fiscal 1981 MHMR expended $38,500 for 408,800 minutes of use on STS for voice services.

1.4.1.2 Teleconferencing

MHMR has a new teleconferencing system, in operation since 12/8/81. It is a Bell system, called Comnet, serving 28 locations with SS4 signalling. There are 2059 miles of TELPAK lines for Comnet, and 114 miles of non-TELPAK lines.

Since the network has been up a fairly short time, usage is probably light compared to what it will eventually be. Nevertheless, there have already been significant increases. It started out in January with 10 hours, rose to 35 hours in March and 45 hours in April. Usage so far appears to be 35% recurring administrative meetings, 40% ad hoc administrative meetings, and the remainder professional (consultations and meetings). The system is said to be substantially displacing travel costs. It has been estimated that $11,000 were saved in travel costs for the first three months, as compared to normal travel costs before the installation of the system. The installation costs are amortized over five years.

The facilities are five rooms per location, equipped with jacks. It was decided to make the arrangements flexible so that meetings can be accommodated as required, rather than have single rooms dedicated to teleconferencing. The main problems are with the non-Bell locations. The circuits are dedicated 24 hours a day.

Also under review with the Community Services are plans to add a 30-node separate teleconferencing network for the local mental health centers. This is planned as separate from the existing teleconference network, so as to avoid having to deal with a 60-node network. A 4-wire to 4-wire bridge to UTHSA will be built between the two.

Fifty percent of the funding for this second network, serving the Community Health Centers, will come from the State. Each center is otherwise independently funded by the locality it serves. All of the centers will come onto the teleconferencing network at once, since there is no point in having a partial network. This will add 2000 miles of STS lines and 150 miles of non-STS.

1.4.2 Data Communications

MHMR has extensive data communications In addition, they are currently asking for bids to improve the design and extend this network. (See Data Communications Plans below.)

The current network is a 4-wire, 4800 baud multi-drop, leased line unconditioned network. A small portion of it is not on STS. There are 15 nodes at separate locations, all of which are MHMR facilities. The network is a 3270-type ETS, using Harris 3270 terminals and Paradyne MP48 modems.

1.4.2.1 Current Information Flows

In addition to RJE, information is shipped in from sites by US mail or bus. Accounting information is sent daily from the State facility schools and hospitals. It is entered locally at the sites on paper forms and keyed in by data entry in Austin. Personnel data, payroll, and client records are also received from the sites. Summary accounting reports are mailed or bussed back to the sites monthly.

The client records are collected manually at the facility, and excerpts subsequently entered on data entry forms, then keyed in at Austin. There are three client application systems: one for residential clients, one for outpatients, and a third whose purpose wasn't determined by the study team. There are approximately 100 fields of information per client, which differ across these systems. A new system design is planned for the client applications, which will unify the three separate ones now being used. This database will be structured with 150 elements that combined the fields for the three different groups. Thirty-five of these fields will be common to all of the types of clients.

The 30 Community Health Centers send in workload and performance measures quarterly. This is currently sent in on paper and keyed in at Austin.

Another database comes from the pharmacy system. There are 15 locations with terminals connected to a service bureau in Dallas/Fort Worth. There is a printer and one or two CRT's at each site, about 90% of which communicate over STS. The pharmacy system is also about to undergo change as early as this summer, because of litigation potential and past problems in the area of client medication. While the operation of the pharmacies themselves is similar to any retail pharmacy operation, there is a requirement to record the activity to have better and more current records of prescriptions made to clients. For this reason, the pharmacy operation will be installed as a standalone now and connected to the new network (see below) when it comes up.

1.4.2.2 Data Communications Plans

As stated above, MHMR currently has an RFQ out for a DDP network design. The circuits on the new network are expected to be the same as on the existing one, except that 9600 baud will be used from Austin out to the first drop. The legs from these points out will be unconditioned 4800 Baud. In addition to the nodes on the plan, there will also be lines to the community centers, which will be brought in to the data network 4-6 months after the installation of the major nodes. The community centers will be tied to the closest facility. An unresolved question, which will be addressed by the new design, is how much of the processing will take place at the local sites.

The system is expected to be installed in the 83-84 time frame.

1.5 Department of Highways and Public Transportation

The Department of Highways and Public Transportation is one of the most technologically advanced of the State Agencies. Apparently it is also famous outside the State for its on-line highway engineering capability. The Agency produced an outstanding document on office automation plans, describing the history, computer applications, current equipment and future plans for office and design technology. This document is used as a model of office automation and DP planning for other agencies.

1.5.1 Organizational Structure

The Department of Highways has one or more maintenance sections in each of the 254 counties in the State. There are 25 District Offices, and a total of 180 resident engineers, not quite one per county. There are a total of 16,000 Agency employees, of which about half work on road crews.

The actual offices outside of Austin contain only few people each. However, these have close communications with Austin via data communications and radio. Data communications were in fact described as their "life's blood". Both highway engineers building new highways and maintenance crews need to be in constant contact with Austin because of legal and property issues that can arise when any change in plan occurs.

The Department is organized in a pyramidal fashion. The District Engineer represents the Highway Department in each district. Under him are the residencies and the maintenance foreman. The maintenance foreman is the contact between the work crews and the Highway Department. Each maintenance foreman is responsible for one section of road. When rights of way have to be purchased for new construction, this is negotiated at the local level by the District Engineer. The construction of new highways is managed in serial fashion as the construction passes through each district.

Austin approval is required for almost everything the people in the field do, because of political, economic and environmental impact issues, in addition to the fact that private property is often involved. Since the work sites constantly move, communications to the field are handled by 2-way radio. There is a radio station in each of the 254 counties. There are 4000 units with 2-way radios. Every construction project has a project office. There are 600 project offices, with 15 employees per project. They currently envision having three CRT's per project office.

1.5.2 History

The nature of the operations has had a direct impact on the technological advancement of the Department. This impact has spread from the original area of need to every other aspect of the Department's operations. Since the use of computer technology has by their report been highly successful, there is no reason why it won't continue to spread to office applications that are just coming on the market.

Highways used to be designed using field parties and drag chains to determine the contour of the land. Then photogrammetry was introduced, whereby the area was flown over and photographed with a stereoptic camera, digitizing the outline of the terrain. Today, navigational satellites are used.

Contours can be determined in almost real-time this way: within 72 minutes of the pass, the elevation of a point can be determined to within one millimeter. Instead of mag tape, the data is recorded by dialling in. They consider that their system of work is "expanding every time they turn around." Now they are concerned with whether they should be using digital or analog transmission.

The design facility that is used is a state of the art package of Integraph software running on a VAX 11/70. The program stores four billion bits of geographical information, and a substantial portion of the State's topography is already on-line, including every shed and telephone pole that sits on the ground. Roads can be drawn and redrawn over the same terrain until a satisfactory design is achieved, in real time. Changes can be called in and even drawn in from the field for real time approval.

Sophisticated design facilities (see below) and interactive data communications enable changes to be approved in real time which otherwise would have taken several days in the mail. Given that crews work with a "hot mix" that must be used in the same day, the capability to issue real-time approvals produces a significant savings in both materials and labor.

1.5.3 Current Equipment -

A detailed description of current computing equipment is contained in the document issued by the Department. It was decided not to duplicate the effort of describing this in the interview. Following are mention of some of the functions served.

The engineering graphics application, which is doubtless the Department's most unique, most advanced and most expensive single application, has been described above in Section][

In connection with this application, there are CRT's in the field over which field engineers can consult with the engineer in Austin. There are 260 such field terminals now. Within two years there will be CRT's in most of the residencies and maintenance sections. It is projected that there will be 1200 of these by 1984, to accommodate which there are plans to add 120 data circuits.

There is an electronic mail package in use, which was acquired in conjunction with a programming package called ROSCOE, sold by Applied Data Research. The districts use this package for electronic mail and for writing reports. Since there are far more individuals than terminals, they supplement the electronic mail system with phone calls to notify recipients that mail is waiting for them. The original acquisition of ROSCOE terminals 4 years ago was 9. The number has gone to 240 in the interval, and stopped there only because of a shortage of memory to support more. There is a requisition in now for an additional 135, and the memory is being added. Only half the districts currently have access to ROSCOE. The growth of this system led them to comment the situation is getting out of hand, meaning that the demand for the terminals and the service will probably continue at the same rate they are supplied.

It is expected the penetration of such CRT's will extend to every field office in the State. In addition to the current topography and highways stored in the VAX, there is a history on every mile of road in the State for the purpose of scheduling repairs. This is also a useful tool for verifying citizens' claims about the condition of roadways in the event citizens appear before the Commission and demand repairs to sections of road.

The online topography itself has multiple levels of resolution, so that it can display the entire State at a top level, and window down successively to a single mile of road.

Word processing is in widespread use. The equipment used is CPT. These are not communicating word processors.

Phone equipment currently in use is almost exclusively Dimension. For data communications they utilize General Data, Racal Milgo, Bell, and Paradyne modems.

In fiscal 1981 the Department expended $443,800 for 4.72 million minutes of use of STS switched voice circuits. During the same period the Department obtained over 16,800 miles of dedicated voice grade circuits from STS.

1.5.4 Plans

Given that the Department has a more than ordinary requirement for real-time data communications, there was a concern expressed that the network design for the State might focus too heavily on voice.

Another concern for the future network is the question of line speed. They need 9600 baud for the engineering application, but don't want to pay the cost of 9600 for the other applications.

A third concern they have is that the new network be able to accommodate future expansion, which they feel is generally underestimated. They feel their agency is "just beginning to touch the tip of the iceberg" in data communications requirements. They "have all but opened a post office," and reflected on "how insignificant something starts off as compared to how it ends up." This comment was supported by the example of the history of how roads are designed.

One thing that was felt to influence the demand for data communications in the Department was population increase. They have found a direct correlation between population shifts within the State, and the amount of data they end up transmitting between a particular locale and Austin.

They are already dealing with equipment incompatibilities, though mainly it concerns the difference between the engineering graphics package that runs on the VAX, and everything else.

The current plan for highway construction extends out 20 years and is continually updated. Funding is acquired through State government bonds. Construction was formerly funded from gasoline tax. These taxes fell behind in 1977-78. The 78 Legislature devised a new funding scheme. The plan involves cost-indexing based on 1977 dollars.

1.6 Texas Employment Commission

The Texas Employment Commission is a federally funded agency. It has 3 State-appointed Commissioners, each of which serves a 6-year term. The Commission receives no State funding at all.

Federal funding is issued on an annual basis, in conformance with a a 5-year plan, which is updated annually. This year, funding was cut from the plan.

The Commission was described as decentralized with 150+- locations around the State. Offices open and close according to the demand for services. As the labor force shifts, the Commission addresses the needs.

There are 10 managerial zones, each with a 5-15 person staff.

Current information flows involve employment information, job orders, referrals, applicant information, as well as the tax information from employers, all being reported in from the field locations, processed and summarized in Austin, and returned to the field locations periodically in summary form. There is also a job bank with clearance of job orders between districts.

The major functions are unemployment insurance and job orders. They tend to fluctuate in inverse ratio, so that as one goes up the other goes down, maintaining a relative balance of data activity between them.

There are 1-1.25 million applications on file. The initial claim loads are 15,000 a week for a total of 503,000 in 1981. Continuing claims amount to 125-150,000 a week. A population flow of 1000 a week into the State, mainly for the purpose of finding employment, adds constantly to the number of applications being processed.

The data communications facilities are not now used for normal administrative functions, such as internal accounting and payroll. They are used exclusively for the functions that directly serve the public. The DP group would like to expand into using the communications facilities for the administrative support functions.

In addition to the transmission of data, many phone calls are generated by the need to clarify this data. In addition, management-type functions are carried out over the telephone in conjunction with personal interviews.

A form of teleconferencing is practiced to facilitate client-employer confrontations in the case of disputes over the reasons for termination as they affect clients' candidacy for benefits. This is currently conducted from the client's homes, but there are plans to expand this teleconferencing capability.

1.6.1 Equipment

Equipment currently in use is IBM 3776 terminals at 7200 baud, and System 3's at 9600. They use Codex modems, 3271-type control units, 3705 front-end, all dedicated. Between 7am and 6pm they operate in TP mode, then switch to RJE. The Austin office uses IBM System 6 and Displaywriters for word processing.

There are some 20-25 PBX's in use which consist of: Dimension 400's, 100's, one Dimension 2000, a ROLM CBX, and some 770-756 and other older PBX's in the 300 series. Some areas use automatic dialers for job services (there are 23 of these in all). Since applicants are usually out during the day looking for work, the dialers phone them at night with recorded messages notifying them to call the office about an employment opportunity. A large office will have 3 or 4 of these automatic dialers. There is also line monitoring equipment, and a diagnostic patch board. This equipment was assembled for the Commission by a systems house, Atlantic Research. There are dial-up communications to Washington, via WATS, as well as TWX. Some communications to Washington are also handled by MCI microwave transmission.

Other out-of-state communications include data communications to Louisiana for claim exchange information. This out-of-state information exchange will probably extend to other states once agreements are reached.

There is currently production of one-way video cassettes for training of two kinds. These are produced in TV production studios in the agency. One use is for the training of TEC employees in the use of CRT's, how to make a claim, etc. Another is a short instruction session for clients on how to fill out an application.

In fiscal 1981 the Commission used STS for three million minutes at a cost of $281,000.

1.6.2 Plans

A major area of planning which will affect transmission is the possibility of interstate job banks. These are by no means firm plans, and major compatibility problems exist. However, there are currently direct communications with Louisiana, and a manual exchange between Texas and Arkansas in an office that spans the state line. The type of labor in question is migrant farm labor, and the States involved would be all those States using such labor: California, Florida, Arkansas, New Mexico, Oklahoma, Wisconsin, Illinois, Kansas, Missouri, Minnesota, and Oregon.

In other areas, their current organization plan is geared to minimize new employees and maximize automation. The tax workload increased 27% in 1977-79, but they were able to decrease staff by 14%, by using electronic media.

In addition to the System 6's and Displaywriters already in use, they want a system that will make a host and disk look like a personal computer on a terminal. Currently they have not seen any terminals that meet their full multi-function requirements.

There are plans to buy a new DP system, two 3033's. It is also possible that DDP will be used to relieve the main architecture, this has already been done in some departments. There is a possibility of installing an SNA network in Austin. Offices with a lot of activity need a local processor for word processing, as well as access to a (remote) mainframe.

The teleconferencing system described above is due for expansion. It is hoped that 20% of the client-employer consultations, or 12,000 cases annually, will be able to be handled by teleconferencing. TEC locations with teleconferencing facilities will be used instead of the conference call through a switch that is currently used for this purpose.

Also being developed is a managerial video conferencing between districts.

CURRENT FACILITIES OF AND RECENT

STATISTICS FROM THE STS NETWORK

APPENDIX B

SWITCH SIZE

Switch	IMT	A/L Local	A/L Inter-City	LONALS	ONALS	NPA Wats
Austin	289	396	520	33	212	31
Abilene	104	53	191	8	95	27
Dallas	175	101	357	60	163	43
Houston	192	206	311	80	132	31

CITIES SERVED BY SWITCH

Austin Switch	A/L	ONALS/LONALS	Switches PBX	Switches CTX
Alice	---	4	---	---
Austin	916	245	46	2
Bastrop	1	4	---	---
Belton	6	---	---	---
Brownsville	8	7	2	---
Burnet	1	---	---	---
Carrizo Springs	1	---	---	---
Corpus Christi	54	16	8	---
Del Rio	2	---	1	---
Edinburg	19	12	2	---
Gatesville	1	3	---	---
Georgetown	1	4	---	---
Gonzales	1	---	---	---
Harlingen	28	7	5	---
Kerrville	6	4	1	---
Killeen	3	6	---	---
Kingsville	13	4	1	1
La Grange	1	---	---	---
Laredo	13	6	5	---
Lockhart	1	---	---	---
McAllen	8	---	2	---
New Braunfels	---	4	---	---
Pharr	11	---	1	---
Port Aransas	5	---	---	---
Rockdale	1	---	---	---
Rockport	3	---	---	---
Round Rock	1	---	---	---
San Antonio	102	31	10	2
San Marcos	1	6	---	---
Seguin	4	4	---	---
Sinton	1	---	---	---
Taylor	1	4	---	---
Temple	10	8	2	---
Uvalde	5	---	3	---
Victoria	15	6	1	---
Waco	35	12	6	---
Yoakum	6	---	1	---

Switches

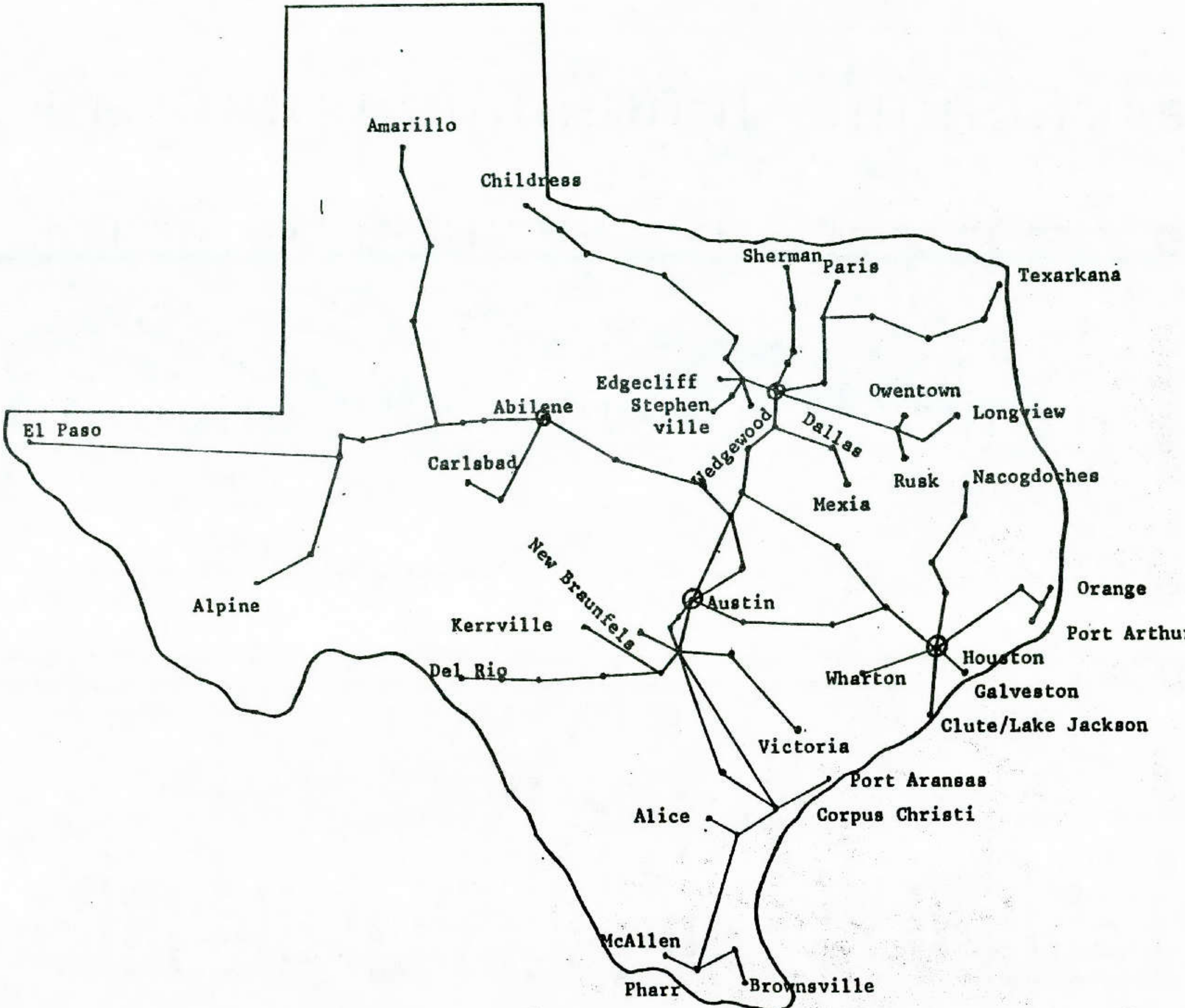
Abilene Switch	A/L	ONALS/LONALS	PBX	CTX
Abilene	244	103	7	---
Alpine	5	---	1	---
Amarillo	35	8	9	---
Big Spring	7	4	1	---
Brownwood	13	5	3	---
Canyon	7	---	1	1
Carlsbad	4	---	1	---
Eastland	1	---	---	---
El Paso	17	11	---	1
Fort Stockton	3	---	---	---
Lubbock	39	11	2	---
Midland	16	---	2	---
Odessa	19	---	3	---
Paducah	1	2	---	---
Plainview	2	5	---	---
Pyote	1	---	1	---
San Angelo	17	6	1	1
Sweetwater	2	---	1	---
Snyder	2	---	1	---
Terminal	---	10	---	---

Dallas Switch	A/L	ONALS/LONALS	PBX	CTX
Arlington	35	---	6	1
Athens	5	4	1	---
Atlanta	6	---	1	---
Canton	1	---	---	---
Childress	4	---	1	---
Commerce	11	---	1	---
Corsicana	10	4	2	---
Dallas	458	123	11	3
Denton	27	9	3	1
Duncanville	3	---	---	---
Farmers Branch	6	---	---	---
Fort Worth	55	24	9	---
Gainsville	3	---	1	---
Garland	1	---	---	---
Grand Prairie	2	---	---	---
Greensville	6	5	---	---
Hallsville	1	---	1	---
Holiday	1	---	---	---
Howe	1	---	---	---
Hurst	2	---	1	---
Hutchins	1	---	---	---
Kaufman	1	---	---	---
Kilgore	3	4	---	---
Lockett	3	---	1	---
Longview	16	6	3	---
McKinney	---	5	---	---
Mexia	6	---	1	---
Mt. Pleasant	---	4	---	---
Overton	4	---	1	---
Owenton	5	---	1	---

Dallas Switch (cont.)	A/L	ONALS/LONALS	Switches PBX	CTX
Paris	16	4	3	---
Renner	4	---	1	---
Richardson	16	---	---	1
Rusk	7	---	1	---
Sherman	5	6	1	---
Stephenville	7	---	2	---
Sulphur Springs	3	---	---	---
Sunnyvale	6	---	1	---
Terrel	6	3	1	---
Texarkana	7	6	2	---
Tyler	40	9	6	---
Vernon	4	3	1	---
Wichita Falls	27	7	6	---
Waxahachie	---	3	---	---

Houston Switch				
Alvin	2	---	1	---
Angelton	3	4	---	---
Beaumont	---	12	4	2
Brenham	---	5	1	---
Bridge City	---	13	---	---
Bryan	5	10	1	---
College Station	53	---	1	---
China	2	---	---	---
Cleveland	1	---	---	---
Clute-Lake Jackson	---	7	---	---
Conroe	9	6	1	---
Crockett	2	---	1	---
Deer Park	2	---	---	---
Dickenson	1	---	---	---
Galveston	49	---	3	1
Houston	517	212	23	4
Huntsville	41	7	4	---
Livingston	1	---	---	---
Lufkin	13	7	1	---
Nacogdoches	17	7	2	1
Nassua Bay	1	---	---	---
Pasadena	2	---	---	---
Pierce	1	---	---	---
Port Arthur	3	---	1	---
Prairie View	12	---	---	1
Richmond	5	---	1	---
Rosenburg	6	---	1	---
Rosharon	9	---	1	---
Springwater	1	---	---	---
Sugarland	5	---	1	---
Texas City	2	12	1	---
Wharton	2	4	---	---

STS ROUTING


Amarillo
Childress
Sherman
Paris
Texarkana
Edgecliff
Stephenville
Owentown
Longview
Abilene
El Paso
Carlsbad
Wedgewood
Dallas
Rusk
Nacogdoches
Mexia
New Braunfels
Austin
Alpine
Kerrville
Orange
Port Arthur
Houston
Del Rio
Wharton
Galveston
Clute/Lake Jackson
Victoria
Port Aransas
Alice
Corpus Christi
McAllen
Pharr
Brownsville

STS Switched Voice and Dedicated Data

Circuit Growth by Fiscal Year

Switched Voice

Fiscal Year	Switches	Intermachine Trunks	Access Lines	ONALS & LONALS	Area Code Circuits	Tie Lines	Detached Stations	Customer Location
1981	4	358	2,067	777	127	101	769	1251
1980	4	355	1,900	775	125	249	764	1222
1979	4	353	1,637	743	126	315	787	1118
1978	4	335	1,478	704	114	312	761	1087
1977	4	305	1,341	627	99	323	700	1006
1976	4	269	1,245	597	99	296	674	964

Dedicated Data Circuits

Fiscal Year	Subvoice Grade Mileage	Voice Grade Mileage	Total Mileage
1981	476	96,351	96,827
1980	587	68,193	68,780
1979	694	59,624	60,318
1978	1,845	54,770	56,615
1977	3,944	40,461	44,405
1976	10,030	30,960	40,990

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MONTH-YEAR (WORK DAYS)	OCT 81(21)	NOV 81(17)	DEC 81(21)	JAN 82(19)	FEB 82(19)	MAR 82(22)	AVERAGE
TOTAL NETWORK ORIGINATING MINS	5,751,735	4,735,475	5,075,625	5,285,830	5,643,905	6,159,615	5,442,031
TOTAL AUSTIN ORGINATING MINS.	2,595,460	2,119,985	2,291,050	2,397,525	2,459,680	2,800,650	2,444,058
% TOTAL NETWORK ORIGINATING	45	45	45	45	44	45	45
TO AUSTIN	1,149,890	934,210	1,024,690	1,062,970	1,084,930	1,234,275	1,081,828
% TOTAL AUSTIN ORIGINATING	44	44	45	44	44	44	44
TO DALLAS	589,455	484,030	519,360	556,810	557,385	639,700	557,790
% TOTAL AUSTIN ORIGINATING	23	23	23	23	23	23	23
TO ABILENE	265,550	212,565	221,365	238,030	248,140	281,720	244,562
% TOTAL AUSTIN ORIGINATING	10	10	10	10	10	10	10
TO HOUSTON	590,565	489,180	525,635	539,715	569,225	644,955	559,879
% TOTAL AUSTIN ORIGINATING	23	23	23	23	23	23	23
TOTAL NETWORK TERMINATING MINS	5,751,735	4,735,475	5,075,625	5,285,830	5,643,905	6,159,615	5,442,031
TOTAL AUSTIN TERMINATING MINS	1,922,990	1,562,545	1,703,550	1,763,620	1,843,060	2,064,810	1,810,096
% TOTAL NETWORK TERMINATING	33	33	34	33	33	34	33
FROM AUSTIN	1,149,890	934,210	1,024,690	1,062,970	1,084,930	1,234,275	1,081,828
% TOTAL AUSTIN TERMINATING	60	60	60	60	59	60	60
FROM DALLAS	235,410	191,430	204,585	218,135	218,720	250,430	219,785
% TOTAL AUSTIN TERMINATING	12	12	12	12	12	12	12
FROM ABILENE	137,390	105,365	119,925	123,215	170,945	154,015	135,143
% TOTAL AUSTIN TERMINATING	7	7	7	7	9	7	7
FROM HOUSTON	400,300	331,540	354,350	359,300	368,465	426,090	373,341
% TOTAL AUSTIN TERMINATING	21	21	21	20	20	21	21

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A U S T I N SWITCHER

MONTH-YEAR (WORK DAYS)	OCT 81(21)	NOV 81(17)	DEC 81(21)	JAN 82(19)	FEB 82(19)	MAR 82(22)	AVERAGE
ON-NET TERMINATING MINUTES	663,965	519,375	556,825	572,750	602,590	663,485	596,499
% TOTAL AUSTIN TERMINATING	35	33	33	32	33	32	33
OFF-NET TERMINATING MINUTES	1,259,025	1,043,170	1,146,725	1,190,870	1,240,470	1,401,325	1,213,597
% TOTAL AUSTIN TERMINATING	65	67	67	68	67	68	67
ONAL TERMINATING MINUTES	1,001,605	836,965	908,390	951,115	994,900	1,112,435	967,568
% OFF-NET TERMINATING	80	80	79	80	80	79	80
NPA TERMINATING MINUTES	257,420	206,205	238,335	239,755	245,570	288,890	246,029
% OFF-NET TERMINATING	20	20	21	20	20	21	20

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D A L L A S SWITCHER

MONTH-YEAR (WORK DAYS)	OCT 81(21)	NOV 81(17)	DEC 81(21)	JAN 82(19)	FEB 82(19)	MAR 82(22)	AVERAGE
TOTAL NETWORK ORIGINATING MINS	5,751,735	4,735,475	5,075,625	5,285,830	5,643,905	6,159,615	5,442,031
TOTAL DALLAS ORGINATING MINS.	1,066,975	897,080	960,995	977,535	1,013,370	1,124,770	1,006,788
% TOTAL NETWORK ORIGINATING	19	19	19	18	18	18	19
TO AUSTIN	235,410	191,430	204,585	218,135	218,720	250,430	219,785
% TOTAL DALLAS ORIGINATING	22	21	21	22	22	22	22
TO DALLAS	629,300	527,165	575,425	582,450	604,320	658,290	596,158
% TOTAL DALLAS ORIGINATING	59	59	60	60	60	59	59
TO ABILENE	59,770	52,255	53,855	55,715	57,980	66,315	57,648
% TOTAL DALLAS ORIGINATING	6	6	6	6	6	6	6
TO HOUSTON	142,495	126,230	127,130	121,235	132,350	149,735	133,196
% TOTAL DALLAS ORIGINATING	13	14	13	12	13	13	13
TOTAL NETWORK TERMINATING MINS	5,751,735	4,735,475	5,075,625	5,285,830	5,643,905	6,159,615	5,442,031
TOTAL DALLAS TERMINATING MINS	1,552,615	1,281,825	1,386,915	1,453,155	1,512,795	1,676,410	1,477,286
% TOTAL NETWORK TERMINATING	27	27	27	27	27	27	27
FROM AUSTIN	589,455	484,030	519,360	556,810	557,385	639,700	557,790
% TOTAL DALLAS TERMINATING	38	38	37	38	37	38	38
FROM DALLAS	629,300	527,165	575,425	582,450	604,320	658,290	596,158
% TOTAL DALLAS TERMINATING	41	41	41	40	40	39	40
FROM ABILENE	89,405	75,000	83,895	88,275	124,970	124,880	97,738
% TOTAL DALLAS TERMINATING	6	6	6	6	8	7	7
FROM HOUSTON	244,455	195,630	208,235	225,620	226,120	253,540	225,600
% TOTAL DALLAS TERMINATING	16	15	15	16	15	15	15

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D A L L A S SWITCHER

MONTH-YEAR (WORK DAYS)	OCT 81(21)	NOV 81(17)	DEC 81(21)	JAN 82(19)	FEB 82(19)	MAR 82(22)	AVERAGE
ON-NET TERMINATING MINUTES	210,660	169,260	188,530	191,695	190,535	221,170	195,308
% TOTAL DALLAS TERMINATING	14	13	14	13	13	13	13
OFF-NET TERMINATING MINUTES	1,341,955	1,112,565	1,198,385	1,261,460	1,322,260	1,455,240	1,281,978
% TOTAL DALLAS TERMINATING	86	87	86	87	87	87	87
ONAL TERMINATING MINUTES	961,050	799,050	844,110	905,455	940,445	1,036,575	914,448
% OFF-NET TERMINATING	72	72	70	72	71	71	71
NPA TERMINATING MINUTES	380,905	313,515	354,275	356,005	381,815	418,665	367,530
% OFF-NET TERMINATING	28	28	30	28	29	29	29

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A B I L E N E SWITCHER

MONTH-YEAR (WORK DAYS)	OCT 81(21)	NOV 81(17)	DEC 81(21)	JAN 82(19)	FEB 82(19)	MAR 82(22)	AVERAGE
TOTAL NETWORK ORIGINATING MINS	5,751,735	4,735,475	5,075,625	5,285,830	5,643,905	6,159,615	5,442,031
TOTAL ABILENE ORGINATING MINS.	571,935	463,800	501,900	533,465	759,520	650,650	580,212
% TOTAL NETWORK ORIGINATING	10	10	10	10	13	11	11
TO AUSTIN	137,390	105,365	119,925	123,215	170,945	154,015	135,143
% TOTAL ABILENE ORIGINATING	24	23	24	23	23	24	23
TO DALLAS	89,405	75,000	83,895	88,275	124,970	124,880	97,738
% TOTAL ABILENE ORIGINATING	16	16	17	17	16	19	17
TO ABILENE	284,380	232,540	249,225	265,355	386,980	302,390	286,812
% TOTAL ABILENE ORIGINATING	50	50	50	50	51	46	49
TO HOUSTON	60,760	50,895	48,855	56,620	76,625	69,365	60,520
% TOTAL ABILENE ORIGINATING	11	11	10	11	10	11	10
TOTAL NETWORK TERMINATING MINS	5,751,735	4,735,475	5,075,625	5,285,830	5,643,905	6,159,615	5,442,031
TOTAL ABILENE TERMINATING MINS	668,875	549,275	579,790	616,700	753,005	713,330	646,829
% TOTAL NETWORK TERMINATING	12	12	11	12	13	12	12
FROM AUSTIN	265,550	212,565	221,365	238,030	248,140	281,720	244,562
% TOTAL ABILENE TERMINATING	40	39	38	39	33	39	38
FROM DALLAS	59,770	52,255	53,855	55,715	57,980	66,315	57,648
% TOTAL ABILENE TERMINATING	9	10	9	9	8	9	9
FROM ABILENE	284,380	232,540	249,225	265,355	386,980	302,390	286,812
% TOTAL ABILENE TERMINATING	43	42	43	43	51	42	44
FROM HOUSTON	59,175	51,915	55,345	57,600	59,905	62,905	57,808
% TOTAL ABILENE TERMINATING	9	9	10	9	8	9	9

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A B I L E N E SWITCHER

MONTH-YEAR (WORK DAYS)	OCT 81(21)	NOV 81(17)	DEC 81(21)	JAN 82(19)	FEB 82(19)	MAR 82(22)	AVERAGE
ON-NET TERMINATING MINUTES	162,435	130,690	136,795	147,495	178,455	187,340	157,201
% TOTAL ABILENE TERMINATING	24	24	24	24	24	26	24
OFF-NET TERMINATING MINUTES	506,440	418,585	442,995	469,205	574,550	525,990	489,628
% TOTAL ABILENE TERMINATING	76	76	76	76	76	74	76
ONAL TERMINATING MINUTES	311,700	254,585	261,155	291,330	338,980	322,280	296,672
% OFF-NET TERMINATING	62	61	59	62	59	61	61
NPA TERMINATING MINUTES	194,740	164,000	181,840	177,875	235,570	203,710	192,956
% OFF-NET TERMINATING	38	39	41	38	41	39	39

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H O U S T O N SWITCHER

MONTH-YEAR (WORK DAYS)	OCT 81(21)	NOV 81(17)	DEC 81(21)	JAN 82(19)	FEB 82(19)	MAR 82(22)	AVERAGE
TOTAL NETWORK ORIGINATING MINS	5,751,735	4,735,475	5,075,625	5,285,830	5,643,905	6,159,615	5,442,031
TOTAL HOUSTON ORGINATING MINS.	1,517,365	1,254,610	1,321,680	1,377,305	1,411,335	1,583,545	1,410,973
% TOTAL NETWORK ORIGINATING	26	26	26	26	25	26	26
TO AUSTIN	400,300	331,540	354,350	359,300	368,465	426,090	373,341
% TOTAL HOUSTON ORIGINATING	26	26	27	26	26	27	26
TO DALLAS	244,455	195,630	208,235	225,620	226,120	253,540	225,600
% TOTAL HOUSTON ORIGINATING	16	16	16	16	16	16	16
TO ABILENE	59,175	51,915	55,345	57,600	59,905	62,905	57,808
% TOTAL HOUSTON ORIGINATING	4	4	4	4	4	4	4
TO HOUSTON	813,435	675,525	703,750	734,785	756,845	841,010	754,225
% TOTAL HOUSTON ORIGINATING	54	54	53	53	54	53	53
TOTAL NETWORK TERMINATING MINS	5,751,735	4,735,475	5,075,625	5,285,830	5,643,905	6,159,615	5,442,031
TOTAL HOUSTON TERMINATING MINS	1,607,255	1,341,830	1,405,370	1,452,355	1,535,045	1,705,065	1,507,820
% TOTAL NETWORK TERMINATING	28	28	28	27	27	28	28
FROM AUSTIN	590,565	489,180	525,635	539,715	569,225	644,955	559,879
% TOTAL HOUSTON TERMINATING	37	36	37	37	37	38	37
FROM DALLAS	142,495	126,230	127,130	121,235	132,350	149,735	133,196
% TOTAL HOUSTON TERMINATING	9	9	9	8	9	9	9
FROM ABILENE	60,760	50,895	48,855	56,620	76,625	69,365	60,520
% TOTAL HOUSTON TERMINATING	4	4	3	4	5	4	4
FROM HOUSTON	813,435	675,525	703,750	734,785	756,845	841,010	754,225
% TOTAL HOUSTON TERMINATING	51	50	50	51	49	49	50

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H O U S T O N SWITCHER

MONTH-YEAR (WORK DAYS)	OCT 81(21)	NOV 81(17)	DEC 81(21)	JAN 82(19)	FEB 82(19)	MAR 82(22)	AVERAGE
ON-NET TERMINATING MINUTES	369,640	294,235	304,520	330,240	349,195	373,715	336,924
% TOTAL HOUSTON TERMINATING	23	22	22	23	23	22	22
OFF-NET TERMINATING MINUTES	1,237,615	1,047,595	1,100,850	1,122,115	1,185,850	1,331,350	1,170,896
% TOTAL HOUSTON TERMINATING	77	78	78	77	77	78	78
ONAL TERMINATING MINUTES	1,014,585	860,130	900,105	920,220	973,325	1,096,765	960,855
% OFF-NET TERMINATING	82	82	82	82	82	82	82
NPA TERMINATING MINUTES	223,030	187,465	200,745	201,895	212,525	234,585	210,041
% OFF-NET TERMINATING	18	18	18	18	18	18	18

TABLE 5.1

DEDICATED CIRCUIT MILEAGE FY 81

	Sep 80	Oct 80	Nov 80	Dec 80	Jan 81	Feb 81	Mar 81	Apr 81	May 81	Jun 81	Jul 81	Aug 81
Comptroller												
VG	4,141	4,141	4,141	4,212	4,305	5,765	5,297	5,312	6,596	7,311	7,376	7,346
Texas Employment Commission												
VG	9,891	9,920	9,920	9,929	9,960	10,023	10,087	10,087	10,087	10,087	10,188	10,188
Human Resources												
VG	5,745	5,745	5,539	5,567	4,926	4,926	5,503	5,542	5,649	5,704	5,730	5,730
Texas Rehabilitation Commission												
VG	2,271	2,271	2,271	2,271	2,271	2,318	2,318	2,318	2,318	2,318	2,318	2,318
Department of Public Safety												
VG	8,308	8,308	8,349	8,349	8,600	11,166	11,166	11,218	12,748	14,206	15,750	15,590
SVG	205	205	94	94	94	94	94	94	94	94	94	94
Industrial Accident Board												
VG	964	964	964	964	964	964	964	964	964	964	964	964
Department of Health												
VG	300	300	300	300	300	300	409	409	409	409	409	409
Highways & Public Transportation												
VG	11,774	11,774	12,652	12,661	13,528	15,323	15,508	16,216	16,302	16,302	16,812	16,812
SVG	382	382	382	382	382	382	382	382	382	382	382	382
MHMR												
VG	3,718	3,718	3,718	3,726	3,726	3,783	3,783	3,783	3,783	3,783	3,783	3,783
Forest Service												
VG	126	126	126	126	252	252	252	252	252	252	252	252
Railroad Commission												
VG	1,357	1,357	1,357	1,357	1,357	1,357	1,357	1,357	1,357	1,357	1,357	1,357

	Sep 80	Oct 80	Nov 80	Dec 80	Jan 81	Feb 81	Mar 81	Apr 81	May 81	Jun 81	Jul 81	Aug 81
Air Control Board												
VG						20	148	148	148	148	148	148
Commission for the Blind												
VG								257	970	1,542	2,237	2,237
UT System Cancer Center												
VG								120	120	120	120	120
Terrell State Hospital												
VG	118	118	118	118	118	118	118	118	118	118	118	118
Texas Education Agency												
VG	797	797	797	840	840	961	961	961	961	961	1,019	1,019
Texas A&M												
VG	1,675	1,696	1,929	3,077	3,129	3,835	3,835	3,835	3,835	4,023	4,361	4,341
Texas A&M University at Galveston												
VG	130	130	130	130	254	388	388	388	388	388	388	388
TSTI												
VG	960	1,036	1,036	1,036	1,036	1,262	1,262	1,262	1,262	1,262	1,297	1,297
UT-Austin												
VG	1,355	1,355	1,405	1,405	1,405	1,405	1,405	1,405	1,405	1,405	1,405	1,405
UT Medical Branch-Galveston												
VG	505	505	505	505	505	505	505	505	505	505	505	505
Texas Youth Council												
VG	87	87	87	87	87	87	87	87	87	87	87	87
Dallas County												
VG	181	181	181	181	181	181	181	181	181	181	181	181
Education Service Center-Reg. IV												
VG	964	964	1,032	996	996	996	996	996	996	996	996	996
Education Service Center-Reg. X												
VG	748	748	824	892	981	999	999	999	999	999	999	999

	Sep 80	Oct 80	Nov 80	Dec 80	Jan 81	Feb 81	Mar 81	Apr 81	May 81	Jun 81	Jul 81	Aug 81
Education Service Center-Reg XII VG	68	68	141	141	141	141	141	141	141	141	141	141
Board of Pardons & Paroles VG	270	270	428	428	428	428	428	428	428	428	428	428
UT-El Paso VG												138
Education Service Center-Reg. XX VG	2,679	2,688	2,952	3,459	3,965	4,061	4,061	4,061	4,061	4,061	4,069	4,114
UTHSC-Dallas VG	237	237	237	237	237	237	237	237	237	237	237	237
Texas Woman's University VG	303	303	303	303	303	303	303	303	303	303	303	482
Pan American University VG	198	198	378	372	372	396	396	396	396	396	396	396
Texas Tech University VG	297	297	297	297	408	408	408	408	408	408	408	698
UT-Permian Basin VG	962	962	962	962	962	962	962	962	962	962	962	962
UT-San Antonio VG	71	71	71	71	71	71	71	71	71	71	71	71
UTHSC-Houston VG	47	47	47	47	47	47	47	47	47	47	47	47
UTHSC-San Antonio VG	2,709	2,709	2,709	2,709	2,636	2,690	2,692	2,692	2,692	2,692	2,692	2,692
UT-Tyler VG	92	92	92	92	92	92	92	92	92	92	222	222
ETSU-Commerce VG	76	76	125	125	125	125	125	125	125	125	125	125

	Sep 80	Oct 80	Nov 80	Dec 80	Jan 81	Feb 81	Mar 81	Apr 81	May 81	Jun 81	Jul 81	Aug 81
North Texas State University												
VG	656	656	656	656	656	656	656	656	656	656	656	656
Sul Ross University												
VG	485	485	485	436	436	436	436	436	436	436	436	436
College of Osteopathic Medicine												
VG							34	34	34	34	34	34
Agriculture Experiment Station												
VG	87	87	87	87	117	117	117	117	117	117	117	117
Agriculture Extension Service												
VG					512	1,708	1,708	1,708	1,708	1,708	1,708	1,708
Laredo State University												
VG	202	202	202	202	202	202	202	202	202	202	202	202
ETSU-Texarkana												
VG	323	323	323	323	323	323	323	323	323	323	323	323
University of Houston-Victoria												
VG	355	355	355	355	473	473	473	473	473	473	473	473
UTHC-Tyler												
VG	490	490	490	490	490	376	376	376	376	376	376	376
Central Texas College												
VG	290	290	290	290	290	290	330	330	354	354	354	354
University of Houston												
VG	47	47	47	47	47	47	47	47	47	47	47	47
Department of Community Affairs												
VG	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,421	1,739	2,252	2,282
TOTALS												
VG	68,480	68,615	70,479	72,279	74,475	82,944	83,615	84,806	88,550	91,856	95,879	96,351
SVG	587	587	476	476	476	476	476	476	476	476	476	476

The dollars generated by the night minutes and by the dedicated circuits are subtracted from the total industry bill and the remainder is spread to the day minutes. The dollars to be apportioned to the day minutes are divided by the month's total of day minutes used. The result is rounded to five decimal places to determine the day minute rate which, of course, varies from month to month. The FY 81 STS voice usage and rates are shown in Table 5.2.

TABLE 5.2
STS NETWORK VOICE USAGE AND RATES

Month	Day Minutes	Day Min. Rate	Night Minutes	Night Min. Rate	Total Minutes	Total Voice Dollars
Sep 80	6,011,291	$0.08099	332,388	$0.06	6,343,679	$506,797.74
Oct 80	6,234,585	0.08119	392,103	0.06	6,626,688	529,712.14
Nov 80	4,880,117	0.10330	351,774	0.06	5,231,891	525,222.53
Dec 80	5,317,572	0.12838	315,189	0.06	5,632,761	701,581.23
Jan 81	6,134,440	0.09916	332,035	0.06	6,466,475	628,213.17
Feb 81	6,076,618	0.09530	380,391	0.06	6,457,009	601,925.16
Mar 81	6,526,582	0.08563	394,580	0.06	6,921,162	582,546.02
Apr 81	6,361,375	0.09901	405,882	0.06	6,767,257	654,192.66
May 81	6,246,983	0.09950	388,150	0.06	6,635,133	644,863.81
Jun 81	6,408,361	0.10000	336,433	0.06	6,744,794	661,022.08
Jul 81	6,599,128	0.09000	338,480	0.06	6,937,608	614,230.32
Aug 81	6,137,712	0.07872	320,221	0.06	6,457,933	502,373.94

Table 5.3 provides an alphabetical listing by state agency of STS switched voice usage and the charges associated with that usage.

TABLE 5.3
STS VOICE USAGE AND CHARGES BY STATE AGENCY

Agency	FY 81 Total Min. Usage	FY 81 Total Voice Charges
Abilene State School	59,254	$ 5,602.09
Adjutant General's Dept.	399,666	37,335.67
Adult Probation Comm., TX	28,536	2,682.61
Aeronautics Commission, TX	47,907	4,542.67
Agriculture Experiment Sta.	162,363	15,094.64
Agriculture Extension Serv.	814,142	75,862.74
Agriculture, TX Dept. of	471,874	43,401.65
Air Control Board, TX	400,479	37,629.88
Alcoholic Beverage Comm.	358,513	33,511.45
Alcoholism, TX Comm. on	105,455	9,924.21
Amarillo St. Center for Human Development	64,730	6,091.80
Amusement Machine Comm., TX	31,855	3,025.71

Agency	FY 81 Total Min. Usage	FY 81 Total Voice Charges
Angelo State University	131,277	$ 12,012.89
Animal Health Comm., TX	116,953	11,036.03
Architectural Examiners, Texas Board of	8,003	725.11
Armory Board, National Guard	14,644	1,373.01
Arts & Humanities, TX Comm.	70,736	6,688.60
Attorney General, Office of the	752,278	70,764.38
Auditor's Office, State	18,889	1,788.11
Austin State Hospital	376,756	33,604.42
Austin State School	104,340	9,794.23
Banking Dept. of Texas	51,799	4,888.72
Barber Examiners, State Bd. of	11,336	1,041.41
Beaumont St. Center for Human Development	56,980	5,226.03
Big Spring St. Hospital	166,651	15,444.04
Blind and Deaf Schools	110,959	10,064.45
Blind, St. Comm. for the	678,516	63,432.24
Brenham State School	160,377	14,478.71
Brownwood State Home & School for Girls	115,445	10,254.49
Civil Appeals, Court of-3rd Dist.	1,135	112.90
Civil Appeals, Court of-4th Dist.	1,263	116.46
Civil Appeals, Court of-8th Dist.	291	26.51
Civil Appeals, Court of-12th Dist.	4,356	403.09
Coastal & Marine Council, TX	5,830	552.02
Community Affairs, TX Dept.	320,049	30,129.51
Comptroller of Public Accounts	3,526,594	331,442.15
Conservation Foundation, Texas	2,027	192.31
Consumer Credit Comm., Office of	34,845	3,265.06
Coordinating Board, TX	304,261	25,315.19
Corpus Christi St. School	106,842	9,971.28
Corpus Christi St. University	165,418	15,000.34
Corrections, TX Dept. of	1,288,969	119,103.91
Corsicana State Home	72,511	6,789.84
Cosmetology Comm., TX	21,698	2,042.29
Court Administration, Office of	28,488	2,681.41
Credit Union Dept.	21,853	2,043.66
Criminal Justice Division	70,425	6,611.14
Crockett St. School for Girls	41,915	3,883.75
Deaf, Commission for the	22,676	2,113.65
Deepwater Port Auth., TX	1,340	126.24
Dental Examiners, St. Bd. of	28,708	2,671.10
Denton State School	249,021	23,357.18
East Texas St. Univ., Commerce	637,726	58,280.95
East Texas St. Univ., Texarkana	150,656	13,938.85
Education Agency, Texas	1,751,980	157,470.21
El Paso St. Ctr. for Human Development	19,515	1,866.98
Employee's Retirement	98,520	9,315.02
Employment Commission, Texas	3,003,085	281,225.56
Employment Training Council, State	3,979	367.88

Agency	FY 81 Total Min. Usage	FY 81 Total Voice Charges
Energy and Natural Resources Advisory Council, Texas	74,810	$ 7,037.36
Engineering Extension Service, South Central Texas	22,138	2,050.39
Engineering Extension Service, TX	27,568	2,604.94
Firemen's Pension Comm.	1,585	151.04
Fire Protection Personnel Stds. and Ed.	168	15.60
Forest Service, Texas	82,798	7,717.02
Fort Worth State School	100,345	9,426.64
Gainesville State School for Girls	51,491	4,782.97
General Land Office	86,385	8,162.63
Good Neighbor Commission	6,721	625.46
Governor, Office of the	249,375	23,518.39
Governor's Budget and Planning Office	69,778	6,548.59
Governor's Commission on Physical Fitness	5,285	508.62
Governor's Committee on Aging	45,002	4,229.05
Guaranteed Student Loan Corp., Texas	35,160	3,233.85
Harlingen St. Chest Hospital	53,130	5,118.50
Health Facilities Comm., TX	31,025	2,930.56
Health, Texas Dept. of	3,218,539	303,240.79
Hearing Aids, Texas Bd. of Exam. in Fit. & Disp. of	4,508	420.19
Highways & Public Transportation, Texas Dept. of	4,720,249	443,841.25
Historical Commission, Texas	70,205	6,602.05
House of Representatives	2,021,382	184,593.09
Housing Agency, Texas	10,733	1,016.07
Human Resources, TX Dept. of	9,347,395	878,359.45
Industrial Accident Board	255,307	23,930.85
Industrial Comm., Texas	122,013	11,499.64
Institute of Texan Cultures UT	36,980	3,474.54
Insurance, State Board of	353,521	33,069.50
Intergovernmental Relations, Texas Adv. Comm. on	4,762	450.24
Irrigators, Board of	300	23.62
Jail Standards, State Comm. on	12,799	1,197.72
Judicial Conduct, State Comm. on	5,702	537.89
Judicial Coord. Committee	3,265	325.71
Kerrville State Hospital	59,619	5,571.75
Labor & Standards, TX Dept. of	163,949	15,429.00
Lamar University	971,189	87,537.14
Laredo State Ctr. for Human Development	24,579	2,306.00
Laredo State University	45,425	4,262.52
Law Enforcement Officer Standards & Education	72,088	6,792.84
Legislative Budget Board	38,434	3,565.54
Legislative Council, Texas	29,925	2,786.33

Agency	FY 81 Total Min. Usage	FY 81 Total Voice Charges
Legislative Ref. Library	910	$ 91.84
Library & Archives Comm., Texas State	33,836	3,225.58
Lubbock State School	58,085	5,451.38
Lufkin State School	123,673	11,495.03
Medical Examiners, State Bd. of	14,799	1,402.90
Mental Health/Mental Retardation, Texas Department of	408,794	38,521.79
Merit System Council	7,345	694.46
Mexia State School	263,046	24,729.83
Midwestern University	132,494	12,715.01
Morticians, Board of	5,087	483.32
Motor Vehicle Commission	11,955	1,130.88
North TX State University	253,233	23,573.34
Optometry Board, Texas	11,879	1,093.59
Pan American University	328,370	30,272.80
Panhandle Plains Historical Museum	4,822	434.42
Pardons & Paroles, Bd. of	331,834	31,178.87
Parks & Wildlife Dept., TX	575,920	53,933.34
Pension Review Board	956	95.91
Pharmacy, Texas State Board of	29,901	2,742.67
Physical Therapy Examiners, Texas Board of	3,475	325.72
Prairie View A&M University	549,356	49,063.05
Private Investigators & Private Security Agents, TX Board of	50,426	4,742.44
Professional Engineers, State Board of Reg. for	19,167	1,801.66
Property Tax Board, State	145,182	13,769.56
Prosecutor's Coordinating Council, Texas	9,363	887.91
Psychologists, St. Board of Examiners of	4,216	383.64
Public Accountancy, State Board of	24,136	2,259.13
Public Employees Training Exchange of SWTSU	2,180	209.24
Public Safety, TX Dept. of	2,541,409	231,449.93
Public Utility Comm., TX	115,824	10,863.40
Purchasing & General Services Commission, State	99,030	9,336.92
Railroad Commission of Texas	721,726	67,905.81
Real Estate Comm., Texas	28,932	2,779.71
Regents, TX St. University System, Board of	15,581	1,453.24
Rehabilitation Comm., Texas	2,669,303	250,861.97
Research Institute of Mental Sciences, Texas	50,413	4,714.24
Richmond State School	78,958	7,250.88
Rio Grande Compact Commission	452	42.81
Rio Grande St. Ctr. For MHMR	100,115	9,017.44
Rural Medical Education Bd., State	1,512	135.84

Agency	FY 81 Total Min. Usage	FY 81 Total Voice Charges
Rusk State Hospital	241,721	$ 22,872.72
Sam Houston St. University	336,565	30,860.08
San Angelo Center	40,510	3,817.65
San Antonio State Chest Hosp.	38,095	3,489.19
San Antonio State Hospital	193,484	18,194.38
Savings & Loan Department	40,000	3,792.25
Secretary of State	160,956	15,122.29
Securities Board, State	65,826	6,222.31
Senate, Texas	882,884	80,151.77
Sesquicentennial Commission, TX	7,137	662.61
Soil & Water Conservation Board	16,061	1,504.37
State Bar of Texas	314,834	29,644.38
State-Federal Relations, Office of	1,075	99.82
Stephen F. Austin State University	769,230	69,259.81
Sul Ross State University	57,827	5,128.93
Supreme Court of Texas	25,261	2,381.82
Tarleton State University	78,660	7,303.87
Teacher Retirement System of TX	87,500	8,250.97
Terrell State Hospital	182,300	17,077.68
Texas A&I University at Kingsville	913,227	81,961.03
Texas A&M University	3,816,732	349,476.57
Texas A&M University at Galveston	152,192	13,962.21
Texas A&M University System Administration	1,462	125.97
Texas College of Osteopathic Med.	138,775	13,077.36
Texas Southern University	243,245	21,874.94
Texas State Tech. Institute	574,048	53,036.79
Texas Tech University	752,336	68,805.02
Texas Tech University Health Science Center	528,095	48,808.67
Texas Woman's University	537,232	49,385.65
Tourist Development Agency, TX	19,454	1,840.00
Traffic Safety, Office of	22	1.78
Transportation Institute, TX	22,420	2,120.03
Travis State School	93,210	8,497.52
Treasury Department, State	26,105	2,465.97
University of Houston	2,411,198	209,983.00
University of Houston, Clear Lake City	125,398	11,532.40
University of Houston, Victoria	6,281	591.54
University of Houston System Administration	5,785	544.44
University of Texas, Arlington	336,430	30,124.74
University of Texas, Austin	1,579,626	145,174.89
University of Texas, Dallas	181,487	16,935.18
University of Texas, El Paso	228,950	20,431.91
University of Texas, Permian Basin	29,431	2,651.42
University of Texas, San Antonio	168,349	15,558.81
University of Texas, Tyler	188,473	17,556.62
University of Texas Health Center at Tyler	186,090	17,279.51

Agency	FY 81 Total Min. Usage	FY 81 Total Voice Charges
University of Texas Health Science Center, Dallas	408,282	$ 37,860.87
University of Texas Health Science Center, Houston	658,252	60,672.88
University of Texas Health Science Center, San Antonio	359,894	33,586.82
UT Medical Branch at Galveston	4,054,401	368,912.24
University of Texas System	16,487	1,549.15
University of Texas System Cancer Center	573,562	53,467.64
University System of South Texas	5,777	560.66
Vernon Center	65,873	6,262.09
Veterans Affairs Commission	9,264	870.02
Veterinary Medical Diagnostic Lab., Texas	10,804	1,003.95
Veterinary Med. Examiners, Texas State Board of	3,769	354.11
Vocational Nurse Examiners, Bd. of	6,916	622.37
Waco Center for Youth	46,631	4,314.70
Water Resources, TX Dept. of	684,450	64,687.90
West Texas Childrens Home	32,110	2,777.86
West Texas State University	129,292	11,532.03
Wichita Falls State Hospital	116,499	10,844.65
Youth Council, Texas	562,342	51,894.37

DATA COMMUNICATIONS ISSUES

APPENDIX C

1 DATA COMMUNICATIONS ISSUES

This appendix will briefly discuss a few of the issues, in a tutorial fashion, involved in the selection of a data communications architecture for the State. The appendix is divided into two major sections which discuss circuit versus packet switching for data and voice/data integration respectively. The degree to which voice and data traffic are integrated and the choice of switching technology will largely depend on the traffic characteristics for the present and forseeable future, as revealed by the data questionnaire.

1.1 Circuit versus Packet Switching for Data

For data communications the choice between circuit and packet switching is unclear at this point. Circuit switching of data is identical to that for voice. In circuit switching a dedicated communications path is established with a fixed bandwidth. This circuit is dedicated to the call whether or not communications are taking place at that instant. Because of this, circuit switching does not make maximum efficient use of the available bandwidth in many applications. For example in terminal-to-computer applications the communications link may be in use less than 10% of the time, the remaining time being taken with the human operator evaluating the data, program execution time, etc.

The current STS network is used to circuit switch some data traffic. In this case, a modem is used to interface a data terminal with the analog STS network. If the end-to-end connection were digital, no modems would be needed. In current switching system developments, higher speed circuit switched data communication are being made possible. This allows the use of circuit switching for high speed computer-to-computer communications instead of just low speed interactive applications between a terminal and a distant mainframe.

Packet switching generally makes more efficient use of transmission facilities when compared to circuit switching. Packet switching in it's simplest form can be thought of as being similar to mailing a letter. The data is put in an "envelope" which contains the destination address of the data packet. This packet is then placed on the transmission facility and passed from node to node until it reaches its destination, where the "letter" (the data content) is removed from the "envelope" (the packet) and delivered to the intended computer or terminal. Like the post office, many packets can be carried in the same "truck" (transmission facility). A large packet might be broken into several smaller pieces that are under the maximum "weight limit" (packet length).

A typical system might break any file that was being transmitted into many pieces, each part of the file being preceded by several bits describing the address of the packet and followed by several bits that indicate the end of the packet. The system may also provide for the detection and possible correction of errors (caused by noise on the transmission facility). The bits preceding or following the data might also contain information to assure that the file is put back together in the correct order, as well as information that specified the route to be used by the packet. Each packet switch would be connected to many data terminals and computers. The switch would temporarily store the data transmitted to it from the various terminals and computers and assemble them into packets. These packets would then be sent out over the appropriate transmission facilities in the order received. This brief storage of the data allows a single transmission facility to serve many terminals and computers. If one of the terminals wants to transmit while the facility is in use, the data is broken into packets and stored. The packets are transmitted on the facility on a first-in-first-out basis. In typical situations, packets are frequently queued to use a transmission facility. In this manner the transmission facility can be in use a high percentage of the time, instead of sitting idle for a large percentage of the time.

Packet switching is not without its drawbacks, however. The use of queuing in a packet switched communications network can become bothersome in some interactive applications. In these situations the user will notice the delay when he or she is entering data at a terminal and the mainframe computer at the distant end is echoing back the characters before they are displayed on the user's screen. The real determinant of the delay is how efficiently the network designer wants to utilize the transmission facilities; the higher the efficiency, the greater the delay a user will experience. Thus the tradeoff is between efficiency and the delay that is acceptable to the user. This is virtually the same tradeoff that occurs when a voice network is designed and the grade of service is selected.

The designer does have a few other options that can help reduce the delay problem. The originating packet switch (the switch that the terminal user is connected to) can eliminate the round trip delay experienced when a user is entering data, by echoing the characters back to the terminal instead of that being done by the distant computer. In this case the communication is not true full duplex, which may introduce some complications. The delay problem can also be reduced by assigning priorities to the packets. Packets for an interactive computer session could have a higher priority that those for a simple file transfer. In this case there would be two or more queues at each packet switch, with the low priority packets being sent only if the high priority queue were empty.

The real tradeoff between packet switching and circuit switching is cost. The designer is trading the added cost of the packet switch (over a circuit switch) against the more efficient use of the transmission facilities. Until the results from the data questionnaire are known, a definitive conclusion about which of these techniques is most appropriate cannot be reached. The decision will depend on the volume and type of data traffic that is and will be occurring in the State, as well as the cost of future transmission and switching facilities.

In summary:

(1) Circuit switching data has the advantage of low switch cost at the price of less efficient use of transmission facilities. If circuit switching is used, the circuit switches used for voice traffic must be considered as candidates for data switching, with the possibility of significant savings.

(2) If packet switching were used the higher cost of the packet switch may be offset by the greater efficiency in the use of transmission facilities. The price of this efficiency would be delay, which would have the greatest effect on interactive users.

1.2 Voice/Data Integration

Besides the advantages discussed in chapter two, digital systems facilitate the integration of voice and data. The integration of voice and data involves the sharing of transmission and/or switching facilities by both data and voice traffic. If, as expected, the greatest sources of voice traffic are also the largest users of inter-location data communications; the sharing of transmission facilities by voice and data traffic could be economically attractive. The key will be the extent to which the communities of interest for the two services are similar. The results from the data questionnaire should help resolve this question.

If the State were to own its own transmission facilities, for example, then the added cost of carrying both voice and data traffic on the same facilities would be less than if totally separate facilities were provided, owing to the increased efficiency of a single larger group of facilities (a statistical fact of life with transmission facilities) over two smaller groups of facilities. This effect may not be significant on a percentage basis, however, given the large size of STS voice trunk groups.

Other cost savings might be gained by using the same sites for the voice and data switching equipment, saving on building and maintenance costs. If circuit switching were used for data traffic (circuit and packet switching will be discussed in the next section) additional savings could be achieved by using the same switching vehicle for both voice and data, avoiding duplication of some common equipment. In this case the savings would come from eliminating the fixed components of a second switch (the second switch's processor, software etc.). The use of a single switch would also reduce maintenance, testing and network management expenses, as there would be one network instead of two.

One final advantage of the integration of voice and data traffic depends on when the busy hours (the periods of peak usage) occur for voice and data traffic. If the busy hours are not coincident for these two services, greater economies will result than just those attendant to group size efficiencies. Transmission facilities are designed to handle traffic in the busy hour. If the busy hours are the same for these traffic types, then facilities must be engineered for the vector sum of them. If their busy hours are not coincident, however, then any facility need only be engineered for the busiest composite hour, and often the traffic in this hour is only slightly larger than that during the voice busy hour alone. Some savings can be significant from an integration of these traffic types, especially if there is a large amount of traffic in the data busy hour. If, for example, the busy hour for data was after 5PM and the busy hour for voice was during the normal work day (the actual voice busy hour is 10-11AM), data traffic could use the almost idle voice facilities during the evening. In this extreme case, few if any additional transmission facilities would be needed to handle data and voice traffic on the same network, as compared to a voice only network.

DATA QUESTIONNAIRE AND DATA MATRIX

APPENDIX D

Data Communications Questionnaire

The Telecommunications Services Division of the State Purchasing and and General Services Commission is studying alternative evolution plans for the State Telecommunications System (STS), formerly called the TEX-AN Network. The outcome of a critical part of this study will be recommendations concerning switched data capabilities for STS, including consideration of speed, code and protocol conversion, the switching of high-bandwidth (> 56kbps) data streams, etc.

Your help in establishing a base of data for this part of the study is most important. Of greatest interest are data concerning your installed equipment and current profiles of the kinds and number of computer transactions that are experienced in your organization, along with firm (budgeted) plans and forecasts. Of secondary importance, but still of great interest, are your strategies and long range forecasts for data processing, messaging, telecopying, data/voice/video/graphics conferencing, etc., during the mid and late 1980s.

As you will immediately notice, there is little likelihood that you will be able to answer all of these questions. Even for those questions whose answers can be found, work will be required to provide them. However, it has been agreed that the most effective way to understand what may be required to support the state's future data communications needs is to query our government's key people in data processing and communications. It is expected that the effort expended now will more than pay for itself in the quality of the evolution plan for communications that is being formulated.

A final note: Some of the following questions are redundant. It has been found that such redundancy helps guarantee completeness of response, given people's perceptions of the questions. Some may seem redundant at first glance but, upon consideration, are not. Please consider each question carefully, and if you think you have given its answer elsewhere in your responses, then do not subject yourself to writing the same answer again. Move on to another question.

Name: ______________________________

Organization: ______________________________

Location: ______________________________

1 EXISTING EQUIPMENT AND SERVICES

DIAGRAMS, GRAPHS OR TABLES ARE WELCOMED in response to any of the following questions.

1.1 Computer Systems

(1) What mainframes and minis do you have in place today, by location and make/model/size (diagrams are welcome)?

(2) What applications are running on each computer? One of the important kinds of information that is sought is a quantification of the amount of traffic between terminals and hosts, by speed and by type (application). This question is somewhat redundant with the following two, in asking for some of the same information but suggesting a few ways to go about supplying an answer. If you think you can give us this kind of usage information by answering any or all of these questions, or by supplying the information in another way that is more convenient to you, please do so.

(3) What data do you have (e.g., from traffic measurements at front-end processors) about traffic types, volumes and distribution?

(4) What are the usage characteristics at your terminals (i.e., what are the characteristics of user transactions via the terminals, in terms of input characters per session and input speed, in characters per second, and output characters per session and output speed, along with numbers of sessions per terminal-business day)? For 3270-type terminals, a breakdown into three additional types of transactions -- keyed data entry, full screen edit and non-full screen edit -- may be most useful) Note: Some or all of this information is often unavailable. An understanding of the transactions with each kind of computer application might allow traffic flows to be calculated for each computer, and then that traffic could be parceled out according to user or terminal populations.

(5) How many terminals, printers and other peripherals are connected to each of these mainframes?

(6) What kinds of terminals are in place, by location? This can be broken down into low-speed hardcopy terminals, low-speed Cathode Ray Tube (CRT)-based terminals, graphics terminals, 3270-type terminals {using binary synchronous or Serial Data Link Control (SDLC) protocols to provide terminal access to hosts running IBM operating systems}, and Remote Job Entry (RJE) terminals.

(7) How are the terminals and other devices interfaced to hosts (i.e., local vs. remote, switched vs. dedicated ports, incoming-only ports from the public telephone network, outgoing ports to the public network for point-to-point connections to remote batch terminals, polled connections to RBTs, etc.)?

(8) Do you use concentrators, bandwidth allocators, etc.?

(9) What are the line speeds for terminal/device-to-host connections?

(10) What protocols are used in these connections?

(11) What inter-host connections do you have?

(12) What uses are made of these inter-host connections (e.g., pass-thru, bulk data transfers, short message/file transfers)?

(13) What speeds and protocols are used?

(14) What performance criteria do you have for satisfactory operation of your systems and their component parts {response times, availability, mean times between failures (MTBF), mean times to repair (MTTR), etc.}?

(15) What are particularly good or bad aspects of your present systems and connections that you would like to pass on to the study team? What would you like to see that is not presently available?

1.2 Special Purpose Systems

(1) What office information systems do you have installed (e.g., word processing systems, text or voice messaging systems, etc.), by location?

(2) What criteria do you employ in determining whether or not to have such a system?

For each system,

(a) How are users connected to it (dial-up, LAN, dedicated line, etc.)?

(b) What line speeds are used?

(c) What editing capabilities does the system have (e.g., line, full screen)

(d) What is its capacity (both in terms of users and memory)?

(e) How many people use the system per day (or during the busiest hour)?

(f) How many messages are generated per day (or during the busiest hour)?

(g) What is the average message length. This can be described in terms of bytes per message, or equivalent text pages, if the format of the text page (characters per line and lines per page) is known.

(h) What is the connect time (and CPU time) per transaction?

(i) Now that you are using such a system, are you happy with it? What functions are you seeking that are not available today?

(j) What is the population of users that have access to it?

(k) Please characterize the user community by the percent of users that fall into each of the following categories:

- Managers
- Secretaries and clerical personnel
- Programmers
- Engineers or other technical personnel
- Other

1.3 Data Communications Equipment

(1) What data switching equipment do you have (including local area networks [LANs]), by location?

(2) For cable-based LANs, please describe (very broadly) the cable layout relative to telephone distribution cable (and PBX location, if you have a PBX at the location). An understanding of the geographical relationships is what is being sought; diagrams constitute the best, and probably the easiest, response.

(3) What are the capacities of your data switching equipment (ports and throughput)?

(4) What performance criteria do you have for satisfactory data communications (e.g., end-to-end transmission quality, availability of circuits)?

(5) What traffic measurements do you have for this equipment?

(6) What has been your experience with this equipment? What capabilities are you seeking that are not being provided by the system(s) today?

(7) Do you own or lease your own data transmission facilities? If so, what types and capacities of equipment do you have, by location?

(8) As above, what has been your experience with this equipment? What capabilities are you seeking that are not being provided today?

1.4 Maintenance and Administration

(1) What communications diagnostic equipment and procedures are in place for your systems, by location?

(2) How are troubles reported?

(3) How many people are assigned to support data communications? May we have an organization chart?

(4) What diagnostic tools would you like to have that you do not have today?

(5) How often are changes required in the location of data processing or communications equipment or terminals or office information systems?

(6) What procedures and personnel are used to accomplish these moves and changes?

2 PLANS AND FORECASTS

(1) What firm plans do you have in the areas of data processing equipment, terminals, and stand-alone or integrated office information system functions? Please give a year-by-year account of what is funded, what you are proposing for the upcoming budget, and what you would like to do in the long term.

(2) What firm plans do you have for data communications equipment, including local area or extended area networks?

(3) What do you see as the demand for new services like two-way video and high-speed graphics communications in your organization? Are there services or features that you think would be particularly useful that are not presently available to you?

(4) Who will be using data processing, data communications and office information systems in the next several years?

3 ACKNOWLEDGEMENT

Your assistance in this work is greatly appreciated. Although you will not see the results of your input immediately, the next budget submission for STS will have, as its major underpinning in the area of data communications, the contributions of you and your key colleagues in State government. Acknowledgement of your contribution will also be made in the evolution plan document itself, as small thanks for your help.

TEXAS DATA MATRIX

Orig.	Terminating 1	2	3	4	5	6	7	8	9	10
11			24	24						
56			162	341						
84			24	24						

Orig.	Terminating 11	12	13	14	15	16	17	18	19	20
3	8									
4	8									
11	322				38		24			
15	17									
17	8									
22	8									
24	8									
25	8									
26	8									
28	8									
32	8									
33	8									
35	8									
36	16									
37	16									
38	14									
44	8									
46	16									
52	8									
53	8									
54	8									
56	451		19		130		98			
60	8									

65	8
69	8
71	8

Orig.	Terminating									
	11	12	13	14	15	16	17	18	19	20
75	8									
79	8									
84	40				24		24			
85	8									
87	8									
103	8									
105	8									
111	8									
112	8									
115	8									
116	8									
118	8									
120	8									
121	16									
124	14									
125	16									
128	8									
131	8									
132	8									
133	8									
134	8									
135	8									

Orig.	Terminating									
	21	22	23	24	25	26	27	28	29	30
11		24		24	24	24		24		
56		98	1	103	124	117		120	20	
84		24		24	24	24		24		
	31	32	33	34	35	36	37	38	39	40

11		24	24		24	48	48	9	
38								189	
56	1	98	98		126	538	221	70	50
84		24	24		24	48	48	10	

Orig.	Terminating									
	41	42	43	44	45	46	47	48	49	50
11				24		48				
56			1	98		557				21
84				24		48				

Orig.	Terminating									
	51	52	53	54	55	56	57	58	59	60
3						32				
4						89				
11		24	24	24		172				24
13						6				
15						45				
17						32				
22						33				
23						3				
24						36				
25						42				
26						38				
28						39				
29						7				
32						32				
33						32				
35						41				
36						162				
37						75				
38						18				
40						12				
43						1				
44						32				
46						174				
50						6				
51						2				
52						110				

53	32
54	38

Orig.					Terminating		
56	6	407	98	117	1118	23	98
57					9		
60					32		
61					11	8	
63					17		
65					42		
68					54		
69					32		
71					43		
75					32		
79					46		
80					5		
82					6		
84		24	24	24	209		24
85					38		
86					20		
87					42		
91					4		
102					1		
103					37		
105					52		
108					6		
110					12		
111					94		
112					36		
115					32		
116					33		
117					6		
118					46		
120					34		
121					96		
124					38		
125					65		

128	116
131	39
132	55
133	56
134	89
135	38

Orig.	Terminating
149	28
150	5
152	5
153	5
155	5
156	5

Orig.	Terminating									
	61	62	63	64	65	66	67	68	69	70
011					24				24	
056	17		62		122			239	98	
057	5									
084					24				24	

Orig.	Terminating									
	71	72	73	74	75	76	77	78	79	80
011	24				24				24	
056	126				98	3	3		131	12
084	24				24				24	

Orig.	Terminating									
	81	82	83	84	85	86	87	88	89	90
003				8						
004				8						
011				57	24		24			
015				8						
017				8						
022				8						
024				8						

025	8
026	8
028	8
032	8
033	8

Orig.			Terminating		
035		8			
036		16			
037		16			
038		16			
044		8			
046		16			
052		8			
053		8			
054		8			
056	19	555	117	75	125
060		8			
065		8			
069		8			
071		8			
075		8			
079		8			
084		65	24		24
085		8			
087		8			
103		8			
105		8			
111		8			
112		8			
115		8			
116		8			
118		8			
120		8			
121		16			
124		8			
125		16			
128		8			

131	8
132	8
133	8
134	8
135	8

Orig.	Terminating									
	91	92	93	94	95	96	97	98	99	100
056	13									

Orig.	Terminating									
	101	102	103	104	105	106	107	108	109	110
011			24		24					
056	1	1	108		171			19		50
084			24		24					

Orig.	Terminating									
	111	112	113	114	115	116	117	118	119	120
011	24	24			24	24		24		24
056	349	100			98	99	19	130		103
084	24	24			24	24		24		24

Orig.	Terminating									
	121	122	123	124	125	126	127	128	129	130
011	48			34	48			24		
056	290			117	196			418		
084	48			24	48			24		

Orig.	Terminating									
	131	132	133	134	135	136	137	138	139	140
011	24	24	24	24	24					
056	119	177	180	344	117					
084	24	24	24	24	24					

Orig.	Terminating									
	141	142	143	144	145	146	147	148	149	[illegible]
055										19
056									50	

Orig.	Terminating									
	151	152	153	154	155	156	157	158	159	160
056		19	19		19	19				14

SEASONAL ANALYSIS DOCUMENTATION

APPENDIX E

13.7 Seasonal Analysis

EMPIRE seasonal analysis, like the popular classical decomposition and census methods, bases its operation on the assumption that a time series may be broken down (or decomposed) into four components:

1. The underlying trend of the data.

2. The cyclical factors.

3. Seasonality (the repetitive fluctuation in the data over fixed intervals of time).

4. Randomness (the residual component containing the portions of the data not explained by the other 3 items).

These components, each of which is itself a time series, are computed to estimate the values of the time series under study in a multiplicative relationship.

General Form: $X_t=T_t*C_t*S_t*R_t$

where:

Xt represents the value of the decomposed series (at time=t).

Tt is the trend component (at time=t).

Ct is the cyclical component (at time=t).

St is the seasonal factor (for time=t).

Rt is the residual randomness (for time=t).

The difference between the approach used within EMPIRE and those found in the more traditional implementations is in the EMPIRE algorithm. This algorithm provides a level of estimating accuracy characteristic of the census method with the simplicity of use found in less sophisticated methods. This estimating algorithm (which is not explained in detail here, as an understanding of the mathematics involved is not necessary for use of the analysis) is capable of improvements in accuracy of as much as 80 percent, compared to techniques using less sensitive approximations.

User input for the seasonal analysis consists of identifying the item containing the data values, specifying the range of time periods to be considered, and selecting the desired table output and value storage options.

After the user identifies the data item and time frame, EMPIRE performs a set of initial computations to determine whether or not seasonality is present in the data. If the data is seasonal, the analysis proceeds. If not, a message to that effect is printed, and the analysis is halted (to use non-seasonal data would be of no value).

Example:

ANALYSIS OPTION? <u>SEASONAL</u>

Initiates the seasonal analysis option.

ITEM NAME? <u>UNITS</u>

In this case, perform a seasonal analysis for the item named UNITS. Any row item may be specified.

ENTER FIRST & LAST COLUMNS TO BE USED: <u>JAN76 DEC82</u>

These are the first and last time periods to be considered.

LENGTH OF SEASONALITY? <u>BEST</u>

If the user feels the number of periods per seasonal cycle is known, that number may be entered here. When BEST is used, EMPIRE determines the number of periods for which the greatest degree of seasonality is exhibited in the data.

(At this point, EMPIRE determines whether or not the data exhibits seasonal behavior. If not, a message is printed, and none of the following questions are asked.)

PRINT DECOMPOSED COMPONENTS OF DATA? <u>YES</u>

Answer YES for a period-by-period listing of the trend, cycle, random, and seasonal components; or NO if the table is not desired.

STORE SEASONAL FACTORS? <u>YES</u>

If a YES response is given, the user is asked to identify the item into which the period seasonal factors are to be stored (as a separate time series). Also the user may specify the number of future periods for which seasonal factors are to be computed and stored. This provides a facility whereby a re-seasonalization of a time series created by a different method may be performed. If a NO response is entered, the next 4 questions are not asked.

NAME OF ITEM FOR STORING VALUES? <u>SFACT</u>

The user identifies the name of a row item into which the seasonal factors are to be stored.

STORE "LOOK-AHEAD" SEASONAL FACTORS? <u>YES</u>

If YES is entered, the user may specify the number of future periods (beyond the last period considered in the analysis) for which the seasonal factors are to be computed and stored. These are stored in the same row item specified two question earlier. A response of NO causes the next question to be skipped.

NUMBER OF PERIODS? <u>12</u>

Any number of periods from 1 to the remaining number of columns defined in the model (the total number of columns less the last column considered in the seasonal analysis) may be specified.

STORE DESEASONALIZED DATA? <u>NO</u>

An answer of YES provides the user the opportunity to identify an item name and starting column for storage of the deseasonalized data values. This is particularly useful for situations in which the user wishes to perform additional analyses on the deseasonalized values of the time series, and perhaps later re-seasonalize a forecasted series.

Output of the results from the seasonal analysis computations is then provided, consisting of the trend line coefficients (intercept and slope) and a listing of the seasonal factors for each period in the detected length of seasonality. These are provided as multiplicative factors, with any factor having a value less than 1 (e.g., .973), indicating a period in which the data values are below average; and any factor with a value greater than 1 (e.g., 1.036) indicating a period in which the data values are above average. A few additional questions are then asked.

PRINT TABLE OF ESTIMATES & RESIDUALS? NO

> Answer YES for a detailed table of each period's computed estimate and residual error; or NO if the table is not needed.

STORE ESTIMATED VALUES? NO

> If a YES response is entered, the user is asked to specify the item name and starting location for storage of the estimated time series values over the studied time frame.

The optional detailed list of estimates, if selected, is then printed, followed by the overall summary statistics. Control is then passed to the forecasting portion of the system, where future estimates may be generated in the same manner as it is used for all available analysis options.

Examples:

ANALYSIS OPTION? SEASONAL

ITEM NAME? NUNITS

ENTER FIRST & LAST COLUMNS TO BE USED: JAN76 AUG77

LENGTH OF SEASONALITY (# OF PERIODS)? 3

PRINT DECOMPOSED COMPONENTS OF DATA? YES

STORE SEASONAL FACTORS? NO

STORE "LOOK-AHEAD" SEASONAL FACTORS? NO

STORE DESEASONALIZED DATA? NO

TREND LINE COEFFICIENTS:

INTERCEPT: -152.921
SLOPE: 49.850

SEASONAL INDICES:

PERIOD OF CYCLE	SEASONAL INDEX
1	1.001
2	.998
3	1.001

COLUMN	ACTUAL	TREND	CYCLE	RANDOM	SEASONAL
JAN76	19.000	-152.921			1.001
FEB76	24.000	-103.071	-.243	.962	.998
MAR76	32.000	-53.222	-.745	.806	1.001
APR76	63.000	-3.372	-19.177	.973	1.001
MAY76	99.000	46.477	2.022	1.056	.998
JUN76	120.000	96.327	1.256	.991	1.001
JUL76	144.000	146.177	1.038	.948	1.001
AUG76	191.000	196.026	.983	.994	.998
SEP76	243.000	245.876	.968	1.020	1.001
OCT76	280.000	295.726	.950	.995	1.001
NOV76	320.000	345.575	.948	.979	.998
DEC76	383.000	395.425	.973	.995	1.001
JAN77	451.000	445.274	1.002	1.010	1.001
FEB77	504.000	495.124	1.020	1.000	.998
MAR77	560.000	544.974	1.042	.985	1.001
APR77	639.000	594.823	1.077	.996	1.001
MAY77	723.000	644.673	1.114	1.009	.998
JUN77	792.000	694.523	1.142	.998	1.001
JUL77	864.000	744.372	1.171	.990	1.001
AUG77	959.000	794.222			.998

PRINT TABLE OF ESTIMATES & RESIDUALS? YES

STORE ESTIMATED VALUES? NO

COLUMN	ACTUAL	FORECAST	ERROR	PERCENT
JAN76	19.000	-153.089	172.089	905.731
FEB76	24.000	24.943	-.943	3.930
MAR76	32.000	39.713	-7.713	24.104
APR76	63.000	64.738	-1.738	2.758
MAY76	99.000	93.787	5.213	5.266
JUN76	120.000	121.142	-1.142	.952
JUL76	144.000	151.833	-7.833	5.440
AUG76	191.000	192.229	-1.229	.644
SEP76	243.000	238.279	4.721	1.943
OCT76	280.000	281.308	-1.308	.467
NOV76	320.000	326.923	-6.923	2.163
DEC76	383.000	385.118	-2.118	.553
JAN77	451.000	446.489	4.511	1.000
FEB77	504.000	503.853	.147	.029
MAR77	560.000	568.332	-8.332	1.488
APR77	639.000	641.370	-2.370	.371
MAY77	723.000	716.370	6.630	.917
JUN77	792.000	793.930	-1.930	.244
JUL77	864.000	872.623	-8.623	.998
AUG77	959.000	792.419	166.581	17.370

MEAN SQUARED ERROR= 2890.629
MEAN PERCENT ERROR= 44.407
MEAN ABSOLUTE PERCENT ERROR= 48.818

NUMBER OF COLUMNS TO FORECAST? 12

STORE THE FORECAST? NO

COLUMN	VALUE
21	845.061
22	894.902
23	941.628
24	994.786
25	1044.615
26	1090.837
27	1144.510
28	1194.328
29	1240.047
30	1294.234
31	1344.041
32	1389.256

ANALYSIS OPTION? END

THE USER SURVEY

APPENDIX F

1 METHODOLOGY

The study team, working with the State of Texas, developed a survey to address the questions raised by the State in connection with the network redesign. The questionnaire sought opinions and information in the following areas:

- o use of STS vs. regular long distance dialing
- o number and type of calls typically made
- o knowledge and use of off-network to on-network dialing
- o knowledge and use of on-network to on-network dialing
- o knowledge and use of on-network to off-network dialing
- o STS connection quality in comparison with other types of connection
- o location and/or nature of STS problems encountered
- o STS problem reporting procedures
- o STS instruction
- o satisfaction with STS and suggestions for improvement

Once the questionnaire was finalized, the State of Texas distributed it to a random sample of STS users, stratified to ensure representation of users in rural as well as urban areas. The surveys were returned by respondents directly to the research team at BNR for analysis. Some 240 questionnaires were returned, 219 of which were accepted for analysis.

Data analysis consisted of the generation of a set of univariate statistics for all variables. Specifically, these consisted of frequency distributions for categorical variables (e.g., "Which type of call do you make most frequently?"); continuous descriptive statistics for interval-level variables (e.g., "percent calls made to citizens"); and multiple response tabulations for open-ended questions (e.g., "What factors would lead you to dial a state office using STS?"). Statistics such as means, medians and standard deviations were output for variables where appropriate.

The program generating the statistics was set up to duplicate the response patterns of the questionnaire. Thus, for example, only those respondents who knew that it was possible to phone someone on the STS network from a phone off the network were considered in generating statistics for percent use of this feature or reasons for use of this dialing pattern. See attachment, "Texas Study File Run".

The data have been summarized in detail in the attached set of charts. These charts have been structured so as to follow the flow of the questionnaire. A brief analysis of these charts is presented below. Following this analysis is a summary of the results of the survey of network users.

2 ANALYSIS OF RESULTS

The survey results confirm what other studies have shown about the interaction of technology with its users: namely, that the user is typically interested in whether the technology serves its function, and not how it serves that function. Thus, for instance, a phone user wants to complete a call and is not interested in how that call is completed.

Questions on STS instruction, comfort and satisfaction all indicate a fairly high level of user understanding and/or satisfaction with the STS network. For example, the point is not that just slightly over half the respondents know about off- to on-network dialing so much as it is that nearly 90% are satisfied with their knowledge of the system.

Comparing STS service with the service from other dialing options (e.g., local calls, regular long distance) revealed a slightly negative distinction. STS quality is seen as being somewhat less attractive compared with local and regular long distance service. Given some amount of response bias (users may have been reluctant to admit dissatisfaction with the system), the results are consistent enough to lead one to assume that the STS system compares favorably with other types of service with respect to service problems and connection.

One might assume that STS use is constrained by an unwillingness of users to accept the requirements of the technology (e.g., dialing different numbers), that users are slow to accept innovations or changes to their routine. In fact, we found little support for this idea. While the complicated nature of STS dialing was cited as a reason for dialing around the network by 13% of the respondents, 52% cited the fact that STS was busy or unavailable and 20% cited the time savings (of which waiting for an STS line is certain to be a factor). Again, 56% of the respondents cited STS being busy and/or unavailable as the reason for dialing state offices directly; only 4% cited the inconvenience of STS as a reason.

In addition to lack of network availability, it turns out that another major inhibitor of STS use is lack of directory information. 37% of the respondents cited reasons relating to lack of directory information as the reason for dialing state offices directly. Many of the suggestions for improving STS had to do with providing directories and/or updates to all state employees.

Any analysis of the costs and benefits of this or a proposed system should take into account such factors as have been related above. The costs of providing greater network availability on the one hand and improved directory information on the other need to be balanced against the savings to be realized by avoiding long distance and/or other non-STS service. Ignoring these costs and benefits would make any economic analysis both simpler and less accurate.

In sum, there is a high degree of satisfaction with the system and when a connection is established the quality is generally good and service problems rare. However, there are areas of action that can be taken to improve access to and utilization of the STS network, areas that are likely to prove cost-effective.

3 SUMMARY OF RESPONSES

3.1 Respondent Demographics

About half (46%) of the respondents are from the Austin switcher area. 16% each are from the Dallas and Houston switcher areas. Another 10% are from the Abilene switcher area. Twelve percent of the respondents were unable to be assigned to a particular area, due to lack of meaningful response to the question.

Respondents report making a median of thirteen phone calls of all types each day. 75% of the respondents make up to 24 calls per day. The type of call most frequently made is the inside call (43%), followed by STS calls (26%) and outside local calls (18%).

3.2 STS Usage Characteristics

Calls were said by users to be almost evenly divided between those made to state offices (53%) and those made to citizens (47%). Of the calls made to citizens, 57% were perceived to be made to citizens in larger cities, with 43% to citizens in smaller cities. Of the calls made to state offices, 58% were reported made using the STS number and 42% were assigned as directly dialed (i.e., using the area code and phone number). Those who dial state offices using STS say they do so because of favorable cost-benefit calculations (27%), because they find

STS convenient (23%), because STS is faster than dialing direct (17% -- note that this is at odds with some other user comments), because STS use is considered a standard procedure (16%) and because the STS number is available (15%). Among those who dial state offices direct, 56% do so, they reported, because the STS network is busy or inoperative, 19% do so because they forgot the party's STS number, 18% do so because they couldn't find the STS number or didn't have a directory and 12% do so because the party isn't on the network.

About half of the respondents (53%) state that it is possible to dial from off the network on to the network; 12% feel this isn't possible and 33% don't know. Those who do know about dialing into the network do so 61% of the time and dial direct 39% of the time. Among those who do dial into the network, the most frequently cited reason is that STS costs less to use (49%). Having an STS directory is cited as a reason 11% of the time, as is the statement that STS use is a mandatory practice. Among those who dial direct, rather than into the network, 52% do so because STS is busy or unavailable. 20% do so to save time and 13% do so because they find the STS dialing procedure too complicated.

81% of the respondents "almost always" or "frequently" are able to reach STS; only 2% are "almost never" able to reach the network. A fourth of the respondents virtually never use STS, while 38% use it to make one to five calls a day and 35% use it to make six or more calls each day.

3.3 Quality Of Phone Connection

The quality of phone connection is rated highly for each of four types of service. 76% of the respondents feel that the phone connection is excellent or very good for local calls, while 65% feel similarly about regular long distance calls. On-network to on-network calls are rated as excellent or very good by 52% of the respondents and on-network to off-network calls are rated similarly by 54% of the respondents. Looking at the mean quality of phone connection (on a one-to-five scale, with lower number representing higher quality), local calls receive a rating of 1.8, regular long distance a rating of 2.1, on- to on-network connections a 2.5 and on- to off-network again receive a 2.5 rating.

3.4 Comparison Of Service Problems

The frequency of service problems is rare for all types of connections listed. For regular long distance dialing, as few as two percent of the respondents experience a problem ("your call fades away") almost always, frequently or regularly and at most twenty-three percent experience a problem ("you hear faint voices on the line") almost always, frequently or regularly. For on-network to off-network calls, as few as six percent experience a problem ("you are cut off in mid call") almost always, frequently or regularly, while as many as twenty three percent experience a problem ("there is hissing noise or static") almost always to regularly. For on-network to on-network calls the range of occurence is from five percent ("your call fades away") to thirty-one percent ("you hear faint voices on the line" and "it sounds like you are talking in a barrel").

3.5 Effect Of Service Problems On STS Use

One sees little effect of any of the service problems on STS use. As few as four percent are inhibited by a problem ("your call fades away") almost always, frequently or regularly while as many as seventeen percent are inhbited in a like manner by a problem ("there is hissing noise or static"). Looking at mean frequency of inhibition, having the call fail to ring is slightly more inhibiting than there being hissing noise or static (4.300 vs. 4.365 on a 1-to-5 scale), but again all the problems have a mean degree of inhibition of 4 or more on a 1-to-5 scale, where 5 represents minimal inhibition.

Combining measures of STS service problem frequency of occurence with degree of network use inhibition led to the development of an impact index for the service problems. The index ranges from one to five, with one representing a great deal of use impact and five representing little or no impact on STS use. The mean impacts on STS use range from there being hissing noise or static on the line (3.56/5) to one's call fading away (4.07/5). The impact index shows that at most, certain service problems occasionaly have an impact on the STS user.

3.6 STS Problems

Twenty percent of the respondents feel that there is a difference in quality among STS calls according to calling location, while fifty-one percent feel there is no such difference and twenty-four percent do not know. Among those who feel there is a difference in STS quality, the switcher area most often cited is the Abilene area (40%), followed by the Houston switcher (38%), the Austin switcher (33%) and the Dallas switcher (28%).

The percents add to more than 100 since multiple responses were permissable.

36% of the respondents have recently experienced an STS problem that disrupted or interrupted their conversation; 56% have not experienced any such problem. Those that have experienced a problem most often cite noise on the line (37%), followed by being cut off in mid-call (32%), encountering busy lines (16%) or other transmission difficulties (16%). 44% of those who experienced a problem reported it, while 56% did not.

24% of the respondents reported their problems every time or most of the time, while 33% reported problems some of the time or never. Just under half the respondents know who to talk with in order to report STS problems. 90% of these listed the title of a person to whom they reported their problems, the operator and an STS service number being most frequently mentioned.

3.7 STS Instruction

69% of the respondents report being instructed in STS use, while 25% do not and 3% don't know. 87% of the respondents are very or somewhat comfortable with their understanding of STS, as opposed to 10% who report being not very or not at all comfortable with their STS knowledge.

3.8 STS Satisfaction

56% of the respondents report being completely or very satisfied with STS, 32% are somewhat satisfied, 5% are not very satisfied and 1% are not at all satisfied. The mean ranking for satisfaction is 2.35 out of 5, with one being completely satisfied and 5 being not at all satisfied.

RESPONDENT LOCATION

Who Are From:	Percent of Respondents N=(219)
Austin	37.4%
College Station	5.9
Houston	3.7
San Antonio	2.3
Tyler	2.3
Beaumont	2.3
Lubbock	2.3
Waco	2.3
Wichita	1.8
Amarillo	1.4
Huntsville	1.4
Arlington	1.4
Big Spring	1.4
El Paso	1.4
Corpus Christi	0.9
Mexia	0.9
Harlingen	0.9
Garland	0.9
Canton	0.9
Fort Worth	0.9
San Angelo	0.9
Commerce	0.9
Denton	0.9
La Costa	0.5
Carlsbad	0.5
Midland	0.5
Fort Stockton	0.5
Riverside	0.5
Crockett	0.5
Brownwood	0.5
Brownsville	0.5
Phan	0.5
Terrell	0.5
Bryan	0.5
Kilgore	0.5
Atlanta	0.5
Port Aransus	0.5
Weslaco	0.5
Praire View	0.5
Temple	0.5
Rutherford	0.5
Edinburg	0.5

RESPONDENT LOCATION (continued)

Who Are From:	Percent of Respondents N=(219)
Alpine	0.5
Dallas	0.5
Angleton	0.5
Paris	0.5
Sulphur Springs	0.5
Rusk	0.5
Richmond	0.5
Childress	0.5
Capitol Station	0.5
Overton	0.5
Hutchins	0.5
Unidentifiable Location	9.6
No Answer	1.4
	100.0%

STS INSTRUCTION

Qu. Have you ever been instructed in the use of STS?

Who Said:	Percent of Respondents N=(219)
Yes	69%
No	25
Don't Know	3
No Answer	3
	100%

SATISFACTION WITH STS

Qu. How would you rate your satisfaction with STS?

Who Said:	Percent of Respondents N=(219)
Completely satisfied	13%
Very satisfied	43
Somewhat satisfied	32
Not very satisfied	5
Not at all satisfied	1
No answer	6
	100%

Mean: 2.35
Median: 2.29
Standard Deviation: 0.84

DEGREE OF COMFORT WITH STS

Qu. How comfortable are you with your understanding of STS?

Who Said:	Percent of Respondents N=(219)
Very comfortable	47%
Somewhat comfortable	40
Not very comfortable	9
Not at all comfortable	1
No answer	3
	100%

STS PROBLEM REPORTING FREQUENCY

Qu. How often do you report problems you have using STS?

Who Said:	Percent of Respondents N=(219)
Every time	11%
Most of the time	13
Some of the time	19
Never	14
No answer	43

	100%

STS PROBLEM REPORTING

Qu. Have you experienced any problems using STS recently that either prevented you from having a successful conversation or caused one to be interrupted?

Qu. Did you report this/these problem(s)?

		Percent of Respondents
Who Said:		N=(219)
Yes	36%	
And Said		
Yes		44%
No		55
No answer		1
		--
No	56	
Don't know	4	
No answer	4	

	100%	

EFFECT OF SERVICE PROBLEMS ON STS USE

Qu. Please rank each of the situations listed below in terms of how much it inhibits your use of STS.

		Percent of Respondents Who Said:				
Type of Situation	N	Almost Always	Fre-quently	Regu-larly	Occa-sionally	Almost Never
The other person's voice is faint	(203)	3%	1	3	36	57
You are cut off in mid-call	(203)	2%	1	2	23	72
There is hissing noise or static	(203)	8%	4	5	36	54
The call doesn't ring--nothing happens	(203)	4%	3	9	27	57
It sounds like you are talking in a barrel	(203)	1%	2	3	23	71
Your voice echoes	(203)	-	2%	3	20	75
You hear faint voices on the line	(202)	2%	4	2	34	58
The person you called can't hear you	(203)	2%	3	4	38	53
Your call fades away	(202)	1%	-	3	12	84

* Percents sum horizontally

SERVICE PROBLEMS: OFF-NETWORK TO OFF-NETWORK

Qu. From your experience in making regular long distance (non-STS) calls at home, as well as at work, please mark how often you notice each of the following situations:

		Percent of Respondents Who Said:				
Type of Situation	N	Almost Always	Fre-quently	Regu-larly	Occa-sionally	Almost Never
The other person's voice is faint	(215)	1%	9	5	63	22
You are cut off in mid-call	(215)	-	2%	2	27	69
There is hissing noise or static	(216)	1%	7	13	59	20
The call doesn't ring--nothing happens	(215)	-	4%	6	36	54
It sounds like you are talking in a barrel	(216)	-	4%	3	42	51
Your voice echoes	(216)	-	2%	4	32	62
You hear faint voices on the line	(216)	2%	9	12	57	20
The person you called can't hear you	(216)	-	2%	7	57	34
Your call fades away		-	1%	1	20	78

* Percents sum horizontally

SERVICE PROBLEMS: ON-NETWORK TO OFF NETWORK

Qu. From your experience in making STS calls to non-STS phone number, please mark how often you notice each of the following situations:

		Percent of Respondents Who Said:				
Type of Situation	N	Almost Always	Frequently	Regularly	Occasionally	Almost Never
The other person's voice is faint	(197)	3%	4	8	53	32
You are cut off in mid-call	(197)	-	2%	4	28	66
There is hissing noise or static	(197)	4%	6	13	52	25
The call doesn't ring--nothing happens	(197)	1%	8	10	40	41
It sounds like you are talking in a barrel	(197)	1%	3	5	40	51
Your voice echoes	(196)	1%	3	1	34	61
You hear faint voices on the line	(197)	3%	9	10	51	27
The person you called can't hear you	(197)	2%	6	10	42	40
Your call fades away	(195)	1%	2	4	17	76

* Percents sum horizontally

SERVICE PROBLEMS: ON-NETWORK TO ON-NETWORK CALLS

Qu. From your experience in making STS calls to other STS locations, please mark how often you notice each of the following situations:

		Percent of Respondents Who Said:				
Type of Situation	N	Almost Always	Frequently	Regularly	Occasionally	Almost Never
The other person's voice is faint	(197)	3%*	8	9	57	23
You are cut off in mid-call	(197)	1%	3	5	31	60
There is hissing noise or static	(197)	3%	9	14	51	23
The call doesn't ring--nothing happens	(197)	2%	7	13	43	35
It sounds like you are talking in a barrel	(196)	21%	4	6	38	50
Your voice echoes	(196)	1%	2	7	30	60
You hear faint voices on the line	(197)	4%	11	16	39	30
The person you called can't hear you	(197)	2%	7	10	47	34
Your call fades away	(196)	-	2%	3	22	73

* Percents sum horizontally

QUALITY OF PHONE CONNECTION

Qu. How would you rate the quality of your phone connection in each of the following types of calls?

		Percent of Respondents Who Said:				
Type of Call	N	Excellent	Very Good	Good	Poor	Unacceptab
Local calls	(214)	44%	36	17	3	-
Regular long distance	(198)	25%	40	31	3	1
STS call to another STS location	(196)	17%	35	35	13	-
STS call to a non-STS location	(197)	16%	39	31	12	2

*Percents sum horizontally

FREQUENCY OF STS CONNECTION

Qu. How often are you able to reach STS?

	Percent of Respondents
	N=(219)
Almost always	62%
Frequently	19
Regularly	11
Occasionally	3
Almost never	2
No answer	3
	100%

FREQUENCY OF STS USE

Qu. On the average, how often do you use STS when making calls?

Who Said:	Percent of Respondents N=(219)
Never	3%
Less than 1 call per day	22
1 to 5 calls per day	38
6 to 10 calls per day	16
10 or more calls per day	19
No answer	2
	100%

MOST FREQUENT TYPE OF CALL

Qu. What type of call do you make most frequently?

Who Said:	Percent of Respondents N = (219)
Inside calls	43%
STS calls	26
Outside local calls	18
Multiple response	6
Non-STS low distance or international calls	4
No answer	3
	100%

STS PROBLEM REPORTING KNOWLEDGE

Qu. Do you know who you should talk with in order to report STS problems?

Qu. What is the title of the person to whom you should report any STS problems?

		Percent of Respondents N = (219)
Who Said:		
Yes	48%	
And		
Listed title		90%
Did not give title		10
No	48	
No answer	4	
	100%	

STS PROBLEM IDENTIFICATION

Qu. Have you experienced any problems using STS recently that either prevented you from having a successful conversation or caused one to be interrupted?

Qu. (If "yes"), what problem(s) did you encounter?

Who Encountered:	Percent of Respondents Who Have Experienced STS Problems
	N = (68)
Noise on the line	37%
Cut off in mid-call	32
Lines busy	18
Weak connection	16
Transmission difficulties	16
Connection not established	10
All other responses	18
	**

**Multiple responses

STS PROBLEM LOCATIONS

Qu. Is there any difference in quality among STS calls, based on where you call?

Qu. If there is a difference in quality, depending on where you call, please list any cities or locations you call using STS, where you encounter problems in phone quality.

Switcher Area Where Problems Were Encountered	Percent of Respondents Who Noticed a Difference in Quality, Based on Call Location
	N = (40)
Abilene	40%
Houston	38
Austin	33
Dallas	28
Areas listed, but unable to be assigned to a particular area	58
	**

**Multiple responses

STS PROBLEM LOCATIONS

Qu. Is there any difference in quality among STS calls, based on where you call?

Who Said:	Percent of Respondents N = (219)
Yes	20%
No	51
Don't know	24
No answer	5
	100%

STS PROBLEM IDENTIFICATION

Qu. Have you experienced any problems using STS recently that either prevented you from having a successful conversation or caused one to be interrupted?

Who Said:	Percent of Respondents
	N = (219)
Yes	36%
No	56
Don't know	4
No answer	4
	100%

OFF-NETWORK TO ON-NETWORK: REASONS FOR DIALING DIRECT

Qu. When calling someone from a phone not served by the STS network, what factors would lead you to dial them directly, rather than dial into the network?

And Said:	Percent of Respondents Who Dialed Directly
	N = (54)
STS busy/unavailable	52%
Save time	20
STS procedure is complicated	13
STS impractical	6
Caller out of state	6
Caller needed operator information	6
All other responses	30
	**

**Multiple responses

OFF-NETWORK TO ON-NETWORK: REASONS FOR STS USE

Qu. When calling someone from a phone not served by the STS network, what factors would lead you to dial into the network, rather than dial them directly?

And Said:	Percent of Respondents Who Dialed Into the STS Network
	N = (75)
STS costs less	49%
Have STS directory	11
Mandatory practice	11
STS procedure easier	8
STS available	8
Standard procedure	7
All other responses	29
	**

**Multiple responses

OFF-NETWORK TO ON-NETWORK DIALING

Qu. Is it possible to call someone on the STS network from a phone not served by the STS network?

Qu. When calling someone from a phone not served by the STS network, what percent of the time do you call by dialing into the STS network, and what percent of the time do you call by dialing them directly?

		Percent of Respondents
		N = (219)
Who Said:		
Yes	53%	
And Said:		
Dial into network		61%
Dial direct		39
No	12	
Don't know	33	
No answer	2	
	100%	

REASONS FOR STS USE ON-NETWORK TO ON-NETWORK

Qu. What factors would lead you to dial a state office using STS; that is, using the STS number?

Who Said:	Percent of Respondents Who Dialed State Offices Using STS
	N = (219)
Cost benefit	27%
STS convenient	23
STS faster	17
Standard procedure	16
STS number available	15
Have current STS directory	6
Regular number busy	3
all other responses	19
	**

**Multiple responses

REASONS FOR DIRECT DIALING ON-NETWORK TO ON-NETWORK

Qu. What factors would lead you to dial a state office without using STS; that is, using the area code and phone number?

And Said:	Percent of Respondents Who Dialed State Office Direct
	N=(162)
Network was busy	32%
STS was not working	24
Forgot STS number	19
Other party was not on STS network	12
Couldn't find STS number	9
Didn't have directory	9
STS inconvenient	4
All other responses	30
	**

**Multiple responses

STATE OFFICE CALLING PATTERN

Qu. Of the calls you make to a state office using STS, what percent are made using the area code and phone number, and what percent are made using the STS number?

	Percent of Respondents Who Called State Offices
And Said:	N=(150)
Use STS number	58%
Use area code and phone number	42
	100%

CALLING DESTINATION: CITY SIZE

Qu. Of the calls you make to citizens, what percent are made to citizens in larger cities (e.g., Abilene, Dallas, San Antonio, Beaumont), and what percent are made to those in smaller cities?

Who Made Calls to:	Percent of Respondents Who Called Citizens
	N=(196)
Larger cities	57%
Smaller cities	43
	100%

CALLING DESTINATION

Qu. What percent of your calls are made to a state office and what percent are made to citizens (not at a state office)?

Who Called:	Percent of Respondents N=(208)
State offices	53%
Citizens	47
	100%

PHONE ACTIVITY

Qu. About how many phone calls of all types (local, long distance and STS) do you make each day?

Mean:	31
Median:	13
Standard Deviation:	94

INDEX OF STS SERVICE PROBLEMS

An index for each STS service problem was created by combining scores on degree of problem frequency with degree of problem inhibition. The index was normalized to a one-to-five scale, comparable to those used to construct the index. One represents a high degree of impact of the STS problem on the user while five represents a low degree of impact on the user.

Service Problem	Mean Impact
There is hissing noise or static	3.555
You hear faint voices on the line	3.564
The other person's voice is faint	3.628
The call doesn't ring--nothing happens	3.628
The person you called can't hear you	3.662
It sounds like you are talking in a barrel	3.872
Your voice echoes	3.961
You are cut off in mid-call	3.966
Your call fades away	4.066

MEAN DEGREE OF PHONE USAGE INHIBITION FOR STS SERVICE PROBLEMS

Service Problem	Mean Degree of Inhibition*
The call doesn't ring--nothing happens	4.300
There is hissing noise or static	4.365
The person you called can't hear you	4.369
You hear faint voices on the line	4.421
The other person's voice is faint	4.429
You are cut off in mid-call	4.631
It sounds like you are talking in a barrel	4.631
Your voice echoes	4.675
Your call fades away	4.772

* 1-to-5 scale; lower numbers reflect a greater degree of inhibition.

MEAN FREQUENCY OF SERVICE PROBLEMS ACCORDING TO TYPE OF SERVICE

Service Problem	Type of Service: Regular Long Distance	STS to STS	STS to Non-STS
The other person's voice is faint	3.967	3.909	4.081
You are cut off in mid-call	4.628	4.477	4.558
There is hissing noise or static	3.889	3.812	3.898
The call doesn't ring--nothing happens	4.400	4.025	4.117
It sounds like you are talking in a barrel	4.398	4.306	4.360
Your voice echoes	4.528	4.464	4.510
You hear faint voices on the line	3.843	3.817	3.888
The person you called can't hear you	4.227	4.051	4.132
Your call fades away	4.745	4.653	4.667

* 1-to-5 scale; lower scores indicate a greater frequency of occurence.

RESPONDENT LOCATION

Who are From:	Percent of Respondents N=(219)
Austin	46%
Dallas	16
Houston	16
Abilene	10
Unable to assign location	12
	100%

QUALITY OF PHONE CONNECTION

Type of Call	Mean	Standard Deviation
Local	1.780	0.824
Regular long distance	2.126	0.836
STS to STS	2.454	0.935
STS to Non-STS	2.462	0.966

1-to-5 scale, ranging from excellent (1) to unacceptable (5).

COST BREAKDOWN FOR NTINDS DESIGN OF THE EXISTING STS NETWORK

APPENDIX G

1 Cost Components of Four-Switch Network (including Lubbock) with 1982 Traffic

Major Four-Switch Network Cost Components

	From	To	Cost	% Total Cost
IMT	Austin	Houston	$38,770	
		Dallas	$46,610	
		Lubbock	$33,725	
	Houston	Austin	$38,770	
		Dallas	$15,597	
		Lubbock	$ 9,519	
	Dallas	Austin	$46,610	
		Houston	$15,597	
		Lubbock	$11,320	
	Lubbock	Austin	$33,725	
		Houston	$ 9,519	
		Dallas	$11,320	
Subtotal :			$155,541	20.5
Access Lines Cost/Location		Austin	$161,526	
		Houston	$ 76,569	
		Dallas	$ 92,288	
		Lubbock	$ 71,160	
Subtotal :			$401,543	52.8
PBX Ports		Austin	$ 23,280	
		Houston	$ 13,440	
		Dallas	$ 15,060	
		Lubbock	$ 6,660	
Subtotal :			$ 58,440	7.7
Tandem Switch Cost/Switch		Austin	$ 57,900	
		Houston	$ 33,050	
		Dallas	$ 36,550	
		Lubbock	$ 16,700	
Subtotal :			$144,200	19.0
Total Network Cost :			$765,653	100.0

2 Cost Components of Four-Switch Network (including Sweetwater) with 1982 Traffic

Major Four-Switch Network Cost Components

	From	To	Cost	% Total Cost
IMT	Austin	Houston	$38,770	
		Dallas	$46,020	
		Sweetwater	$24,097	
	Houston	Austin	$38,770	
		Dallas	$15,597	
		Sweetwater	$ 7,503	
	Dallas	Austin	$46,020	
		Houston	$15,597	
		Sweetwater	$ 9,001	
	Sweet-water	Austin	$24,097	
		Houston	$ 7,503	
		Dallas	$ 9,001	
Subtotal :			$140,989	18.7
Access Lines Cost/Location		Austin	$158,180	
		Houston	$ 76,569	
		Dallas	$ 90,810	
		Sweetwater	$ 83,737	
Subtotal :			$409,296	54.4
PBX Ports		Austin	$ 23,010	
		Houston	$ 13,440	
		Dallas	$ 14,940	
		Sweetwater	$ 7,050	
Subtotal :			$ 58,440	7.8
Tandem Switch Cost/Switch		Austin	$ 57,350	
		Houston	$ 33,050	
		Dallas	$ 36,300	
		Lubbock	$ 17,400	
Subtotal :			$144,100	119.1
Total Network Cost :			$752,825	100.0

3 Cost Components of Five-Switch Network (With Sweetwater) with 1982 Traffic

Major Five-Switch Network Cost Components

	From	To	Cost	% Total Cost
IMT	Austin	Houston	$35,222	
		Dallas	$46,315	
		Sweetwater	$24,097	
		Harlingen	$27,975	
	Houston	Austin	$35,222	
		Dallas	$15,597	
		Sweetwater	$ 7,503	
		Harlingen	$ 2,913	
	Dallas	Austin	$46,315	
		Houston	$15,597	
		Sweetwater	$ 9,001	
		Harlingen	0	
	Sweet-water	Austin	$24,097	
		Houston	$ 7,503	
		Dallas	$ 9,001	
		Harlingen	0	
	Harlingen	Austin	$27,975	
		Houston	$ 2,913	
		Dallas	0	
		Sweetwater	0	
Subtotal :			$168,625	22.9
Access Lines Cost/Location		Austin	$85,257	
		Houston	$63,287	
		Dallas	$90,810	
		Sweetwater	$83,737	
		Harlingen	$38,284	
Subtotal :			$361,375	48.9
PBX Ports		Austin	$ 18,720	
		Houston	$ 12,720	
		Dallas	$ 14,940	
		Sweetwater	$ 7,050	
		Harlingen	$ 5,010	
Subtotal :			$ 58,440	7.9

Major Five-Switch Network Cost Components (Cont.)

From	To	Cost	% Total Cost
Tandem Switch Cost/Switch	Austin Houston Dallas Sweetwater Harlingen	\$ 52,950 \$ 31,500 \$ 36,350 \$ 17,400 \$ 12,100	
Subtotal :		\$150,300	20.3
Total Network Cost :		\$738,740	100.0

4 Cost Components of Five-Switch Network (With Lubbock) with 1982 Traffic

Major Five-Switch Network Cost Components

	From	To	Cost	% Total Cost
IMT	Austin	Houston Dallas Lubbock Harlingen	$35,222 $46,610 $33,725 $27,975	
	Houston	Austin Dallas Lubbock Harlingen	$35,222 $15,597 $ 7,519 $ 2,913	
	Dallas	Austin Houston Lubbock Harlingen	$46,610 $15,597 $11,320 0	
	Lubbock	Austin Houston Dallas Harlingen	$33,725 $ 9,519 $11,320 0	
	Harlingen	Austin Houston Dallas Lubbock	$27,975 $ 2,913 0 0	
Subtotal :			$182,882	24.5
Access Lines Cost/Location		Austin Houston Dallas Lubbock Harlingen	$88,603 $63,287 $92,288 $71,160 $38,284	
Subtotal :			$353,622	47.5
PBX Ports		Austin Houston Dallas Lubbock Harlingen	$ 18,990 $ 12,720 $ 15,060 $ 6,660 $ 5,010	
Subtotal :			$ 58,440	7.8

Major Five-Switch Network Cost Components (Cont.)

From	To	Cost	% Total Cost
Tandem Switch Cost/Switch	Austin Houston Dallas Lubbock Harlingen	\$ 53,450 \$ 31,500 \$ 36,550 \$ 16,700 \$ 12,100	
Subtotal :		\$150,300	20.2
Total Network Cost :		\$745,244	100.0

5 Cost Components of Six-Switch Network (4-Primaries) with 1982 Traffic

Major Six-Switch Network Cost Components

	From	To	Cost	% Total Cost
IMT	Austin	Houston	$34,969	
		Dallas	$46,315	
		Sweetwater	$24,097	
		Harlingen	$15,633	
		Corpus Chr	$20,081	
	Houston	Austin	$34,969	
		Dallas	$15,597	
		Sweetwater	$ 7,503	
		Harlingen	$ 1,248	
		Corpus Chr	$ 2,894	
	Dallas	Austin	$46,315	
		Houston	$15,597	
		Sweetwater	$ 9,001	
		Harlingen	0	
		Corpus Chr	0	
	Sweet-water	Austin	$24,097	
		Houston	$ 7,503	
		Dallas	$ 9,001	
		Harlingen	0	
		Corpus Chr	0	
	Harlingen	Austin	$15,633	
		Houston	$ 1,248	
		Dallas	0	
		Sweetwater	0	
		Corpus Chr	$ 3,087	
	Corpus Christi	Austin	$20,081	
		Houston	$ 2,894	
		Dallas	0	
		Sweetwater	0	
		Harlingen	$ 3,087	
Subtotal :			$180,427	24.7

Major Six-Switch Network Cost Components (Cont.)

From	To	Cost	% Total Cost
Access Lines Cost/Location	Austin	$80,489	
	Houston	$63,287	
	Dallas	$90,810	
	Sweetwater	$83,737	
	Harlingen	$12,504	
	Corpus Chr	$ 9,025	
Subtotal :		$339,852	46.5
From	**To**	**Cost**	**% Total Cost**
PBX Ports	Austin	$ 18,300	
	Houston	$ 12,720	
	Dallas	$ 14,940	
	Sweetwater	$ 7,050	
	Harlingen	$ 2,730	
	Corpus Chr	$ 2,700	
Subtotal :		$ 58,440	8.0
Tandem Switch Cost/Switch	Austin	$ 52,850	
	Houston	$ 31,550	
	Dallas	$ 36,350	
	Sweetwater	$ 17,400	
	Harlingen	$ 7,050	
	Corpus Chr	$ 7,400	
Subtotal :		$152,600	20.8
Total Network Cost :		$731,319	100.0

6 Cost Components of Six-Switch Network (5-Primaries) with 1989 Traffic

Major Six-Switch Network Cost Components

	From	To	Cost	% Total Cost
IMT	Austin	Houston	$55,748	
		Dallas	$74,635	
		Lubbock	$39,425	
		Abilene	$15,901	
		Harlingen	$40,728	
	Houston	Austin	$55,748	
		Dallas	$25,648	
		Lubbock	$11,422	
		Abilene	$ 5,053	
		Harlingen	$ 4,994	
	Dallas	Austin	$74,635	
		Houston	$25,648	
		Lubbock	$11,755	
		Abilene	$ 9,457	
		Harlingen	$ 2,490	
	Lubbock	Austin	$39,425	
		Houston	$11,422	
		Dallas	$11,755	
		Abilene	$ 6,515	
		Harlingen	0	
	Abilene	Austin	$15,901	
		Houston	$ 5,053	
		Dallas	$ 9,457	
		Lubbock	$ 6,515	
		Harlingen	0	
	Harlingen	Austin	$40,728	
		Houston	$ 2,490	
		Dallas	0	
		Lubbock	0	
		Abilene	0	
Subtotal :			$303,776	26.5

Major Six-Switch Network Cost Components (Cont.)

From	To	Cost	% Total Cost
Access Lines Cost/Location	Austin	$125,350	
	Houston	$ 92,468	
	Dallas	$134,857	
	Lubbock	$ 67,220	
	Abilene	$ 34,282	
	Harlingen	$ 54,110	
Subtotal :		$508,287	44.3
PBX Ports	Austin	$ 29,160	
	Houston	$ 19,290	
	Dallas	$ 23,490	
	Lubbock	$ 7,560	
	Abilene	$ 4,920	
	Harlingen	$ 7,110	
Subtotal :		$ 91,530	8.0
Tandem Switch Cost/Switch	Austin	$ 83,950	
	Houston	$ 48,900	
	Dallas	$ 58,700	
	Lubbock	$ 20,300	
	Abilene	$ 14,300	
	Harlingen	$ 17,600	
Subtotal :		$243,750	21.2
Total Network Cost :		$1,147,343	100.0

7 Cost Components of Seven-Switch Network (5-Primaries) with 1989 Traffic

Major Seven-Switch Network Cost Components

	From	To	Cost	% Total Cost
IMT	Austin	Houston	$55,494	
		Dallas	$75,225	
		Lubbock	$39,425	
		Abilene	$15,901	
		Harlingen	$23,449	
		Corpus Chr	$29,421	
	Houston	Austin	$55,494	
		Dallas	$25,648	
		Lubbock	$11,422	
		Abilene	$ 5,053	
		Harlingen	$ 1,664	
		Corpus Chr	$ 4,824	
	Dallas	Austin	$75,225	
		Houston	$25,648	
		Lubbock	$11,755	
		Abilene	$ 9,457	
		Harlingen	0	
		Corpus Chr	0	
	Lubbock	Austin	$39,425	
		Houston	$11,422	
		Dallas	$11,755	
		Abilene	$ 6,515	
		Harlingen	0	
		Corpus Chr	0	
	Abilene	Austin	$15,901	
		Houston	$ 5,053	
		Dallas	$ 9,457	
		Lubbock	$ 6,515	
		Harlingen	0	
		Corpus Chr	0	
	Harlingen	Austin	$23,449	
		Houston	$ 1,664	
		Dallas	0	
		Lubbock	0	
		Abilene	0	
		Corpus Chr	$ 4,802	
Subtotal :			$320,061	28.2

Major Seven-Switch Network Cost Components (Cont.)

From	To	Cost	% Total Cost
Access Lines Cost/Location	Austin	$118,538	
	Houston	$ 92,468	
	Dallas	$134,857	
	Lubbock	$ 67,220	
	Abilene	$ 34,282	
	Harlingen	$ 17,253	
	Corpus Chr	$ 12,601	
Subtotal :		$477,219	42.0
PBX Ports	Austin	$ 28,560	
	Houston	$ 19,290	
	Dallas	$ 23,490	
	Lubbock	$ 7,560	
	Abilene	$ 4,920	
	Harlingen	$ 3,840	
	Corpus Chr	$ 3,870	
Subtotal :		$ 91,530	8.0
Tandem Switch Cost/Switch	Austin	$ 84,050	
	Houston	$ 48,950	
	Dallas	$ 58,600	
	Lubbock	$ 20,300	
	Abilene	$ 14,300	
	Harlingen	$ 10,150	
	Corpus Chr	$ 10,800	
Subtotal :		$247,150	21.8
Total Network Cost :		$1,135,960	100.0

8 Node to Switch Homing Plan for 4-Switch Network: Austin(56), Houston(84), Dallas(11), Sweetwater(122)

PBX NO.	LOCATION	PBX NO HOME-SW
1	HUTCHINS,TX	11
2	SUNNYVALE,TX	11
3	RICHARDSON,TX	11
4	LONGVIEW,TX	11
5	FARMERSBR,TX	11
6	RENNER,TX	11
7	IRVING,TX	11
8	GRANDPRA,TX	11
9	GARLAND,TX	11
10	DUNCANVILLE,TX	11
11	DALLAS,TX	11
12	BENFRANK,TX	11
13	GREENVILLE,TX	11
14	COMMERCE,TX	11
15	TYLER,TX	11
16	HOWE,TX	11
17	MCKINNEY,TX	11
18	TERRELL,TX	11
19	CANTON,TX	11
20	MTPLEASANT,TX	11
21	HALLSVILLE,TX	11
22	ATHENS,TX	11

PBX NO.	LOCATION	PBX NO HOME-SW
23	RUSK,TX	11
24	PARIS,TX	11
25	TEXARKANA,TX	11
26	ATLANTA,TX	11
27	OVERTON,TX	11
28	SHERMAN,TX	11
29	CORSICANA,TX	11
30	OWENTOWN,TX	11
31	SULPHURSP,TX	11
32	KAUFMAN,TX	11
33	WAXAHACHLE,TX	11
34	KILGORE,TX	11
35	ARLINGTON,TX	11
36	FTWORTH,TX	11
37	WICHITAFA,TX	11
38	DENTON,TX	11
39	VERNON,TX	122
40	MEXIA,TX	11
41	HOLIDAY,TX	11
42	EASTLAND,TX	122
43	GAINSVILLE,TX	11
44	CHILDRESS,TX	122
45	STEPHENVI,TX	11
46	SANANTONIO,TX	56
47	ROUNDROCK,TX	56
48	SANMARCOS,TX	56

PBX NO.	LOCATION	PBX NO HOME-SW
49	PFLUGERVI,TX	56
50	KERRVILLE,TX	56
51	UVALDE,TX	56
52	CORPUSCHR,TX	56
53	YOAKUM,TX	56
54	DELRIO,TX	56
55	BASTROP,TX	56
56	AUSTIN,TX	56
57	BROWNSVIL,TX	56
58	TAYLOR,TX	56
59	SINTON,TX	56
60	SEGUIN,TX	56
61	EDINBURG,TX	56
62	LOCKHART,TX	56
63	HARLINGEN,TX	56
64	ROCKDATE,TX	56
65	VICTORIA,TX	56
66	KINGSVILLE,TX	56
67	NEWBRAUNFELS,TX	56
68	MCALLEN,TX	56
69	ALICE,TX	56
70	GONZOLES,TX	56
71	LAREDO,TX	56
72	ROCKPORT,TX	84
73	PORTARANSAS,TX	84
74	BURNET,TX	56

PBX NO.	LOCATION	PBX NO HOME-SW
75	PHARR,TX	56
76	GEORGETOWN,TX	56
77	CARRIZOSP,TX	56
78	KILLEEN,TX	56
79	WACO,TX	11
80	TEMPLE,TX	56
81	GATESVILLE,TX	56
82	BELTON,TX	56
83	CLEVELAND,TX	84
84	HOUSTON,TX	84
85	CONROE,TX	84
86	RICHMONDRO,TX	84
87	BRYAN,TX	56
88	APOLLO,TX	84
89	WHARTON,TX	84
90	SPRING,TX	84
91	HUNTSVILLE,TX	84
92	CLUTE-LAKE JACKSON,TX	84
93	LIVINGSTON,TX	84
94	ALVIN,TX	84
95	NASSAU BAY,TX	84
96	DICKINSON,TX	84
97	NEWWAVERLY,TX	84
98	BAYTOWN,TX	84
99	DEER PARK,TX	84
100	SUGARLAND,TX	84

PBX NO.	LOCATION	PBX NO HOME-SW
101	ELCAMPO,TX	84
102	CROCKETT,TX	84
103	NACOGDOUCH,TX	84
104	ROSHARON,TX	84
105	LUFKIN,TX	84
106	BRIDGE CITY,TX	84
107	PORTARTHUR,TX	84
108	GALVESTON,TX	84
109	CHINA,TX	84
110	BRENHAM,TX	84
111	BEAUMONT,TX	84
112	ANGLETON,TX	84
113	PRAIRIEVI,TX	84
114	ALTO,TX	11
115	TEXCITYLM,TX	84
116	LAGRANGE,TX	56
117	PLAINVIEW,TX	122
118	AMARILLO,TX	122
119	PADUCAH,TX	122
120	CANYON,TX	122
121	LUBBOCK,TX	122
122	SWEETWATER,TX	122
123	BIGSPRING,TX	122
124	ODESSA,TX	122
125	FTSTOCKTON,TX	122
126	PYOTE,TX	122

PBX NO.	LOCATION	PBX NO HOME-SW
127	CARLSBAD, TX	122
128	ELPASO, TX	122
129	TERMINAL, TX	122
130	SNYDER, TX	122
131	BROWNWOOD, TX	122
132	SANANGELO, TX	122
133	ABILENE, TX	122
134	MIDLAND, TX	122
135	ALPHINE, TX	122

PBX NO.	LOCATION	PBX NO HOME-SW
9	Node to Switch Homing Plan for 6-Switch Network: Primaries-- Austin(56), Houston(84), Dallas(11), Lubbock(121), Abilene(133); One Secondary-- Harlingen(63)	5
1	HUTCHINS,TX	11
2	SUNNYVALE,TX	11
3	RICHARDSON,TX	11
4	LONGVIEW,TX	11
5	FARMERSBR,TX	11
6	RENNER,TX	11
7	IRVING,TX	11
8	GRANDPRA,TX	11
9	GARLAND,TX	11
10	DUNCANVILLE,TX	11
11	DALLAS,TX	11
12	BENFRANK,TX	11
13	GREENVILLE,TX	11
14	COMMERCE,TX	11
15	TYLER,TX	11
16	HOWE,TX	11
17	MCKINNEY,TX	11
18	TERRELL,TX	11
19	CANTON,TX	11
20	MTPLEASANT,TX	11
21	HALLSVILLE,TX	11
22	ATHENS,TX	11
23	RUSK,TX	11

PBX NO.	LOCATION	PBX NO HOME-SW
24	PARIS, TX	11
25	TEXARKANA, TX	11
26	ATLANTA, TX	11
27	OVERTON, TX	11
28	SHERMAN, TX	11
29	CORSICANA, TX	11
30	OWENTOWN, TX	11
31	SULPHURSP, TX	11
32	KAUFMAN, TX	11
33	WAXAHACHLE, TX	11
34	KILGORE, TX	11
35	ARLINGTON, TX	11
36	FTWORTH, TX	11
37	WICHITAFA, TX	133
38	DENTON, TX	11
39	VERNON, TX	133
40	MEXIA, TX	11
41	HOLIDAY, TX	133
42	EASTLAND, TX	133
43	GAINSVILLE, TX	11
44	CHILDRESS, TX	121
45	STEPHENVI, TX	133
46	SANANTONIC, TX	56
47	ROUNDROCK, TX	56
48	SANMARCOS, TX	56
49	PFLUGERVI, TX	56

PBX NO.	LOCATION	PBX NO HOME-SW
50	KERRVILLE,TX	56
51	UVALDE,TX	56
52	CORPUSCHR,TX	63
53	YOAKUM,TX	56
54	DELRIO,TX	56
55	BASTROP,TX	56
56	AUSTIN,TX	56
57	BROWNSVIL,TX	63
58	TAYLOR,TX	56
59	SINTON,TX	63
60	SEGUIN,TX	56
61	EDINBURG,TX	63
62	LOCKHART,TX	56
63	HARLINGEN,TX	63
64	ROCKDATE,TX	56
65	VICTORIA,TX	56
66	KINGSVILLE,TX	63
67	NEWBRAUNFELS,TX	56
68	MCALLEN,TX	63
69	ALICE,TX	63
70	GONZOLES,TX	56
71	LAREDO,TX	63
72	ROCKPORT,TX	63
73	PORTARANSAS,TX	63
74	BURNET,TX	56
75	PHARR,TX	63

PBX NO.	LOCATION	PBX NO HOME-SW
76	GEORGETOWN,TX	56
77	CARRIZOSP,TX	56
78	KILLEEN,TX	56
79	WACO,TX	11
80	TEMPLE,TX	56
81	GATESVILLE,TX	56
82	BELTON,TX	56
83	CLEVELAND,TX	84
84	HOUSTON,TX	84
85	CONROE,TX	84
86	RICHMONDRO,TX	84
87	BRYAN,TX	56
88	APOLLO,TX	84
89	WHARTON,TX	84
90	SPRING,TX	84
91	HUNTSVILLE,TX	84
92	CLUTE-LAKE JACKSON,TX	84
93	LIVINGSTON,TX	84
94	ALVIN,TX	84
95	NASSAU BAY,TX	84
96	DICKINSON,TX	84
97	NEWWAVERLY,TX	84
98	BAYTOWN,TX	84
99	DEER PARK,TX	84
100	SUGARLAND,TX	84
101	ELCAMPO,TX	84

PBX NO.	LOCATION	PBX NO HOME-SW
102	CROCKETT,TX	84
103	NACOGDOUCH,TX	84
104	ROSHARON,TX	84
105	LUFKIN,TX	84
106	BRIDGE CITY,TX	84
107	PORTARTHUR,TX	84
108	GALVESTON,TX	84
109	CHINA,TX	84
110	BRENHAM,TX	84
111	BEAUMONT,TX	84
112	ANGLETON,TX	84
113	PRAIRIEVI,TX	84
114	ALTO,TX	11
115	TEXCITYLM,TX	84
116	LAGRANGE,TX	56
117	PLAINVIEW,TX	121
118	AMARILLO,TX	121
119	PADUCAH,TX	121
120	CANYON,TX	121
121	LUBBOCK,TX	121
122	SWEETWATER,TX	133
123	BIGSPRING,TX	121
124	ODESSA,TX	121
125	FTSTOCKTON,TX	121
126	PYOTE,TX	121
127	CARLSBAD,TX	133

PBX NO.	LOCATION	PBX NO HOME-SW
128	ELPASO,TX	121
129	TERMINAL,TX	121
130	SNYDER,TX	133
131	BROWNWOOD,TX	133
132	SANANGELO,TX	133
133	ABILENE,TX	133
134	MIDLAND,TX	121
135	ALPHINE,TX	121

LEASED LINE COST DERIVATION

APPENDIX H

1 DERIVATION OF LEASE COSTS

This appendix will describe the assumptions used to derive an estimate of the charges for the leased portion of the STS network for all of the options, including continuance of the present method of operation. For all of these calculations, the TELPAK tariff was not used, as it is scheduled to be eliminated on December 1, 1985. As a result, it was assumed that future private line tariffs after the elimination of TELPAK would resemble the regular Series 300 and 400 private line tariffs.

1.1 WATS

For this calculation, the circuit quantities described in the main body of the report (Section [][]) were used. As the Local Area WATS service has been grandfathered to existing users, it was assumed that this service would be withdrawn by the end of 1985. Full Business Day WATS, if national trends are followed, will also be eliminated by the end of 1985 (Full Business Day WATS is no longer offered in the interstate jurisdiction). In its place, we would expect a tariff resembling the current WATS 50 service. For these calculations this tariff was used with an assumed average usage of 80 hours per trunk.

1.2 Leased Access Lines

For alternatives to the existing network, the circuit requirements were derived in the manner described in Section [][] of the report. The appropriate charges were then calculated using the Series 300 and 400 tariffs, the V and H coordinates of the served city, the city where the serving tandem is located (local exchange charges were added, in the case of off net facilities).

In the case of access line facilities serving the same city where the tandem or drop/insert point (on owned facilities) is located, the average length of a local access line was estimated. To model this situation, it was assumed that the repeater or tandem would be located at the center of the city in question and that State offices are evenly distributed in each of these cities. As a result the average length of an access line was assumed to be half the distance between the center of the city and the most distant city boundary. This average length was arrived at by using USGS maps of the State to determine the longest distance across the metropolitan areas in question. In the case of Kingsville the distance was assumed to be zero, as there is only one State facility served by STS in Kingsville. In the case of the Belton/Killeen/Temple drop/insert point, the drop/insert repeater was assumed to be located in Temple. The average lengths calculated in this manner were as follows:

Table [.1
Average Length of Local Access Line Facilities

City	Length in Miles
Abilene	1.5
Austin	2.5
Brownwood	1.0
Bryan/College Station	1.75
Corpus Christi	1.75
Dallas	6.5
Harlingen	1.75
Houston	4.5
Kingsville	0.0
Lubbock	2.5
San Antonio	4.5
Temple	1.5
Waco	2.0

To estimate the costs of continuing the existing situation, the present circuits were expanded at the growth rate determined by the network design tools. The charges for these circuits were then determined in a manner identical to that described in the first paragraph of this section.

To model the effect of improving the grade of service on the existing network to the grade of service for the other alternatives, a correction factor was developed. The results from a study of the effect in Dallas of changing the grade of service from P.07 to P.02 on access lines were used to develop this correction factor (1.44). This factor is the ratio between the number of access line circuits required for Dallas at a P.02 and a P.07 grade of service. This factor was then applied to the network's predicted P.07 circuit requirements to arrive at the P.02 requirements.

1.3 IMT's

To calculate the future IMT requirements for the existing STS network, the results from the network design tools for 1982 and 1989 were used. The intermediate year circuit requirements were arrived at by linear interpolation. After the circuit requirements were determined, the Series 300 and 400 private line tariffs were used to determine the lease costs in 1982 dollars.

1.4 CCSA

CCSA switch costs were determined using the current CCSA tariff and the results from the analysis of circuit requirements of the existing network. Thus, the total access line, WATS, and IMT requirements were calculated, and the appropriate charge from the tariff was used to determine the year-by-year expenditures in 1982 dollars.

1.5 Data Circuits, Existing Network

To calculate the future cost of dedicated data circuits, information on the total circuit miles of dedicated circuits and cost avoidance of the current network, contained in the "Annual Report to the Legislature on the Cost Effectiveness of the State Telecommunications System" for Fiscal 1981, was used. The future growth rate of 24.6% per year developed in the data communications section (Section 3.2.1.3) was used to derive future circuit requirements. It was assumed that the cost avoidance experienced by users utilizing STS TELPAK circuits, instead of Series 300 and 400 private line circuits, would disappear when the TELPAK tariff is withdrawn in 1985.

1.6 Data Circuits, Recommended Network

The circuit requirements for the recommended network were calculated utilizing the results from the network design tools as described in section 3.2.2. These circuits consist of access lines which connect users with the owned microwave facilities. The private line tariff was used to calculate the annual lease costs in 1982 dollars. It was assumed that all of these circuits would operate at 9.6 Kbps and, as a result, D-1 conditioning would be required.

ECONOMIC ANALYSIS - NETWORK

APPENDIX I

Continuing With the Existing STS Network (P.07)

(Costs in $1000)

	FY 1984	FY 1985	FY 1986	FY 1987	FY 1988	FY 1989	FY 1990	FY 1991	FY 1992	FY 1993
Tandem Switch Tariff	$2,691.53	$3,148.52	$3,666.70	$4,252.66	$4,918.24	$5,360.89	$5,843.37	$6,369.27	$6,942.50	$7,567.33
Leased Facilities										
IMTs	$1,695.42	$1,994.69	$2,747.11	$3,212.44	$3,754.29	$4,092.17	$4,460.47	$4,861.91	$5,299.48	$5,776.43
Other Leased Fac.	$11,874.08	$16,245.04	$22,521.00	$27,699.71	$34,538.40	$37,646.86	$41,035.07	$44,728.23	$48,753.77	$53,141.61
WATS	$1,902.33	$2,238.32	$4,209.33	$4,902.79	$5,686.97	$6,198.80	$6,756.69	$7,364.79	$8,027.63	$8,750.11
Centrex/PBX	$17,640.84	$20,553.85	$23,848.30	$27,569.28	$31,766.86	$34,625.88	$37,742.20	$41,139.00	$44,841.51	$48,877.25
System Administration	$811.00	$892.10	$981.31	$1,079.45	$1,187.39	$1,306.13	$1,436.74	$1,580.42	$1,738.46	$1,912.30
TOTAL CASH FLOW	$36,615.20	$45,072.53	$57,973.76	$68,716.31	$81,852.15	$89,230.72	$97,274.55	$106,043.62	$115,603.35	$126,025.04
CUMULATIVE CASH FLOW	$36,615.20	$81,687.73	$139,661.49	$208,377.81	$290,229.96	$379,460.68	$476,735.23	$582,778.85	$698,382.20	$824,407.24
COST OF CAPITAL	12.00%									
DISCOUNT FACTOR	1.0000	0.8929	0.7972	0.7118	0.6355	0.5674	0.5066	0.4523	0.4039	0.3606
DISC. CASH FLOW (1984$)	$36,615.20	$40,243.33	$46,216.33	$48,910.92	$52,018.52	$50,631.91	$49,282.31	$47,968.75	$46,690.26	$45,445.89
CUMULATIVE DISCOUNTED CASH FLOW (1984$)	$36,615.20	$76,858.53	$123,074.86	$171,985.77	$224,004.30	$274,636.20	$323,918.52	$371,887.27	$418,577.52	$464,023.41

Continuing With the Existing STS Network (P.07)

(Costs in $1000)

	FY 1984	FY 1985	FY 1986	FY 1987	FY 1988	FY 1989	FY 1990	FY 1991	FY 1992	FY 1993
Tandem Switch Tariff	$2,691.53	$3,148.52	$3,666.70	$4,252.66	$4,918.24	$5,360.89	$5,843.37	$6,369.27	$6,942.50	$7,567.33
Leased Facilities										
IMTs	$1,695.42	$1,994.69	$2,747.11	$3,212.44	$3,754.29	$4,092.17	$4,460.47	$4,861.91	$5,299.48	$5,776.43
Other Leased Fac.	$11,874.08	$16,245.04	$22,521.00	$27,699.71	$34,538.40	$37,646.86	$41,035.07	$44,728.23	$48,753.77	$53,141.61
WATS	$1,902.33	$2,238.32	$4,209.33	$4,902.79	$5,686.97	$6,198.80	$6,756.69	$7,364.79	$8,027.63	$8,750.11
Centrex/PBX	$17,640.84	$20,553.85	$23,848.30	$27,569.28	$31,766.86	$34,625.88	$37,742.20	$41,139.00	$44,841.51	$48,877.25
System Administration	$811.00	$892.10	$981.31	$1,079.45	$1,187.39	$1,306.13	$1,436.74	$1,580.42	$1,738.46	$1,912.30
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TOTAL CASH FLOW	$36,615.20	$45,072.53	$57,973.76	$68,716.31	$81,852.15	$89,230.72	$97,274.55	$106,043.62	$115,603.35	$126,025.04
CUMULATIVE CASH FLOW	$36,615.20	$81,687.73	$139,661.49	$208,377.81	$290,229.96	$379,460.68	$476,735.23	$582,778.85	$698,382.20	$824,407.24
COST OF CAPITAL	12.00%									
DISCOUNT FACTOR	0.8929	0.7972	0.7118	0.6355	0.5674	0.5066	0.4523	0.4039	0.3606	0.3220
DISC. CASH FLOW (1984$)	$32,692.14	$35,931.55	$41,264.58	$43,670.46	$46,445.11	$45,207.06	$44,002.06	$42,829.24	$41,687.73	$40,576.69
CUMULATIVE DISCOUNTED CASH FLOW (1984$)	$32,692.14	$68,623.69	$109,888.27	$153,558.73	$200,003.84	$245,210.90	$289,212.96	$332,042.20	$373,729.93	$414,306.62

Continuing With the Existing STS Network (P.02/P.01)

(Costs in $1000)

	FY 1984	FY 1985	FY 1986	FY 1987	FY 1988	FY 1989	FY 1990	FY 1991	FY 1992	FY 1993
Tandem Switch Tariff	$2,691.53	$3,734.88	$5,027.80	$5,828.31	$6,728.32	$7,333.87	$7,993.92	$8,713.37	$9,497.57	$10,352.36
Leased Facilities										
IMTs	$1,695.42	$2,302.68	$3,069.35	$3,593.99	$4,178.29	$4,554.33	$4,964.22	$5,411.00	$5,897.99	$6,428.81
Other Leased Fac.	$11,874.08	$18,833.37	$28,544.91	$34,610.73	$42,568.56	$46,399.73	$50,575.70	$55,127.52	$60,088.99	$65,497.00
WATS	$1,902.33	$2,238.32	$4,209.33	$4,902.79	$5,686.97	$6,198.80	$6,756.69	$7,364.79	$8,027.63	$8,750.11
Centrex/PBX	$17,640.84	$20,553.85	$23,848.30	$27,569.28	$31,766.86	$34,625.88	$37,742.20	$41,139.00	$44,841.51	$48,877.25
System Administration	$811.00	$892.10	$981.31	$1,079.45	$1,187.39	$1,306.13	$1,436.74	$1,580.42	$1,738.46	$1,912.30
TOTAL CASH FLOW	$36,615.20	$48,555.20	$65,681.01	$77,584.54	$92,116.39	$100,418.74	$109,469.48	$119,336.10	$130,092.16	$141,817.84
CUMULATIVE CASH FLOW	$36,615.20	$85,170.40	$150,851.41	$228,435.95	$320,552.34	$420,971.07	$530,440.56	$649,776.66	$779,868.82	$921,686.66
COST OF CAPITAL	12.00%									
DISCOUNT FACTOR	1.0000	0.8929	0.7972	0.7118	0.6355	0.5674	0.5066	0.4523	0.4039	0.3606
DISC. CASH FLOW (1984$)	$36,615.20	$43,352.86	$52,360.50	$55,223.14	$58,541.63	$56,980.29	$55,460.65	$53,981.59	$52,542.04	$51,140.93
CUMULATIVE DISCOUNTED CASH FLOW (1984$)	$36,615.20	$79,968.06	$132,328.56	$187,551.70	$246,093.33	$303,073.62	$358,534.26	$412,515.86	$465,057.90	$516,198.83

Alternative Plan A

(Costs in $ 1000)

	FY 1984	FY 1985	FY 1986	FY 1987	FY 1988	FY 1989	FY 1990	FY 1991	FY 1992	FY 1993
Tandem Switch Costs	$4,260.57	$9,431.84	$0.00	$682.80	$0.00	$0.00	$0.00	$0.00	$0.00	($3,655.82)
Facility Costs										
IMTs	$1,695.42	$997.35	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Other Leased Fac.	$11,874.09	$13,506.12	$15,136.69	$17,804.49	$21,555.16	$23,495.13	$25,609.69	$27,914.56	$30,426.87	$33,165.29
Owned Radio	$6,945.39	$15,002.04	$45.17	$484.73	$118.70	$0.00	$0.00	$0.00	$0.00	($19,140.18)
Owned Multiplex	$458.75	$103.98	$166.69	$183.72	$278.24	$0.00	$0.00	$0.00	$0.00	($158.62)
Owned Modems	$1,227.05	$322.49	$435.36	$570.10	$787.09	$0.00	$0.00	$0.00	$0.00	$0.00
WATS	$1,902.31	$2,238.30	$4,209.31	$4,902.76	$5,686.95	$6,198.77	$6,756.66	$7,364.76	$8,027.59	$8,750.07
Centrex/PBX	$17,640.84	$20,553.85	$23,848.30	$27,569.28	$31,766.86	$34,625.88	$37,742.20	$41,139.00	$44,841.51	$48,877.25
System Administration	$811.00	$3,255.60	$1,730.14	$1,908.32	$2,104.88	$2,273.21	$2,500.53	$2,750.58	$3,025.64	$2,649.72
TOTAL CASH FLOW	$46,815.42	$65,411.56	$45,571.65	$54,106.21	$62,297.87	$66,592.98	$72,609.08	$79,168.90	$86,321.61	$70,487.71
CUMULATIVE CASH FLOW	$46,815.42	$112,226.98	$157,798.63	$211,904.84	$274,202.71	$340,795.69	$413,404.78	$492,573.68	$578,895.29	$649,383.00
COST OF CAPITAL	12.00%									
DISCOUNT FACTOR	1.0000	0.8929	0.7972	0.7118	0.6355	0.5674	0.5066	0.4523	0.4039	0.3606
DISC. CASH FLOW (1984$)	$46,815.42	$58,403.18	$36,329.44	$38,511.73	$39,591.42	$37,786.65	$36,786.02	$35,811.99	$34,863.85	$25,418.57
CUMULATIVE DISCOUNTED CASH FLOW (1984$)	$46,815.42	$105,218.60	$141,548.04	$180,059.77	$219,651.19	$257,437.84	$294,223.86	$330,035.85	$364,899.70	$390,318.28

Alternative Plan B

(Costs in $1000)

	FY 1984	FY 1985	FY 1986	FY 1987	FY 1988	FY 1989	FY 1990	FY 1991	FY 1992	FY 1993
Tandem Switch Costs	$4,260.57	$9,431.84	$0.00	$682.80	$0.00	$0.00	$0.00	$0.00	$0.00	($3,655.82)
Facility Costs										
IHTs	$1,695.42	$997.35	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Other Leased Fac.	$11,874.07	$13,506.12	$15,136.69	$17,804.49	$21,555.16	$23,495.13	$25,609.69	$27,914.56	$30,426.87	$33,165.29
Owned Radio	$6,945.39	$15,002.04	$45.17	$484.73	$118.70	$0.00	$0.00	$0.00	$0.00	($19,140.18)
Owned Multiplex	$458.75	$103.98	$166.69	$183.72	$278.24	$0.00	$0.00	$0.00	$0.00	($158.62)
Owned Modems	$1,227.05	$322.49	$435.36	$570.10	$787.09	$0.00	$0.00	$0.00	$0.00	$0.00
WATS	$1,902.31	$2,238.30	$4,209.31	$4,902.76	$5,686.95	$6,198.77	$6,756.66	$7,364.76	$8,027.59	$8,750.07
Centrex/PBX	$17,640.83	$20,553.85	$57,862.29	$4,468.16	$7,686.88	$5,674.23	$6,184.91	$6,741.56	$7,348.30	$6,966.99
System Administration	$811.00	$3,504.52	$3,421.72	$4,447.48	$5,041.76	$5,503.78	$6,054.16	$6,659.58	$7,325.54	$7,379.61
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TOTAL CASH FLOW	$46,815.40	$65,660.48	$81,277.22	$33,544.25	$41,154.78	$40,871.91	$44,605.42	$48,680.45	$53,128.29	$33,307.33
CUMULATIVE CASH FLOW	$46,815.40	$112,475.88	$193,753.10	$227,297.34	$268,452.12	$309,324.04	$353,929.46	$402,609.91	$455,738.21	$489,045.54
COST OF CAPITAL	12.00%									
DISCOUNT FACTOR	1.0000	0.8929	0.7972	0.7118	0.6355	0.5674	0.5066	0.4523	0.4039	0.3606
DISC. CASH FLOW (1984$)	$46,815.40	$58,625.43	$64,793.70	$23,876.13	$26,154.60	$23,191.82	$22,598.50	$22,020.57	$21,457.63	$12,010.96
CUMULATIVE DISCOUNTED CASH FLOW (1984$)	$46,815.40	$105,440.82	$170,234.53	$194,110.66	$220,265.26	$243,457.09	$266,055.58	$288,076.15	$309,533.77	$321,544.73

Alternative Plan C

(Costs in $ 1000)

	FY 1984	FY 1985	FY 1986	FY 1987	FY 1988	FY 1989	FY 1990	FY 1991	FY 1992	FY 1993
Tandem Switch Costs	$4,695.76	$14,300.88	$0.00	$431.10	$0.00	$0.00	$0.00	$0.00	$0.00	($5,385.50)
Facility Costs										
IMTs	$1,695.42	$997.35	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Other Leased Fac.	$11,874.09	$13,167.67	$14,811.04	$17,425.24	$21,115.22	$23,015.58	$25,086.99	$27,344.82	$29,805.85	$32,488.38
Owned Radio	$6,945.39	$15,002.04	$45.17	$484.73	$118.70	$0.00	$0.00	$0.00	$0.00	($19,140.18)
Owned Multiplex	$458.75	$103.98	$166.69	$183.72	$278.24	$0.00	$0.00	$0.00	$0.00	($158.62)
Owned Modems	$1,227.05	$322.49	$435.36	$570.10	$787.09	$0.00	$0.00	$0.00	$0.00	$0.00
WATS	$1,902.31	$2,238.30	$4,209.31	$4,902.76	$5,686.95	$6,198.77	$6,756.66	$7,364.76	$8,027.59	$8,750.07
Centrex/PBX	$17,640.83	$20,553.85	$56,433.64	$4,468.16	$7,441.78	$5,674.23	$6,184.91	$6,741.56	$7,348.30	$7,069.99
System Administration	$811.00	$4,134.38	$3,459.79	$4,489.35	$5,087.82	$5,554.45	$6,109.89	$6,720.88	$7,392.97	$7,220.62
TOTAL CASH FLOW	$47,250.59	$70,820.92	$79,560.98	$32,955.18	$40,515.80	$40,443.04	$44,138.46	$48,172.02	$52,574.71	$30,844.75
CUMULATIVE CASH FLOW	$47,250.59	$118,071.51	$197,632.49	$230,587.67	$271,103.47	$311,546.51	$355,684.97	$403,856.98	$456,431.69	$487,276.44
COST OF CAPITAL	12.00%									
DISCOUNT FACTOR	1.0000	0.8929	0.7972	0.7118	0.6355	0.5674	0.5066	0.4523	0.4039	0.3606
DISC. CASH FLOW (1984$)	$47,250.59	$63,232.97	$63,425.53	$23,456.84	$25,748.52	$22,948.47	$22,361.92	$21,790.57	$21,234.04	$11,122.93
CUMULATIVE DISCOUNTED CASH FLOW (1984$)	$47,250.59	$110,483.56	$173,909.08	$197,365.93	$223,114.45	$246,062.92	$268,424.83	$290,215.41	$311,449.45	$322,572.38

Continuing With the Existing STS Network (P.07)

(Costs in $1000)

	FY 1984	FY 1985	FY 1986	FY 1987	FY 1988	FY 1989	FY 1990	FY 1991	FY 1992	FY 1993
Tandem Switch Tariff	$2,691.53	$3,148.52	$3,666.70	$4,252.66	$4,918.24	$5,360.89	$5,843.37	$6,369.27	$6,942.50	$7,567.33
Leased Facilities										
IMTs	$1,695.42	$1,994.69	$2,747.11	$3,212.44	$3,754.29	$4,092.17	$4,460.47	$4,861.91	$5,299.48	$5,776.43
Other Leased Fac.	$11,874.08	$16,245.04	$22,521.00	$27,699.71	$34,538.40	$37,646.86	$41,035.07	$44,728.23	$48,753.77	$53,141.61
WATS	$1,902.33	$2,238.32	$4,209.33	$4,902.79	$5,686.97	$6,198.80	$6,756.69	$7,364.79	$8,027.63	$8,750.11
Centrex/PBX	$17,640.84	$20,553.85	$23,848.30	$27,569.28	$31,766.86	$34,625.88	$37,742.20	$41,139.00	$44,841.51	$48,877.25
System Administration	$811.00	$892.10	$981.31	$1,079.45	$1,187.39	$1,306.13	$1,436.74	$1,580.42	$1,738.46	$1,912.30
TOTAL CASH FLOW	$36,615.20	$45,072.53	$57,973.76	$68,716.31	$81,852.15	$89,230.72	$97,274.55	$106,043.62	$115,603.35	$126,025.04
CUMULATIVE CASH FLOW	$36,615.20	$81,687.73	$139,661.49	$208,377.81	$290,229.96	$379,460.68	$476,735.23	$582,778.85	$698,382.20	$824,407.24
COST OF CAPITAL	14.00%									
DISCOUNT FACTOR	1.0000	0.8772	0.7695	0.6750	0.5921	0.5194	0.4556	0.3996	0.3506	0.3075
DISC. CASH FLOW (1984$)	$36,615.20	$39,537.31	$44,608.93	$46,381.56	$48,463.05	$46,343.64	$44,316.97	$42,378.99	$40,525.80	$38,753.70
CUMULATIVE DISCOUNTED CASH FLOW (1984$)	$36,615.20	$76,152.51	$120,761.43	$167,142.99	$215,606.04	$261,949.68	$306,266.65	$348,645.64	$389,171.44	$427,925.14

Continuing With the Existing STS Network (P.02/P.01)

(Costs in $1000)

	FY 1984	FY 1985	FY 1986	FY 1987	FY 1988	FY 1989	FY 1990	FY 1991	FY 1992	FY 1993
Tandem Switch Tariff	$2,691.53	$3,734.88	$5,027.80	$5,828.31	$6,728.32	$7,333.87	$7,993.92	$8,713.37	$9,497.57	$10,352.36
Leased Facilities										
IMTs	$1,695.42	$2,302.68	$3,069.35	$3,593.99	$4,178.29	$4,554.33	$4,964.22	$5,411.00	$5,897.99	$6,428.81
Other Leased Fac.	$11,874.08	$18,833.37	$28,544.91	$34,610.73	$42,568.56	$46,399.73	$50,575.70	$55,127.52	$60,088.99	$65,497.00
WATS	$1,902.33	$2,238.32	$4,209.33	$4,902.79	$5,686.97	$6,198.80	$6,756.69	$7,364.79	$8,027.63	$8,750.11
Centrex/PBX	$17,640.84	$20,553.85	$23,848.30	$27,569.28	$31,766.86	$34,625.88	$37,742.20	$41,139.00	$44,841.51	$48,877.25
System Administration	$811.00	$892.10	$981.31	$1,079.45	$1,187.39	$1,306.13	$1,436.74	$1,580.42	$1,738.46	$1,912.30
TOTAL CASH FLOW	$36,615.20	$48,555.20	$65,681.01	$77,584.54	$92,116.39	$100,418.74	$109,469.48	$119,336.10	$130,092.16	$141,817.84
CUMULATIVE CASH FLOW	$36,615.20	$85,170.40	$150,851.41	$228,435.95	$320,552.34	$420,971.07	$530,440.56	$649,776.66	$779,868.82	$921,686.66
COST OF CAPITAL	14.00%									
DISCOUNT FACTOR	1.0000	0.8772	0.7695	0.6750	0.5921	0.5194	0.4556	0.3996	0.3506	0.3075
DISC. CASH FLOW (1984$)	$36,615.20	$42,592.28	$50,539.40	$52,367.35	$54,540.30	$52,154.34	$49,872.82	$47,691.16	$45,604.98	$43,610.11
CUMULATIVE DISCOUNTED CASH FLOW (1984$)	$36,615.20	$79,207.48	$129,746.88	$182,114.24	$236,654.54	$288,808.88	$338,681.70	$386,372.87	$431,977.85	$475,587.96

Alternative Plan A

(Costs in $ 1000)

	FY 1984	FY 1985	FY 1986	FY 1987	FY 1988	FY 1989	FY 1990	FY 1991	FY 1992	FY 1993
Tandem Switch Costs	$4,260.57	$9,431.84	$0.00	$682.80	$0.00	$0.00	$0.00	$0.00	$0.00	($3,655.82)
Facility Costs										
IMTs	$1,695.42	$997.35	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Other Leased Fac.	$11,874.09	$13,506.12	$15,136.69	$17,804.49	$21,555.16	$23,495.13	$25,609.69	$27,914.56	$30,426.87	$33,165.29
Owned Radio	$6,945.39	$15,002.04	$45.17	$484.73	$118.70	$0.00	$0.00	$0.00	$0.00	($19,140.18)
Owned Multiplex	$458.75	$103.98	$166.69	$183.72	$278.24	$0.00	$0.00	$0.00	$0.00	($158.62)
Owned Modems	$1,227.05	$322.49	$435.36	$570.10	$787.09	$0.00	$0.00	$0.00	$0.00	$0.00
WATS	$1,902.31	$2,238.30	$4,209.31	$4,902.76	$5,686.95	$6,198.77	$6,756.66	$7,364.76	$8,027.59	$8,750.07
Centrex/PBX	$17,640.84	$20,553.85	$23,848.30	$27,569.28	$31,766.86	$34,625.88	$37,742.20	$41,139.00	$44,841.51	$48,877.25
System Administration	$811.00	$3,255.60	$1,730.14	$1,908.32	$2,104.88	$2,273.21	$2,500.53	$2,750.58	$3,025.64	$2,649.72
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TOTAL CASH FLOW	$46,815.42	$65,411.56	$45,571.65	$54,106.21	$62,297.87	$66,592.98	$72,609.08	$79,168.90	$86,321.61	$70,487.71
CUMULATIVE CASH FLOW	$46,815.42	$112,226.98	$157,798.63	$211,904.84	$274,202.71	$340,795.69	$413,404.78	$492,573.68	$578,895.29	$649,383.00
COST OF CAPITAL	14.00%									
DISCOUNT FACTOR	1.0000	0.8772	0.7695	0.6750	0.5921	0.5194	0.4556	0.3996	0.3506	0.3075
DISC. CASH FLOW (1984$)	$46,815.42	$57,378.56	$35,065.91	$36,520.15	$36,885.34	$34,586.31	$33,079.72	$31,638.85	$30,260.82	$21,675.53
CUMULATIVE DISCOUNTED CASH FLOW (1984$)	$46,815.42	$104,193.98	$139,259.89	$175,780.04	$212,665.38	$247,251.69	$280,331.41	$311,970.26	$342,231.08	$363,906.61

Alternative Plan B

(Costs in $ 1000)

	FY 1984	FY 1985	FY 1986	FY 1987	FY 1988	FY 1989	FY 1990	FY 1991	FY 1992	FY 1993
Tandem Switch Costs	$4,260.57	$9,431.84	$0.00	$682.80	$0.00	$0.00	$0.00	$0.00	$0.00	($3,655.82)
Facility Costs										
IMTs	$1,695.42	$997.35	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Other Leased Fac.	$11,874.07	$13,506.12	$15,136.69	$17,804.49	$21,555.16	$23,495.13	$25,609.69	$27,914.56	$30,426.87	$33,165.29
Owned Radio	$6,945.39	$15,002.04	$45.17	$484.73	$118.70	$0.00	$0.00	$0.00	$0.00	($19,140.18)
Owned Multiplex	$458.75	$103.98	$166.69	$183.72	$278.24	$0.00	$0.00	$0.00	$0.00	($158.62)
Owned Modems	$1,227.05	$322.49	$435.36	$570.10	$787.09	$0.00	$0.00	$0.00	$0.00	$0.00
WATS	$1,902.31	$2,238.30	$4,209.31	$4,902.76	$5,686.95	$6,198.77	$6,756.66	$7,364.76	$8,027.59	$8,750.07
Centrex/PBX	$17,640.83	$20,553.85	$57,862.29	$4,468.16	$7,686.88	$5,674.23	$6,184.91	$6,741.56	$7,348.30	$6,966.99
System Administration	$811.00	$3,504.52	$3,421.72	$4,447.48	$5,041.76	$5,503.78	$6,054.16	$6,659.58	$7,325.54	$7,379.61
TOTAL CASH FLOW	$46,815.40	$65,660.48	$81,277.22	$33,544.25	$41,154.78	$40,871.91	$44,605.42	$48,680.45	$53,128.29	$33,307.33
CUMULATIVE CASH FLOW	$46,815.40	$112,475.88	$193,753.10	$227,297.34	$268,452.12	$309,324.04	$353,929.46	$402,609.91	$455,738.21	$489,045.54
COST OF CAPITAL	14.00%									
DISCOUNT FACTOR	1.0000	0.8772	0.7695	0.6750	0.5921	0.5194	0.4556	0.3996	0.3506	0.3075
DISC. CASH FLOW (1984$)	$46,815.40	$57,596.91	$62,540.18	$22,641.41	$24,366.93	$21,227.59	$20,321.63	$19,454.53	$18,624.60	$10,242.27
CUMULATIVE DISCOUNTED CASH FLOW (1984$)	$46,815.40	$104,412.31	$166,952.49	$189,593.90	$213,960.83	$235,188.43	$255,510.06	$274,964.58	$293,589.19	$303,831.46

Alternative Plan C

(Costs in $1000)

	FY 1984	FY 1985	FY 1986	FY 1987	FY 1988	FY 1989	FY 1990	FY 1991	FY 1992	FY 1993
Tandem Switch Costs	$4,695.76	$14,300.88	$0.00	$431.10	$0.00	$0.00	$0.00	$0.00	$0.00	($5,385.50)
Facility Costs										
IMTs	$1,695.42	$997.35	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Other Leased Fac.	$11,874.09	$13,167.67	$14,811.04	$17,425.24	$21,115.22	$23,015.58	$25,086.99	$27,344.82	$29,805.85	$32,488.38
Owned Radio	$6,945.39	$15,002.04	$45.17	$484.73	$118.70	$0.00	$0.00	$0.00	$0.00	($19,140.18)
Owned Multiplex	$458.75	$103.98	$166.69	$183.72	$278.24	$0.00	$0.00	$0.00	$0.00	($158.62)
Owned Modems	$1,227.05	$322.49	$435.36	$570.10	$787.09	$0.00	$0.00	$0.00	$0.00	$0.00
WATS	$1,902.31	$2,238.30	$4,209.31	$4,902.76	$5,686.95	$6,198.77	$6,756.66	$7,364.76	$8,027.59	$8,750.07
Centrex/PBX	$17,640.83	$20,553.85	$56,433.64	$4,468.16	$7,441.78	$5,674.23	$6,184.91	$6,741.56	$7,348.30	$7,069.99
System Administration	$811.00	$4,134.38	$3,459.79	$4,489.35	$5,087.82	$5,554.45	$6,109.89	$6,720.88	$7,392.97	$7,220.62
TOTAL CASH FLOW	$47,250.59	$70,820.92	$79,560.98	$32,955.18	$40,515.80	$40,443.04	$44,138.46	$48,172.02	$52,574.71	$30,844.75
CUMULATIVE CASH FLOW	$47,250.59	$118,071.51	$197,632.49	$230,587.67	$271,103.47	$311,546.51	$355,684.97	$403,856.98	$456,431.69	$487,276.44
COST OF CAPITAL	14.00%									
DISCOUNT FACTOR	1.0000	0.8772	0.7695	0.6750	0.5921	0.5194	0.4556	0.3996	0.3506	0.3075
DISC. CASH FLOW (1984$)	$47,250.59	$62,123.62	$61,219.59	$22,243.81	$23,988.60	$21,004.85	$20,108.89	$19,251.34	$18,430.54	$9,485.01
CUMULATIVE DISCOUNTED CASH FLOW (1984$)	$47,250.59	$109,374.21	$170,593.80	$192,837.60	$216,826.21	$237,831.06	$257,939.94	$277,191.28	$295,621.82	$305,106.83

Continuing With the Existing STS Network (P.07)

(Costs in $1000)

	FY 1984	FY 1985	FY 1986	FY 1987	FY 1988	FY 1989	FY 1990	FY 1991	FY 1992	FY 1993
Tandem Switch Tariff	$2,691.53	$3,148.52	$3,666.70	$4,252.66	$4,918.24	$5,360.89	$5,843.37	$6,369.27	$6,942.50	$7,567.33
Leased Facilities										
IMTs	$1,695.42	$1,994.69	$2,747.11	$3,212.44	$3,754.29	$4,092.17	$4,460.47	$4,861.91	$5,299.48	$5,776.43
Other Leased Fac.	,11,874.08	$16,245.04	$22,521.00	$27,699.71	$34,538.40	$37,646.86	$41,035.07	$44,728.23	$48,753.77	$53,141.61
WATS	$1,902.33	$2,238.32	$4,209.33	$4,902.79	$5,686.97	$6,198.80	$6,756.69	$7,364.79	$8,027.63	$8,750.11
Centrex/PBX	$17,640.84	$20,553.85	$23,848.30	$27,569.28	$31,766.86	$34,625.88	$37,742.20	$41,139.00	$44,841.51	$48,877.25
System Administration	$811.00	$892.10	$981.31	$1,079.45	$1,187.39	$1,306.13	$1,436.74	$1,580.42	$1,738.46	$1,912.30
TOTAL CASH FLOW	$36,615.20	$45,072.53	$57,973.76	$68,716.31	$81,852.15	$89,230.72	$97,274.55	$106,043.62	$115,603.35	$126,025.04
CUMULATIVE CASH FLOW	$36,615.20	$81,687.73	$139,661.49	$208,377.81	$290,229.96	$379,460.68	$476,735.23	$582,778.85	$698,382.20	$824,407.24
COST OF CAPITAL	10.00%									
DISCOUNT FACTOR	1.0000	0.9091	0.8264	0.7513	0.6830	0.6209	0.5645	0.5132	0.4665	0.4241
DISC. CASH FLOW (1984$)	$36,615.20	$40,975.03	$47,912.20	$51,627.58	$55,906.12	$55,405.26	$54,908.95	$54,417.15	$53,929.82	$53,446.92
CUMULATIVE DISCOUNTED CASH FLOW (1984$)	$36,615.20	$77,590.23	$125,502.43	$177,130.01	$233,036.13	$288,441.39	$343,350.34	$397,767.48	$451,697.30	$505,144.22

Continuing With the Existing STS Network (P.02/P.01)

(Costs in $1000)

	FY 1984	FY 1985	FY 1986	FY 1987	FY 1988	FY 1989	FY 1990	FY 1991	FY 1992	FY 1993
Tandem Switch Tariff	$2,691.53	$3,734.88	$5,027.80	$5,828.31	$6,728.32	$7,333.87	$7,993.92	$8,713.37	$9,497.57	$10,352.36
Leased Facilities										
IMTs	$1,695.42	$2,302.68	$3,069.35	$3,593.99	$4,178.29	$4,554.33	$4,964.22	$5,411.00	$5,897.99	$6,428.81
Other Leased Fac.	$11,874.08	$18,833.37	$28,544.91	$34,610.73	$42,568.56	$46,399.73	$50,575.70	$55,127.52	$60,088.99	$65,497.00
WATS	$1,902.33	$2,238.32	$4,209.33	$4,902.79	$5,686.97	$6,198.80	$6,756.69	$7,364.79	$8,027.63	$8,750.11
Centrex/PBX	$17,640.84	$20,553.85	$23,848.30	$27,569.28	$31,766.86	$34,625.88	$37,742.20	$41,139.00	$44,841.51	$48,877.25
System Administration	$811.00	$892.10	$981.31	$1,079.45	$1,187.39	$1,306.13	$1,436.74	$1,580.42	$1,738.46	$1,912.30
TOTAL CASH FLOW	$36,615.20	$48,555.20	$65,681.01	$77,584.54	$92,116.39	$100,418.74	$109,469.48	$119,336.10	$130,092.16	$141,817.84
CUMULATIVE CASH FLOW	$36,615.20	$85,170.40	$150,851.41	$228,435.95	$320,552.34	$420,971.07	$530,440.56	$649,776.66	$779,868.82	$921,686.66
COST OF CAPITAL	10.00%									
DISCOUNT FACTOR	1.0000	0.9091	0.8264	0.7513	0.6830	0.6209	0.5645	0.5132	0.4665	0.4241
DISC. CASH FLOW (1984$)	$36,615.20	$44,141.09	$54,281.82	$58,290.41	$62,916.73	$62,352.13	$61,792.67	$61,238.29	$60,688.95	$60,144.61
CUMULATIVE DISCOUNTED CASH FLOW (1984$)	$36,615.20	$80,756.29	$135,038.12	$193,328.53	$256,245.26	$318,597.40	$380,390.07	$441,628.36	$502,317.31	$562,461.92

Alternative Plan A

(Costs in $ 1000)

	FY 1984	FY 1985	FY 1986	FY 1987	FY 1988	FY 1989	FY 1990	FY 1991	FY 1992	FY 1993
Tandem Switch Costs	$4,260.57	$9,431.84	$0.00	$682.80	$0.00	$0.00	$0.00	$0.00	$0.00	($3,655.82)
Facility Costs										
IMTs	$1,695.42	$997.35	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Other Leased Fac.	$11,874.09	$13,506.12	$15,136.69	$17,804.49	$21,555.16	$23,495.13	$25,609.69	$27,914.56	$30,426.87	$33,165.29
Owned Radio	$6,945.39	$15,002.04	$45.17	$484.73	$118.70	$0.00	$0.00	$0.00	$0.00	($19,140.18)
Owned Multiplex	$458.75	$103.98	$166.69	$183.72	$278.24	$0.00	$0.00	$0.00	$0.00	($158.62)
Owned Modems	$1,227.05	$322.49	$435.36	$570.10	$787.09	$0.00	$0.00	$0.00	$0.00	$0.00
WATS	$1,902.31	$2,238.30	$4,209.31	$4,902.76	$5,686.95	$6,198.77	$6,756.66	$7,364.76	$8,027.59	$8,750.07
Centrex/PBX	$17,640.84	$20,553.85	$23,848.30	$27,569.28	$31,766.86	$34,625.88	$37,742.20	$41,139.00	$44,841.51	$48,877.25
System Administration	$811.00	$3,255.60	$1,730.14	$1,908.32	$2,104.88	$2,273.21	$2,500.53	$2,750.58	$3,025.64	$2,649.72
TOTAL CASH FLOW	$46,815.42	$65,411.56	$45,571.65	$54,106.21	$62,297.87	$66,592.98	$72,609.08	$79,168.90	$86,321.61	$70,487.71
CUMULATIVE CASH FLOW	$46,815.42	$112,226.98	$157,798.63	$211,904.84	$274,202.71	$340,795.69	$413,404.78	$492,573.68	$578,895.29	$649,383.00
COST OF CAPITAL	10.00%									
DISCOUNT FACTOR	1.0000	0.9091	0.8264	0.7513	0.6830	0.6209	0.5645	0.5132	0.4665	0.4241
DISC. CASH FLOW (1984$)	$46,815.42	$59,465.05	$37,662.52	$40,650.79	$42,550.29	$41,349.00	$40,985.93	$40,626.17	$40,269.67	$29,893.67
CUMULATIVE DISCOUNTED CASH FLOW (1984$)	$46,815.42	$106,280.47	$143,943.00	$184,593.79	$227,144.08	$268,493.08	$309,479.01	$350,105.18	$390,374.85	$420,268.52

Alternative Plan B

(Costs in $ 1000)

	FY 1984	FY 1985	FY 1986	FY 1987	FY 1988	FY 1989	FY 1990	FY 1991	FY 1992	FY 1993
Tandem Switch Costs	$4,260.57	$9,431.84	$0.00	$682.80	$0.00	$0.00	$0.00	$0.00	$0.00	($3,655.82)
Facility Costs										
IHTs	$1,695.42	$997.35	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Other Leased Fac.	$11,874.07	$13,506.12	$15,136.69	$17,804.49	$21,555.16	$23,495.13	$25,609.69	$27,914.56	$30,426.87	$33,165.29
Owned Radio	$6,945.39	$15,002.04	$45.17	$484.73	$118.70	$0.00	$0.00	$0.00	$0.00	($19,140.18)
Owned Multiplex	$458.75	$103.98	$166.69	$183.72	$278.24	$0.00	$0.00	$0.00	$0.00	($158.62)
Owned Modems	$1,227.05	$322.49	$435.36	$570.10	$787.09	$0.00	$0.00	$0.00	$0.00	$0.00
WATS	$1,902.31	$2,238.30	$4,209.31	$4,902.76	$5,686.95	$6,198.77	$6,756.66	$7,364.76	$8,027.59	$8,750.07
Centrex/PBX	$17,640.83	$20,553.85	$57,862.29	$4,468.16	$7,686.88	$5,674.23	$6,184.91	$6,741.56	$7,348.30	$6,966.99
System Administration	$811.00	$3,504.52	$3,421.72	$4,447.48	$5,041.76	$5,503.78	$6,054.16	$6,659.58	$7,325.54	$7,379.61
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TOTAL CASH FLOW	$46,815.40	$65,660.48	$81,277.22	$33,544.25	$41,154.78	$40,871.91	$44,605.42	$48,680.45	$53,128.29	$33,307.33
CUMULATIVE CASH FLOW	$46,815.40	$112,475.88	$193,753.10	$227,297.34	$268,452.1[illegible]	$309,324.04	$353,929.46	$402,609.91	$455,738.21	$489,045.54
COST OF CAPITAL	10.00%									
DISCOUNT FACTOR	1.0000	0.9091	0.8264	0.7513	0.6830	0.6209	0.5645	0.5132	0.4665	0.4241
DISC. CASH FLOW (1984$)	$46,815.40	$59,691.34	$67,171.26	$25,202.29	$28,109.27	$25,378.24	$25,178.60	$24,980.77	$24,784.74	$14,125.56
CUMULATIVE DISCOUNTED CASH FLOW (1984$)	$46,815.40	$106,506.74	$173,678.00	$198,880.29	$226,989.55	$252,367.80	$277,546.40	$302,527.17	$327,311.91	$341,437.47

Alternative Plan C

(Corts in $ 1000)

	FY 1984	FY 1985	FY 1986	FY 1987	FY 1988	FY 1989	FY 1990	FY 1991	FY 1992	FY 1993
Tandem Switch Costs	$4,695.76	$14,300.88	$0.00	$431.10	$0.00	$0.00	$0.00	$0.00	$0.00	($5,385.50)
Facility Costs										
IMTs	$1,695.42	$997.35	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Other Leased Fac.	$11,874.09	$13,167.67	$14,811.04	$17,425.24	$21,115.22	$23,015.58	$25,086.99	$27,344.82	$29,805.85	$32,488.38
Owned Radio	$6,945.39	$15,002.04	$45.17	$484.73	$118.70	$0.00	$0.00	$0.00	$0.00	($19,140.18)
Owned Multiplex	$458.75	$103.98	$166.69	$183.72	$278.24	$0.00	$0.00	$0.00	$0.00	($158.62)
Owned Modems	$1,227.05	$322.49	$435.36	$570.10	$787.09	$0.00	$0.00	$0.00	$0.00	$0.00
WATS	$1,902.31	$2,238.30	$4,209.31	$4,902.76	$5,686.95	$6,198.77	$6,756.66	$7,364.76	$8,027.59	$8,750.07
Centrex/PBX	$17,640.83	$20,553.85	$56,433.64	$4,468.16	$7,441.78	$5,674.23	$6,184.91	$6,741.56	$7,348.30	$7,069.99
System Administration	$811.00	$4,134.38	$3,459.79	$4,489.35	$5,087.82	$5,554.45	$6,109.89	$6,720.88	$7,392.97	$7,220.62
TOTAL CASH FLOW	$47,250.59	$70,820.92	$79,560.98	$32,955.18	$40,515.80	$40,443.04	$44,138.46	$48,172.02	$52,574.71	$30,844.75
CUMULATIVE CASH FLOW	$47,250.59	$118,071.51	$197,632.49	$230,587.67	$271,103.47	$311,546.51	$355,684.97	$403,856.98	$456,431.69	$487,276.44
COST OF CAPITAL	10.00%									
DISCOUNT FACTOR	1.0000	0.9091	0.8264	0.7513	0.6830	0.6209	0.5645	0.5132	0.4665	0.4241
DISC. CASH FLOW (1984$)	$47,250.59	$64,382.66	$65,752.88	$24,759.71	$27,672.84	$25,111.95	$24,915.01	$24,719.86	$24,526.49	$13,081.19
CUMULATIVE DISCOUNTED CASH FLOW (1984$)	$47,250.59	$111,633.25	$177,386.12	$202,145.84	$229,818.67	$254,930.62	$279,845.63	$304,565.49	$329,091.98	$342,173.16

Continuing With the Existing STS Network (P.07)
(Costs in $1000)

	FY 1984	FY 1985	FY 1986	FY 1987	FY 1988	FY 1989	FY 1990	FY 1991	FY 1992	FY 1993
Tandem Switch Add. (1982$)	$152.57	$165.83	$166.35	$166.35	$168.65	$0.00	$0.00	$0.00	$0.00	$0.00
TOTAL TANDEM SW. COSTS (1982$)	$2,265.41	$2,431.24	$2,597.59	$2,763.94	$2,932.59	$2,932.59	$2,932.59	$2,932.59	$2,932.59	$2,932.59
Inflation Factor	118.81%	129.50%	141.16%	153.86%	167.71%	182.80%	199.26%	217.19%	236.74%	258.04%
INFLATED SW. COSTS	$2,691.53	$3,148.52	$3,666.70	$4,252.66	$4,918.24	$5,360.89	$5,843.37	$6,369.27	$6,942.50	$7,567.33
Leased Facilities										
IMT Additions (1982$)	$129.57	$113.27	$405.85	$141.74	$150.69	$0.00	$0.00	$0.00	$0.00	$0.00
TOTAL IMT COSTS (1982$)	$1,427.00	$1,540.27	$1,946.12	$2,087.86	$2,238.56	$2,238.56	$2,238.56	$2,238.56	$2,238.56	$2,238.56
Inflation Factor	118.81%	129.50%	141.16%	153.86%	167.71%	182.80%	199.26%	217.19%	236.74%	258.04%
INFLATED IMT COSTS	$1,695.42	$1,994.69	$2,747.11	$3,212.44	$3,754.29	$4,092.17	$4,460.47	$4,861.91	$5,299.48	$5,776.43
Other Facility Add. (1982$)	$0.00	$2,549.97	$3,410.29	$2,048.47	$2,591.21	$0.00	$0.00	$0.00	$0.00	$0.00
TOTAL OTHER FAC. COSTS (1982$)	$9,994.18	$12,544.15	$15,954.44	$18,002.91	$20,594.12	$20,594.12	$20,594.12	$20,594.12	$20,594.12	$20,594.12
Inflation Factor	118.81%	129.50%	141.16%	153.86%	167.71%	182.80%	199.26%	217.19%	236.74%	258.04%
INFLATED OTH. FAC. COSTS	$11,874.08	$16,245.04	$22,521.00	$27,699.71	$34,538.40	$37,646.86	$41,035.07	$44,728.23	$48,753.77	$53,141.61
WATS Additions (1982$)	$127.24	$127.24	$1,253.60	$204.48	$204.48	$0.00	$0.00	$0.00	$0.00	$0.00
TOTAL WATS COSTS (1982$)	$1,601.15	$1,728.40	$2,982.00	$3,186.48	$3,390.96	$3,390.96	$3,390.96	$3,390.96	$3,390.96	$3,390.96
Inflation Factor	118.81%	129.50%	141.16%	153.86%	167.71%	182.80%	199.26%	217.19%	236.74%	258.04%
INFLATED WATS COSTS	$1,902.33	$2,238.32	$4,209.33	$4,902.79	$5,686.97	$6,198.80	$6,756.69	$7,364.79	$8,027.63	$8,750.11
Centrex/PBX Costs (1982$)	$1,023.40	$1,023.40	$1,023.40	$1,023.40	$1,023.40	$0.00	$0.00	$0.00	$0.00	$0.00
TOTAL CNTRX/PBX COSTS (1982$)	$14,847.94	$15,871.34	$16,894.74	$17,918.14	$18,941.54	$18,941.54	$18,941.54	$18,941.54	$18,941.54	$18,941.54
Inflation Factor	118.81%	129.50%	141.16%	153.86%	167.71%	182.80%	199.26%	217.19%	236.74%	258.04%
INFLATED CNTRX/PBX COSTS	$17,640.84	$20,553.85	$23,848.30	$27,569.28	$31,766.86	$34,625.88	$37,742.20	$41,139.00	$44,841.51	$48,877.25
Add. Sys. Admin. Costs (1982$)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
TOTAL SYS. ADMIN. COSTS (1982$)	$670.25	$670.25	$670.25	$670.25	$670.25	$670.25	$670.25	$670.25	$670.25	$670.25
Inflation Factor	121.00%	133.10%	146.41%	161.05%	177.16%	194.87%	214.36%	235.79%	259.37%	285.31%
INFLATED SYS. ADMIN. COSTS	$811.00	$892.10	$981.31	$1,079.45	$1,187.39	$1,306.13	$1,436.74	$1,580.42	$1,738.46	$1,912.30

Continuing With the Existing STS Network (P.02/P.01)
(Costs in $1000)

	FY 1984	FY 1985	FY 1986	FY 1987	FY 1988	FY 1989	FY 1990	FY 1991	FY 1992	FY 1993
Tandem Switch Add. (1982$)	$152.57	$618.61	$677.81	$226.18	$223.88	$0.00	$0.00	$0.00	$0.00	$0.00
TOTAL TANDEM SW. COSTS (1982$)	$2,265.41	$2,884.02	$3,561.82	$3,788.00	$4,011.88	$4,011.88	$4,011.88	$4,011.88	$4,011.88	$4,011.88
Inflation Factor	118.81%	129.50%	141.16%	153.86%	167.71%	182.80%	199.26%	217.19%	236.74%	258.04%
INFLATED SW. COSTS	$2,691.53	$3,734.88	$5,027.80	$5,828.31	$6,728.32	$7,333.87	$7,993.92	$8,713.37	$9,497.57	$10,352.36
Leased Facilities										
IMT Additions (1982$)	$129.57	$351.09	$396.31	$161.45	$155.53	$0.00	$0.00	$0.00	$0.00	$0.00
TOTAL IMT COSTS (1982$)	$1,427.00	$1,778.09.	$2,174.40	$2,335.85	$2,491.38	$2,491.38	$2,491.38	$2,491.38	$2,491.38	$2,491.38
Inflation Factor	118.81%	129.50%	141.16%	153.86%	167.71%	182.80%	199.26%	217.19%	236.74%	258.04%
INFLATED IMT COSTS	$1,695.42	$2,302.68	$3,069.35	$3,593.99	$4,178.29	$4,554.33	$4,964.22	$5,411.00	$5,897.99	$6,428.81
Other Facility Add. (1982$)	$0.00	$4,548.64	$5,679.12	$2,272.67	$2,887.64	$0.00	$0.00	$0.00	$0.00	$0.00
TOTAL OTHER FAC. COSTS (1982$)	$9,994.18	$14,542.82	$20,221.93	$22,494.60	$25,382.24	$25,382.24	$25,382.24	$25,382.24	$25,382.24	$25,382.24
Inflation Factor	118.81%	129.50%	141.16%	153.86%	167.71%	182.80%	199.26%	217.19%	236.74%	258.04%
INFLATED OTH. FAC. COSTS	$11,874.08	$18,833.37	$28,544.91	$34,610.73	$42,568.56	$46,399.73	$50,575.70	$55,127.52	$60,088.99	$65,497.00
WATS Additions (1982$)	$127.24	$127.24	$1,253.60	$204.48	$204.48	$0.00	$0.00	$0.00	$0.00	$0.00
TOTAL WATS COSTS (1982$)	$1,601.15	$1,728.40	$2,982.00	$3,186.48	$3,390.96	$3,390.96	$3,390.96	$3,390.96	$3,390.96	$3,390.96
Inflation Factor	118.81%	129.50%	141.16%	153.86%	167.71%	182.80%	199.26%	217.19%	236.74%	258.04%
INFLATED WATS COSTS	$1,902.33	$2,238.32	$4,209.33	$4,902.79	$5,686.97	$6,198.80	$6,756.69	$7,364.79	$8,027.63	$8,750.11
Centrex/PBX Costs (1982$)	$1,023.40	$1,023.40	$1,023.40	$1,023.40	$1,023.40	$0.00	$0.00	$0.00	$0.00	$0.00
TOTAL CNTRX/PBX COSTS (1982$)	$14,847.94	$15,871.34	$16,894.74	$17,918.14	$18,941.54	$18,941.54	$18,941.54	$18,941.54	$18,941.54	$18,941.54
Inflation Factor	118.81%	129.50%	141.16%	153.86%	167.71%	182.80%	199.26%	217.19%	236.74%	258.04%
INFLATED CNTRX/PBX COSTS	$17,640.84	$20,553.85	$23,848.30	$27,569.28	$31,766.86	$34,625.88	$37,742.20	$41,139.00	$44,841.51	$48,877.25
Add. Sys. Admin. Costs (1982$)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
TOTAL SYS. ADMIN. COSTS (1982$)	$670.25	$670.25	$670.25	$670.25	$670.25	$670.25	$670.25	$670.25	$670.25	$670.25
Inflation Factor	121.00%	133.10%	146.41%	161.05%	177.16%	194.87%	214.36%	235.79%	259.37%	285.31%
INFLATED SYS. ADMIN. COSTS	$811.00	$892.10	$981.31	$1,079.45	$1,187.39	$1,306.13	$1,436.74	$1,580.42	$1,738.46	$1,912.30

STS Ownership of the Network (Plan A)
(Costs in $1000)

	FY 1984	FY 1985	FY 1986	FY 1987	FY 1988	FY 1989	FY 1990	FY 1991	FY 1992	FY 1993
Tandem Switch Tariff (1982$)	$2,265.41	$1,215.62	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Inflation Factor	118.81%	129.50%	141.16%	153.86%	167.71%	182.80%	199.26%	217.19%	236.74%	258.04%
Tandem Sw. Purchase (1982$)	$1,345.20	$6,237.60	$0.00	$464.70	$0.00	$0.00	$0.00	$0.00	$0.00	($1,567.92)
Inflation Factor	116.64%	125.97%	136.05%	146.93%	158.69%	171.38%	185.09%	199.90%	215.89%	233.16%
TOTAL SWITCH COSTS (1982$)	$3,610.61	$7,453.22	$0.00	$464.70	$0.00	$0.00	$0.00	$0.00	$0.00	($1,567.92)
INFLATED SW. COSTS	$4,260.57	$9,431.84	$0.00	$682.80	$0.00	$0.00	$0.00	$0.00	$0.00	($3,655.82)
Facility Costs										
IMT Tariff (1982$)	$1,427.00	$770.14	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Inflation Factor	118.81%	129.50%	141.16%	153.86%	167.71%	182.80%	199.26%	217.19%	236.74%	258.04%
INFLATED IMT COSTS	$1,695.42	$997.35	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Other Fac. Tariff (1982$)	$9,994.18	$10,429.20	$10,723.21	$11,571.70	$12,852.64	$12,852.64	$12,852.64	$12,852.64	$12,852.64	$12,852.64
Inflation Factor	118.81%	129.50%	141.16%	153.86%	167.71%	182.80%	199.26%	217.19%	236.74%	258.04%
INFLATED OTH. FAC. COSTS	$11,874.09	$13,506.12	$15,136.69	$17,804.49	$21,555.16	$23,495.13	$25,609.69	$27,914.56	$30,426.87	$33,165.29
Owned Radio Facility (1982$)	$5,954.55	$11,909.10	$33.20	$329.90	$74.80	$0.00	$0.00	$0.00	$0.00	($8,208.90)
Inflation Factor	116.64%	125.97%	136.05%	146.93%	158.69%	171.38%	185.09%	199.90%	215.89%	233.16%
INFLATED OWNED RADIO FAC. COST	$6,945.39	$15,002.04	$45.17	$484.73	$118.70	$0.00	$0.00	$0.00	$0.00	($19,140.18)
Owned Multiplex (1982$)	$393.30	$82.54	$122.52	$125.04	$175.34	$0.00	$0.00	$0.00	$0.00	($68.03)
Inflation Factor	116.64%	125.97%	136.05%	146.93%	158.69%	171.38%	185.09%	199.90%	215.89%	233.16%
INFLATED OWNED MULTIPLEX COSTS	$458.75	$103.98	$166.69	$183.72	$278.24	$0.00	$0.00	$0.00	$0.00	($158.62)
Owned Modems (1982$)	$1,052.00	$256.00	$320.00	$388.00	$496.00	$0.00	$0.00	$0.00	$0.00	$0.00
Inflation Factor	116.64%	125.97%	136.05%	146.93%	158.69%	171.38%	185.09%	199.90%	215.89%	233.16%
INFLATED OWNED MODEMS COSTS	$1,227.05	$322.49	$435.36	$570.10	$787.09	$0.00	$0.00	$0.00	$0.00	$0.00
WATS Additions (1982$)	$127.24	$127.24	$1,253.60	$204.48	$204.48	$0.00	$0.00	$0.00	$0.00	$0.00
TOTAL WATS COSTS (1982$)	$1,601.14	$1,728.38	$2,981.98	$3,186.46	$3,390.94	$3,390.94	$3,390.94	$3,390.94	$3,390.94	$3,390.94
Inflation Factor	118.81%	129.50%	141.16%	153.86%	167.71%	182.80%	199.26%	217.19%	236.74%	258.04%
INFLATED WATS COSTS	$1,902.31	$2,238.30	$4,209.31	$4,902.76	$5,686.95	$6,198.77	$6,756.66	$7,364.76	$8,027.59	$8,750.07
Cntrx Tariff/PBX lse. (1982$)	$14,847.94	$15,871.34	$16,894.74	$17,918.14	$18,941.54	$18,941.54	$18,941.54	$18,941.54	$18,941.54	$18,941.54
Inflation Factor	118.81%	129.50%	141.16%	153.86%	167.71%	182.80%	199.26%	217.19%	236.74%	258.04%
PBX Purchase (1982$)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Inflation Factor	116.64%	125.97%	136.05%	146.93%	158.69%	171.38%	185.09%	199.90%	215.89%	233.16%
TOTAL PBX/CENTREX (1982$)	$14,847.94	$15,871.34	$16,894.74	$17,918.14	$18,941.54	$18,941.54	$18,941.54	$18,941.54	$18,941.54	$18,941.54
INFLATED PBX/CENTREX COSTS	$17,640.84	$20,553.85	$23,848.30	$27,569.28	$31,766.86	$34,625.88	$37,742.20	$41,139.00	$44,841.51	$48,877.25
SYSTEM ADMINISTRATION										
Asset Costs:										
Management Center	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Test Equipment (Radio)	$0.00	$85.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	($17.00)
Test Equipment (Trans.)	$0.00	$725.25	$24.15	$24.15	$24.15	$0.00	$0.00	$0.00	$0.00	($174.03)
Spare parts (Tandem)	$0,00	$364.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Spare Parts (PBX)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Spare Parts/Gen. (Audio)	$0.00	$169.50	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Emg. Pwr. for Tandem site	$0.00	$147.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	($99.96)
TOTAL ASSET COSTS (1982$)	$0.00	$1,490.75	$24.15	$24.15	$24.15	$0.00	$0.00	$0.00	$0.00	($290.99)
Inflation Factor	116.64%	125.97%	136.05%	146.93%	158.69%	171.38%	185.09%	199.90%	215.89%	233.16%
Labor:										
Operations (Network Only)	$206.64	$571.46	$571.46	$571.46	$571.46	$571.46	$571.46	$571.46	$571.46	$571.46
Operations (PBX)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Maint. Trans. Test Eq.	$0.00	$0.00	$14.40	$14.40	$14.40	$14.40	$14.40	$14.40	$14.40	$14.40
Maint. of Management Center	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Adm/Cust Svc/Data Proc	$463.62	$463.62	$463.62	$463.62	$463.62	$463.62	$463.62	$463.62	$463.62	$463.62
Tandem Repair	$0.00	$0.00	$53.79	$57.41	$61.04	$61.04	$61.04	$61.04	$61.04	$61.04
PBX Repair	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Radio Repair	$0.00	$0.00	$56.00	$56.00	$56.00	$56.00	$56.00	$56.00	$56.00	$56.00
TOTAL LABOR (1982$)	$670.25	$1,035.08	$1,159.27	$1,162.89	$1,166.52	$1,166.52	$1,166.52	$1,166.52	$1,166.52	$1,166.52
Inflation Factor	121.00%	133.10%	146.41%	161.05%	177.16%	194.87%	214.36%	235.79%	259.37%	285.31%
TOTAL SYS. ADMIN. (1982$)	$670.25	$2,525.83	$1,183.42	$1,187.04	$1,190.67	$1,166.52	$1,166.52	$1,166.52	$1,166.52	$875.53
INFLATED SYS. ADMIN. COSTS	$811.00	$3,255.60	$1,730.14	$1,908.32	$2,104.88	$2,273.21	$2,500.53	$2,750.58	$3,025.64	$2,649.72

STS Ownership of the Network (Plan B)
(Costs in $1000)

	FY 1984	FY 1985	FY 1986	FY 1987	FY 1988	FY 1989	FY 1990	FY 1991	FY 1992	FY 1993
Tandem Switch Tariff (1982$)	$2,265.41	$1,215.62	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Inflation Factor	118.81%	129.50%	141.16%	153.86%	167.71%	182.80%	199.26%	217.19%	236.74%	258.04%
Switch Purchase (1982$)	$1,345.20	$6,237.60	$0.00	$464.70	$0.00	$0.00	$0.00	$0.00	$0.00	($1,567.92)
Inflation Factor	116.64%	125.97%	136.05%	146.93%	158.69%	171.38%	185.09%	199.90%	215.89%	233.16%
TOTAL SWITCH COSTS (1982$)	$3,610.61	$7,453.22	$0.00	$464.70	$0.00	$0.00	$0.00	$0.00	$0.00	($1,567.92)
INFLATED SW. COSTS	$4,260.57	$9,431.84	$0.00	$682.80	$0.00	$0.00	$0.00	$0.00	$0.00	($3,655.82)
Facility Costs										
IMT Tariff (1982$)	$1,427.00	$770.14	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Inflation Factor	118.81%	129.50%	141.16%	153.86%	167.71%	182.80%	199.26%	217.19%	236.74%	258.04%
INFLATED IMT COSTS	$1,695.42	$997.35	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Other Fac. Tariff (1982$)	$9,994.17	$10,429.21	$10,723.21	$11,571.70	$12,852.64	$12,852.64	$12,852.64	$12,852.64	$12,852.64	$12,852.64
Inflation Factor	118.81%	129.50%	141.16%	153.86%	167.71%	182.80%	199.26%	217.19%	236.74%	258.04%
INFLATED OTH. FAC. COSTS	$11,874.07	$13,506.12	$15,136.69	$17,804.49	$21,555.16	$23,495.13	$25,609.69	$27,914.56	$30,426.87	$33,165.29
Owned Radio Facility (1982$)	$5,954.55	$11,909.10	$33.20	$329.90	$74.80	$0.00	$0.00	$0.00	$0.00	($8,208.90)
Inflation Factor	116.64%	125.97%	136.05%	146.93%	158.69%	171.38%	185.09%	199.90%	215.89%	233.16%
INFLATED OWNED RADIO FAC. COST	$6,945.39	$15,002.04	$45.17	$484.73	$118.70	$0.00	$0.00	$0.00	$0.00	($19,140.18)
Owned Multiplex (1982$)	$393.30	$82.54	$122.52	$125.04	$175.34	$0.00	$0.00	$0.00	$0.00	($68.03)
Inflation Factor	116.64%	125.97%	136.05%	146.93%	158.69%	171.38%	185.09%	199.90%	215.89%	233.16%
INFLATED OWNED MULTIPLEX COSTS	$458.75	$103.98	$166.69	$183.72	$278.24	$0.00	$0.00	$0.00	$0.00	($158.62)
Owned Modems (1982$)	$1,052.00	$256.00	$320.00	$388.00	$496.00	$0.00	$0.00	$0.00	$0.00	$0.00
Inflation Factor	116.64%	125.97%	136.05%	146.93%	158.69%	171.38%	185.09%	199.90%	215.89%	233.16%
INFLATED OWNED MODEMS COSTS	$1,227.05	$322.49	$435.36	$570.10	$787.09	$0.00	$0.00	$0.00	$0.00	$0.00
WATS Additions (1982$)	$127.24	$127.24	$1,253.60	$204.48	$204.48	$0.00	$0.00	$0.00	$0.00	$0.00
TOTAL WATS COSTS (1982$)	$1,601.14	$1,728.38	$2,981.98	$3,186.46	$3,390.94	$3,390.94	$3,390.94	$3,390.94	$3,390.94	$3,390.94
Inflation Factor	118.81%	129.50%	141.16%	153.86%	167.71%	182.80%	199.26%	217.19%	236.74%	258.04%
INFLATED WATS COSTS	$1,902.31	$2,238.30	$4,209.31	$4,902.76	$5,686.95	$6,198.77	$6,756.66	$7,364.76	$8,027.59	$8,750.07
Cntrx Tariff/PBX lea. (1982$)	$14,847.93	$15,871.34	$9,805.37	$2,904.00	$3,104.00	$3,104.00	$3,104.00	$3,104.00	$3,104.00	$3,104.00
Inflation Factor	118.81%	129.50%	141.16%	153.86%	167.71%	182.80%	199.26%	217.19%	236.74%	258.04%
PBX Purchase (1982$)	$0.00	$0.00	$32,356.90	$0.00	$1,563.55	$0.00	$0.00	$0.00	$0.00	($447.18)
Inflation Factor	116.64%	125.97%	136.05%	146.93%	158.69%	171.38%	185.09%	199.90%	215.89%	233.16%
TOTAL PBX/CENTREX (1982$)	$14,847.93	$15,871.34	$42,162.27	$2,904.00	$4,667.55	$3,104.00	$3,104.00	$3,104.00	$3,104.00	$2,656.82
INFLATED PBX/CENTREX COSTS	$17,640.83	$20,553.85	$57,862.29	$4,468.16	$7,686.88	$5,674.23	$6,184.91	$6,741.56	$7,348.30	$6,966.99
SYSTEM ADMINISTRATION										
Asset Costs:										
Management Center	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Test Equipment (Radio)	$0.00	$85.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	($17.00)
Test Equipment (Trans.)	$0.00	$725.25	$24.15	$24.15	$24.15	$0.00	$0.00	$0.00	$0.00	($174.03)
Spare parts (Tandem)	$0.00	$364.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Spare Parts (PBX)	$0.00	$197.60	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Spare Parts/Gen. (Radio)	$0.00	$169.50	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Eng. Pwr. for Tandem site	$0.00	$147.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	($99.96)
TOTAL ASSET COSTS (1982$)	$0.00	$1,688.35	$24.15	$24.15	$24.15	$0.00	$0.00	$0.00	$0.00	($290.99)
Inflation Factor	116.64%	125.97%	136.05%	146.93%	158.69%	171.38%	185.09%	199.90%	215.89%	233.16%
Labor:										
Operations (Network Only)	$206.64	$571.46	$571.46	$571.46	$571.46	$571.46	$571.46	$571.46	$571.46	$571.46
Operations (PBX)	$0.00	$0.00	$1,155.38	$1,214.63	$1,273.88	$1,273.88	$1,273.88	$1,273.88	$1,273.88	$1,273.88
Maint. Trans. Test Eq.	$0.00	$0.00	$14.40	$14.40	$14.40	$14.40	$14.40	$14.40	$14.40	$14.40
Maint. of Management Center	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Adm/Cust Svc/Data Proc	$463.62	$463.62	$463.62	$463.62	$463.62	$463.62	$463.62	$463.62	$463.62	$463.62
Tandem Repair	$0.00	$0.00	$53.79	$57.41	$61.04	$61.04	$61.04	$61.04	$61.04	$61.04
PBX Repair	$0.00	$0.00	$0.00	$361.99	$383.92	$383.92	$383.92	$383.92	$383.92	$383.92
Radio Repair	$0.00	$0.00	$56.00	$56.00	$56.00	$56.00	$56.00	$56.00	$56.00	$56.00
TOTAL LABOR (1982$)	$670.25	$1,035.08	$2,314.64	$2,739.50	$2,824.31	$2,824.31	$2,824.31	$2,824.31	$2,824.31	$2,824.31
Inflation Factor	121.00%	133.10%	146.41%	161.05%	177.16%	194.87%	214.36%	235.79%	259.37%	285.31%
TOTAL SYS. ADMIN. (1982$)	$670.25	$2,723.43	$2,338.79	$2,763.65	$2,848.46	$2,824.31	$2,824.31	$2,824.31	$2,824.31	$2,533.32
INFLATED SYS. ADMIN. COSTS	$811.00	$3,504.52	$3,421.72	$4,447.48	$5,041.76	$5,503.78	$6,054.16	$6,659.58	$7,325.54	$7,379.61

STS Ownership of the Network (Plan C)
(Costs in $1000)

	FY 1984	FY 1985	FY 1986	FY 1987	FY 1988	FY 1989	FY 1990	FY 1991	FY 1992	FY 1993
Tandem Switch Tariff (1982$)	$2,265.41	$1,215.62	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Inflation Factor	118.81%	129.50%	141.16%	153.86%	167.71%	182.80%	199.26%	217.19%	236.74%	258.04%
Tandem Sw. Purchase (1982$)	$1,718.30	$10,102.80	$0.00	$293.40	$0.00	$0.00	$0.00	$0.00	$0.00	($2,309.75)
Inflation Factor	116.64%	125.97%	136.05%	146.93%	158.69%	171.38%	185.09%	199.90%	215.89%	233.16%
TOTAL SWITCH COSTS (1982$)	$3,983.71	$11,318.42	$0.00	$293.40	$0.00	$0.00	$0.00	$0.00	$0.00	($2,309.75)
INFLATED SW. COSTS	$4,695.76	$14,300.88	$0.00	$431.10	$0.00	$0.00	$0.00	$0.00	$0.00	($5,385.50)
Facility Costs										
INT Tariff (1982$)	$1,427.00	$770.14	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Inflation Factor	118.81%	129.50%	141.16%	153.86%	167.71%	182.80%	199.26%	217.19%	236.74%	258.04%
INFLATED INT COSTS	$1,695.42	$997.35	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Other Fac. Tariff (1982$)	$9,994.18	$10,167.86	$10,492.51	$11,325.21	$12,590.31	$12,590.31	$12,590.31	$12,590.31	$12,590.31	$12,590.31
Inflation Factor	118.81%	129.50%	141.16%	153.86%	167.71%	182.80%	199.26%	217.19%	236.74%	258.04%
INFLATED OTH. FAC. COSTS	$11,874.09	$13,167.67	$14,811.04	$17,425.24	$21,115.22	$23,015.58	$25,086.99	$27,344.82	$29,805.85	$32,488.38
Owned Radio Facility (1982$)	$5,954.55	$11,909.10	$33.20	$329.90	$74.80	$0.00	$0.00	$0.00	$0.00	($8,208.90)
Inflation Factor	116.64%	125.97%	136.05%	146.93%	158.69%	171.38%	185.09%	199.90%	215.89%	233.16%
INFLATED OWNED RADIO FAC. COST	$6,945.39	$15,002.04	$45.17	$484.73	$118.70	$0.00	$0.00	$0.00	$0.00	($19,140.18)
Owned Multiplex (1982$)	$393.30	$82.54	$122.52	$125.04	$175.34	$0.00	$0.00	$0.00	$0.00	($68.03)
Inflation Factor	116.64%	125.97%	136.05%	146.93%	158.69%	171.38%	185.09%	199.90%	215.89%	233.16%
INFLATED OWNED MULTIPLEX COSTS	$458.75	$103.98	$166.69	$183.72	$278.24	$0.00	$0.00	$0.00	$0.00	($158.62)
Owned Modems (1982$)	$1,052.00	$256.00	$320.00	$388.00	$496.00	$0.00	$0.00	$0.00	$0.00	$0.00
Inflation Factor	116.64%	125.97%	136.05%	146.93%	158.69%	171.38%	185.09%	199.90%	215.89%	233.16%
INFLATED OWNED MODEMS COSTS	$1,227.05	$322.49	$435.36	$570.10	$787.09	$0.00	$0.00	$0.00	$0.00	$0.00
WATS Additions (1982$)	$127.24	$127.24	$1,253.60	$204.48	$204.48	$0.00	$0.00	$0.00	$0.00	$0.00
TOTAL WATS COSTS (1982$)	$1,601.14	$1,728.38	$2,981.98	$3,186.46	$3,390.94	$3,390.94	$3,390.94	$3,390.94	$3,390.94	$3,390.94
Inflation Factor	118.81%	129.50%	141.16%	153.86%	167.71%	182.80%	199.26%	217.19%	236.74%	258.04%
INFLATED WATS COSTS	$1,902.31	$2,238.30	$4,209.31	$4,902.76	$5,686.95	$6,198.77	$6,756.66	$7,364.76	$8,027.59	$8,750.07
Cntrx Tariff/PBX lea. (1982$)	$14,847.93	$15,871.34	$9,805.37	$2,904.00	$3,104.00	$3,104.00	$3,104.00	$3,104.00	$3,104.00	$3,104.00
Inflation Factor	118.81%	129.50%	141.16%	153.86%	167.71%	182.80%	199.26%	217.19%	236.74%	258.04%
PBX Purchase (1982$)	$0.00	$0.00	$31,306.80	$0.00	$1,409.10	$0.00	$0.00	$0.00	$0.00	($403.00)
Inflation Factor	116.64%	125.97%	136.05%	146.93%	158.69%	171.38%	185.09%	199.90%	215.89%	233.16%
TOTAL PBX/CENTREX (1982$)	$14,847.93	$15,871.34	$41,112.17	$2,904.00	$4,513.10	$3,104.00	$3,104.00	$3,104.00	$3,104.00	$2,701.00
INFLATED PBX/CENTREX COSTS	$17,640.83	$20,553.85	$56,433.64	$4,468.16	$7,441.78	$5,674.23	$6,184.91	$6,741.56	$7,348.30	$7,069.99
SYSTEM ADMINISTRATION										
Asset Costs:										
Management Center	$0.00	$500.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	($100.00)
Test Equipment (Radio)	$0.00	$85.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	($17.00)
Test Equipment (Trans.)	$0.00	$725.25	$24.15	$24.15	$24.15	$0.00	$0.00	$0.00	$0.00	($174.03)
Spare parts (Tandem)	$0.00	$364.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Spare Parts (PBX)	$0.00	$197.60	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Spare Parts/Gen. (Radio)	$0.00	$169.50	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Emg. Pwr. for Tandem site	$0.00	$147.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	($99.96)
TOTAL ASSET COSTS (1982$)	$0.00	$2,188.35	$24.15	$24.15	$24.15	$0.00	$0.00	$0.00	$0.00	($390.99)
Inflation Factor	116.64%	125.97%	136.05%	146.93%	158.69%	171.38%	185.09%	199.90%	215.89%	233.16%
Labor:										
Operations (Network Only)	$206.64	$571.46	$571.46	$571.46	$571.46	$571.46	$571.46	$571.46	$571.46	$571.46
Operations (PBX)	$0.00	$0.00	$1,155.38	$1,214.63	$1,273.88	$1,273.88	$1,273.88	$1,273.88	$1,273.88	$1,273.88
Maint. Trans. Test Eq.	$0.00	$0.00	$14.40	$14.40	$14.40	$14.40	$14.40	$14.40	$14.40	$14.40
Maint. of Management Center	$0.00	$0.00	$26.00	$26.00	$26.00	$26.00	$26.00	$26.00	$26.00	$26.00
Adm/Cust Svc/Data Proc	$463.62	$463.62	$463.62	$463.62	$463.62	$463.62	$463.62	$463.62	$463.62	$463.62
Tandem Repair	$0.00	$0.00	$53.79	$57.41	$61.04	$61.04	$61.04	$61.04	$61.04	$61.04
PBX Repair	$0.00	$0.00	$0.00	$361.99	$383.92	$383.92	$383.92	$383.92	$383.92	$383.92
Radio Repair	$0.00	$0.00	$56.00	$56.00	$56.00	$56.00	$56.00	$56.00	$56.00	$56.00
TOTAL LABOR (1982$)	$670.25	$1,035.08	$2,340.64	$2,765.50	$2,850.31	$2,850.31	$2,850.31	$2,850.31	$2,850.31	$2,850.31
Inflation Factor	121.00%	133.10%	146.41%	161.05%	177.16%	194.87%	214.36%	235.79%	259.37%	285.31%
TOTAL SYS. ADMIN. (1982$)	$670.25	$3,223.43	$2,364.79	$2,789.65	$2,874.46	$2,850.31	$2,850.31	$2,850.31	$2,850.31	$2,459.32
INFLATED SYS. ADMIN. COSTS	$811.00	$4,134.38	$3,459.79	$4,489.35	$5,087.82	$5,554.45	$6,109.89	$6,720.88	$7,392.97	$7,220.62

ECONOMIC ANALYSIS - AUSTIN

APPENDIX J

Austin Comparison
Costs in $1000

PLAN 1 PMO	FY 1984	FY 1985	FY 1986	FY 1987	FY 1988	FY 1989	FY 1990	FY 1991	FY 1992	FY 1993
CCSA (1982$)	$823.00	$1,074.00	$1,35[illegible].00	$1,433.00	$1,516.00	$1,516.00	$1,516.00	$1,516.00	$1,516.00	$1,516.00
Centrex (1982$)	$3,243.00	$3,466.00	$3,689.00	$3,912.00	$4,135.00	$4,135.00	$4,135.00	$4,135.00	$4,135.00	$4,135.00
Total (1982$)	$4,066.00	$4,540.00	$5,040.00	$5,345.00	$5,651.00	$5,651.00	$5,651.00	$5,651.00	$5,651.00	$5,651.00
Inflation Factor	118.81%	129.50%	141.16%	153.86%	167.71%	182.80%	199.26%	217.19%	236.74%	258.04%
TOTAL CASH FLOW	$4,830.81	$5,879.43	$7,114.37	$8,223.95	$9,477.29	$10,330.25	$11,259.97	$12,273.37	$13,377.97	$14,581.99
CUMULATIVE CASH FLOW	$4,830.81	$10,710.25	$17,824.62	$26,048.56	$35,525.86	$45,856.10	$57,116.08	$69,389.44	$82,767.42	$97,349.41
COST OF CAPITAL	12.00%									
DISCOUNT FACTOR	1.0000	0.8929	0.7972	0.7118	0.6355	0.5674	0.5066	0.4523	0.4039	0.3606
DISC. CASH FLOW (1984$)	$4,830.81	$5,249.49	$5,671.53	$5,853.64	$6,022.99	$5,861.66	$5,704.65	$5,551.85	$5,403.14	$5,258.41
CUMULATIVE DISCOUNTED CASH FLOW (1984$)	$4,830.81	$10,080.31	$15,751.84	$21,605.48	$27,628.47	$33,490.13	$39,194.79	$44,746.63	$50,149.77	$55,408.18

Austin Comparison
Costs in $1000

	FY 1984	FY 1985	FY 1986	FY 1987	FY 1988	FY 1989	FY 1990	FY 1991	FY 1992	FY 1993
PLAN 2 Tandem Only										
CCSA (1982$)	$823.00	$440.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Centrex (1982$)	$3,243.00	$3,466.00	$3,689.00	$3,912.00	$4,135.00	$4,135.00	$4,135.00	$4,135.00	$4,135.00	$4,135.00
Subtotal (1982$)	$4,066.00	$3,906.00	$3,689.00	$3,912.00	$4,135.00	$4,135.00	$4,135.00	$4,135.00	$4,135.00	$4,135.00
Inflation Factor	118.81%	129.50%	141.16%	153.86%	167.71%	182.80%	199.26%	217.19%	236.74%	258.04%
Inflated Cash Flow	$4,830.81	$5,058.38	$5,207.32	$6,019.10	$6,934.81	$7,558.94	$8,239.25	$8,980.78	$9,789.05	$10,670.06
Tandem (1982$)	$1,011.00	$1,011.00	$0.00	$145.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Inflation Factor	116.64%	125.97%	136.05%	146.93%	158.69%	171.38%	185.09%	199.90%	215.89%	233.16%
Inflated Cash Flow	$1,179.23	$1,273.57	$0.00	$213.05	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
TOTAL CASH FLOW	$6,010.05	$6,331.95	$5,207.32	$6,232.15	$6,934.81	$7,558.94	$8,239.25	$8,980.78	$9,789.05	$10,670.06
CUMULATIVE CASH FLOW	$6,010.05	$12,342.00	$17,549.32	$23,781.47	$30,716.28	$38,275.22	$46,514.47	$55,495.25	$65,284.30	$75,954.36
COST OF CAPITAL	12.00%									
DISCOUNT FACTOR	1.0000	0.8929	0.7972	0.7118	0.6355	0.5674	0.5066	0.4523	0.4039	0.3606
DISC. CASH FLOW (1984$)	$6,010.05	$5,653.53	$4,151.25	$4,435.92	$4,407.20	$4,289.15	$4,174.26	$4,062.45	$3,953.63	$3,847.73
CUMULATIVE DISCOUNTED CASH FLOW (1984$)	$6,010.05	$11,663.57	$15,814.82	$20,250.74	$24,657.94	$28,947.08	$33,121.34	$37,183.79	$41,137.42	$44,985.16

Austin Comparison
Costs in $1000

	FY 1984	FY 1985	FY 1986	FY 1987	FY 1988	FY 1989	FY 1990	FY 1991	FY 1992	FY 1993
PLAN 3 Tandem + PBX (Separated)										
CCSA (1982$)	$823.00	$440.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Centrex*(1982$)	$3,243.00	$3,466.00	$2,139.50	$631.00	$675.00	$675.00	$675.00	$675.00	$675.00	$675.00
Subtotal (1982$)	$4,066.00	$3,906.00	$2,139.50	$631.00	$675.00	$675.00	$675.00	$675.00	$675.00	$675.00
Inflation Factor	118.81%	129.50%	141.16%	153.86%	167.71%	182.80%	199.26%	217.19%	236.74%	258.04%
Inflated Cash Flow	$4,830.81	$5,058.38	$3,020.08	$970.87	$1,132.04	$1,233.93	$1,344.98	$1,466.03	$1,597.97	$1,741.79
Tandem (1982$)	$1,011.00	$1,011.00	$0.00	$145.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
PBX Switch (1982$)	$0.00	$0.00	$6,848.00	$0.00	$340.00	$0.00	$0.00	$0.00	$0.00	$0.00
PBX Cabling (1982$)	$0.00	$0.00	$258.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Subtotal (1982$)	$1,011.00	$1,011.00	$7,106.00	$145.00	$340.00	$0.00	$0.00	$0.00	$0.00	$0.00
Inflation Factor	116.64%	125.97%	136.05%	146.93%	158.69%	171.38%	185.09%	199.90%	215.89%	233.16%
Inflated Cash Flow	$1,179.23	$1,273.57	$9,667.63	$213.05	$539.54	$0.00	$0.00	$0.00	$0.00	$0.00
TOTAL CASH FLOW	$6,010.05	$6,331.95	$12,687.71	$1,183.92	$1,671.58	$1,233.93	$1,344.98	$1,466.03	$1,597.97	$1,741.79
CUMULATIVE CASH FLOW	$6,010.05	$12,342.00	$25,029.71	$26,213.63	$27,885.21	$29,119.14	$30,464.12	$31,930.15	$33,528.12	$35,269.91
COST OF CAPITAL	12.00%									
DISCOUNT FACTOR	1.0000	0.8929	0.7972	0.7118	0.6355	0.5674	0.5066	0.4523	0.4039	0.3606
DISC. CASH FLOW (1984$)	$6,010.05	$5,653.53	$10,114.57	$842.69	$1,062.32	$700.16	$681.41	$663.16	$645.39	$628.11
CUMULATIVE DISCOUNTED CASH FLOW (1984$)	$6,010.05	$11,663.57	$21,778.14	$22,620.84	$23,683.15	$24,383.32	$25,064.73	$25,727.88	$26,373.28	$27,001.38

* INCLUDES ACCESS CHARGES & FEATURE CHARGES FOR PBX'S IN AND AFTER 1986

Austin Comparison
Costs in $1000

PLAN 4 Tandem + PBX (Combined)	FY 1984	FY 1985	FY 1986	FY 1987	FY 1988	FY 1989	FY 1990	FY 1991	FY 1992	FY 1993
CCSA (1982$)	$823.00	$440.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Centrex*(1982$)	$3,243.00	$3,466.00	$2,139.50	$631.00	$675.00	$675.00	$675.00	$675.00	$675.00	$675.00
Subtotal (1982$)	$4,066.00	$3,906.00	$2,139.50	$631.00	$675.00	$675.00	$675.00	$675.00	$675.00	$675.00
Inflation Factor	118.81%	129.50%	141.16%	153.86%	167.71%	182.80%	199.26%	217.19%	236.74%	258.04%
Inflated Cash Flow	$4,830.81	$5,058.38	$3,020.08	$970.87	$1,132.04	$1,233.93	$1,344.98	$1,466.03	$1,597.97	$1,741.79
Tandem (1982$)	$1,472.00	$1,472.00	$0.00	$81.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
PBX Switch (1982$)	$0.00	$0.00	$5,706.00	$0.00	$304.50	$0.00	$0.00	$0.00	$0.00	$0.00
PBX Cabling (1982$)	$0.00	$0.00	$774.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Fac. Savings (1982$)	$0.00	$0.00	($137.00)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Subtotal (1982$)	$1,472.00	$1,472.00	$6,343.00	$81.00	$304.50	$0.00	$0.00	$0.00	$0.00	$0.00
Inflation Factor	116.64%	125.97%	136.05%	146.93%	158.69%	171.38%	185.09%	199.90%	215.89%	233.16%
Inflated Cash Flow	$1,716.94	$1,854.30	$8,629.58	$119.02	$483.20	$0.00	$0.00	$0.00	$0.00	$0.00
TOTAL CASH FLOW	$6,547.76	$6,912.68	$11,649.66	$1,089.89	$1,615.25	$1,233.93	$1,344.98	$1,466.03	$1,597.97	$1,741.79
CUMULATIVE CASH FLOW	$6,547.76	$13,460.43	$25,110.10	$26,199.98	$27,815.23	$29,049.15	$30,394.13	$31,860.16	$33,458.13	$35,199.92
COST OF CAPITAL	12.00%									
DISCOUNT FACTOR	1.0000	0.8929	0.7972	0.7118	0.6355	0.5674	0.5066	0.4523	0.4039	0.3606
DISC. CASH FLOW (1984$)	$6,547.76	$6,172.04	$9,287.04	$775.76	$1,026.52	$700.16	$681.41	$663.16	$645.39	$628.11
CUMULATIVE DISCOUNTED CASH FLOW (1984$)	$6,547.76	$12,719.79	$22,006.83	$22,782.59	$23,809.11	$24,509.27	$25,190.68	$25,853.83	$26,499.23	$27,127.33

* INCLUDES ACCESS CHARGES & FEATURE CHARGES FOR PBX's IN AND AFTER 1986.

1982 CENTREX CHARGES

APPENDIX K

CAPITOL CENTREX
COMPARISON OF CURRENT SWB RATES VS RATES FILED JUN 21, 1982
DOCKET 4545
AS PROPOSED BY SWB

BILLING MONTH USED AS BASE -- MAY 82

			PROPOSED		-CURRENT-				REFERENCE		
SOC	DESCRIPTION	QTY	RATE	COST	RATE	COST	DIFF	% CHG	TARIFF	SEC	SHEET
K	DATA SET NU TONE CHIME SPCL ABLY	2	1.500	3.00	1.500	3.00	0.00	0.00	GET	000	000( )
	GET SECTION 000 SUB TOTAL			3.00		3.00	0.00				4545 · old
2	AUTO ANS ONLY - ROTARY	1	61.500	61.50	61.500	61.50	0.00	0.00	GET	003	01A 28/28
T	CODE-A-PHONE, AUTO ANS/REC	2	55.100	110.20	55.100	110.20	0.00	0.00	GET	003	01A 65/70
P	COE-A-PHONE, AUTO ANS/REC	3	55.100	165.30	55.100	165.30	0.00	0.00	GET	003	01A 65/75
	GET SECTION 003 SUB TOTAL			337.00		337.00	0.00				
J	POSITION BUSY FEATURE	3	3.650	10.95	3.650	10.95	0.00	0.00	GET	005	028 0/0
	DICTAION RECORDING EQ, ATT STA	1	0.500	0.50	0.500	0.50	0.00	0.00	GET	005	043( )
2H1R	CTX II, ALL CALL FORWARDING	46	54.100	2,488.60	54.100	2,488.60	0.00	0.00	GET	005	036 0/0
G	ESS CTX, SPEED CALLING	40	0.800	32.00	0.800	32.00	0.00	0.00	GET	005	060 3/3
G	EXX CTX, CALL FORWARDING	77	0.300	23.10	0.300	23.10	0.00	0.00	GET	005	043 4.20/4.20
N	ESS CTX, CALL WAITING	1	1.900	1.90	1.900	1.90	0.00	0.00	GET	005	043 4.20/4.20
7G	ESS CTX, CALL FORWARDING, D/A	264	0.750	198.00	0.300	79.20	118.80	50.00	GET	005	043 5.40/5.40
2	CTX CALL HOLD & PICK-UP	474	1.600	758.40	1.600	758.40	0.00	0.00	GET	005	043 3.50/3.50
T	CTX CALL FORWARDING, VARIABLE	508	1.600	812.80	1.600	812.80	0.00	0.00	GET	005	043 3.50/3.50
V	ATTENDANT TRK TERM, CUST PREM	3	9.450	28.35	9.450	28.35	0.00	0.00	GET	005	028 370/285
05	PRIMARY CONSOLE EQUIP, CUST PREM	1	296.000	296.00	296.000	296.00	0.00	0.00	GET	005	028 11,100/8,20
06	ADD'L COMMON EQUIP	1	53.200	53.20	53.200	53.20	0.00	0.00	GET	005	028 430/330
07XT	CONSOLE TYPE 27A, CUST PREM	3	86.000	258.00	86.000	258.00	0.00	0.00	GET	005	028 420/330
0A	ATTENDANT ACCESS LINE	24	21.650	519.60	21.650	519.60	0.00	0.00	GET	005	028 0/0
	CONSOLE, CTRL OFC EQUIP	1	35.900	35.90	35.900	35.90	0.00	0.00	GET	005	028 0/0
DF	ATTENDANT TRK TERM, CNTRL OFC	3	44.500	133.50	39.400	118.20	15.30	12.94	GET	005	028 0/0

CAPITOL CENTREX
COMPARISON OF CURRENT SWB RATES VS RATES FILED JUN 21, 1982
DOCKET 4545
AS PROPOSED BY SWB

BILLING MONTH USED AS BASE -- MAY 82

			PROPOSED		-CURRENT-				REFERENCE		
SOC	DESCRIPTION	QTY	RATE	COST	RATE	COST	DIFF	% CHG	TARIFF	SEC	SHEET
DG	LAMP, MULTIPLE UNIT	1	22.600	22.60	22.600	22.60	0.00	0.00	GET	005	028 370/28
DK	PRIMARY CONSOLE EQUIP, CNTRL OFC	1	117.000	117.00	117.000	117.00	0.00	0.00	GET	005	028 0/0
DP	RESERVE POWER SUPPLY	1	157.000	157.00	157.000	157.00	0.00	0.00	GET	005	028 3,225/2,1?
H6	ESS, CIRCULAR HUNT	321	0.250	80.25	0.050	16.05	64.20	500.00	GET	005	043 36/36
H7	ESS, UNIFORM CALL DIST	2	3.000	6.00	3.000	6.00	0.00	0.00	GET	005	062 4.20/4.20
MC	ESS, CONF CALL ARRGMT	1	105.000	105.00	105.000	105.00	0.00	0.00	GET	005	043 15/15
SZ	CTX CALL WAIT FEA	2	1.900	3.80	1.900	3.80	0.00	0.00	GET	005	043 4.20/4.20
TB	ESS, STA TOLL REST	24	0.700	16.80	0.400	9.60	7.20	75.00	GET	005	062 36/36
FNAA	CTX STA PRIMARY ON PREM	1183	13.950	16,502.85	13.950	16,502.85	0.00	0.00	GET	005	019 —
B	CTX STA PRIMARY OFF PREM	3346	5.150	17,231.90	4.300	14,387.80	2,844.10	19.77	GET	005	019 —
X3	CTX STA PRIMARY OFF PREM	3337	4.350	14,515.95	4.350	14,515.95	0.00	0.00	GET	005	019 —
X5	FULLY REST MAIN STA, ON PREM	12	19.350	232.20	19.350	232.20	0.00	0.00	GET	005	019 —
X6	CTX EXTENSION STA LINE	14	4.500	63.00	4.450	62.30	0.70	1.12	GET	005	019 —
XR	CTX STA, PRIMARY ON PREM	1191	7.700	9,170.70	7.700	9,170.70	0.00	0.00	GET	005	019 —
	GET SECTION 005 SUB TOTAL			63,875.85		60,825.55	3,050.30				
DT	TERM EQUIP, MANUAL, CPE	1	2.000	2.00	2.000	2.00	0.00	0.00	GET	007	[illegible](014) 5/5
R8	PAGING EQUIP, COAM	2	0.500	1.00	0.500	1.00	0.00	0.00	GET	007	~~028~~(044) 10/10
ZU	KEY STM INTERCOM ACESS TO COAM	1	4.100	4.10	4.100	4.10	0.00	0.00	GET	007	~~065~~(045) 14.40/M.
KT	CUST PROVIDED VOICE CONNECTION	10	0.500	5.00	0.500	5.00	0.00	0.00	GET	007	~~027~~(019) 5/5
CZ	RECORDER CONNECTOR	2	2.000	4.00	2.000	4.00	0.00	0.00	GET	007	~~029~~(019) 5/5
DL	RECORDER COUPLER, COAM	13	4.000	52.00	4.000	52.00	0.00	0.00	GET	007	033([illegible]) 25/25
[illegible]	EXCH SERV, RECORDER COUPLER	7	4.750	33.25	3.750	26.25	7.00	26.67	GET	007	033([illegible]) 25/25
DY	AUTO CONNECT ARRGMT, COAM	6	5.250	31.50	5.250	31.50	0.00	0.00	GET	007	~~031(025)~~ 023 10/10

CAPITOL CENTREX
COMPARISON OF CURRENT SWB RATES VS RATES FILED JUN 21, 1982
DOCKET 4545
AS PROPOSED BY SWB

BILLING MONTH USED AS BASE -- MAY 82

			PROPOSED		-CURRENT-				REFERENCE		
OC	DESCRIPTION	QTY	RATE	COST	RATE	COST	DIFF	% CHG	TARIFF	SEC	SHEET
	GET SECTION 007 SUB TOTAL			132.85		125.85	7.00				
F	ESS, SPEED CALLING, 30 CODES	2	7.800	15.60	7.800	15.60	0.00	0.00	GET	~~009~~ (5)	~~002~~(060) 15/15
M	CUSTOM CALLING	2	2.500	5.00	2.500	5.00	0.00	0.00	GET	009	002 5/5
X	ESS, CALL WAITING	3	1.300	3.90	1.300	3.90	0.00	0.00	GET	009 (5)	002(043) 4.20/4
	GET SECTION 009 SUB TOTAL			24.50		24.50	0.00				
T	EXTRA LISTING - BUSINESS	1134	1.350	1,530.90	1.350	1,530.90	0.00	0.00	GET	011	003 —
L	FOREIGN LISTING	23	1.350	31.05	1.350	31.05	0.00	0.00	GET	011	004 —
	ALT CALL LISTING	3	1.350	4.05	1.350	4.05	0.00	0.00	GET	011	004 —
SV	SUPPL ADDRESS INFO	7	1.350	9.45	1.350	9.45	0.00	0.00	GET	011	004 —
	GET SECTION 011 SUB TOTAL			1,575.45		1,575.45	0.00				
LU	DIAL ICM, W/BUSY LAMP	25	10.500	262.50	10.500	262.50	0.00	0.00	GET	018	011 40/40
OR	DIAL ICM BUSY TONE (6A)	173	3.950	683.35	3.950	683.35	0.00	0.00	GET	018	011 25/25
FF	CUT OFF, MANUAL	203	3.700	751.10	3.700	751.10	0.00	0.00	GET	018	010 30/15
KF25	COMKEY 416 STA LINE	2	1.750	3.50	1.750	3.50	0.00	0.00	GET	018	087 25/15
KF2A	COMKEY 416 STA LINE	2	0.900	1.80	0.900	1.80	0.00	0.00	GET	018	087 19/13
KY25	COMKEY 718 STA LINE	69	0.900	62.10	0.900	62.10	0.00	0.00	GET	018	039 16/10
KY2A	COMKEY 2152 STA LINE	2	0.900	1.80	0.900	1.80	0.00	0.00	GET	018	070 18/13
KY2B	COMKEY 2152 INTERCOM ONLY	2	1.400	2.80	1.400	2.80	0.00	0.00	GET	018	070 18/13
KY5A	COMKEY 2152, 34 STA, MSG WT LN	1	1.950	1.95	1.950	1.95	0.00	0.00	GET	018	071 35/25
50	COMKEY 1434 STA LINE	61	2.500	152.50	2.500	152.50	0.00	0.00	GET	018	048 30/25
KYB5	COMKEY 2152, 52 STA, MSG WT LN	1	9.300	9.30	9.300	9.30	0.00	0.00	GET	018	071 150/100

CAPITOL CENTREX
COMPARISON OF CURRENT SWB RATES VS RATES FILED JUN 21, 1982
DOCKET 4545
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BILLING MONTH USED AS BASE -- MAY 82

			PROPOSED		-CURRENT-				REFERENCE		
SOC	DESCRIPTION	QTY	RATE	COST	RATE	COST	DIFF	% CHG	TARIFF	SEC	SHEET
0Z	LINE EQUIPMENT	3670	4.950	18,166.50	4.950	18,166.50	0.00	0.00	GET	018	006 0/0
IT	MANUAL RINGER CUT-OFF	15	0.700	10.50	0.700	10.50	0.00	0.00	GET	018	010 0/0
B09	COMPACT DIAL INTERCOM SYS	5	30.000	150.00	30.000	150.00	0.00	0.00	GET	018	010 45/45
K	DIAL ICM, W/O BUSY LAMP	11	6.250	68.75	6.250	68.75	0.00	0.00	GET	018	011 35/35
2	INTERCOM, 6A SEL, ADD'L STA	778	0.850	661.30	0.850	661.30	0.00	0.00	GET	018	011 9/9
9	INTERCOM, 6A SEL, 1ST 9 STA	315	20.250	6,378.75	20.250	6,378.75	0.00	0.00	GET	018	011 90/90
U	INTERCOM, 6A, 1 LINK, ADD'L STA	10	2.500	25.00	2.500	25.00	0.00	0.00	GET	018	011 15/15
9	INTERCOM, 6A, 1 LINK, 1ST 9 STA	2	41.500	83.00	41.500	83.00	0.00	0.00	GET	018	011 130/130
9	INTERCOM, 2 LINK, 1ST 9 STA	69	58.500	4,036.50	58.500	4,036.50	0.00	0.00	GET	018	011 200/200
J	20/40 DIAL PACK, COMM EQUIP	5	119.100	595.50	119.100	595.50	0.00	0.00	GET	018	009 0/0
M	INTERCOM 6A, BUSY TONE & CAMP-ON	1	7.200	7.20	7.200	7.20	0.00	0.00	GET	018	011 45/45
P	INTERCOM 6A, PRESET CONF GRP	1	7.850	7.85	7.850	7.85	0.00	0.00	GET	018	011 40/40
Y	20/40 DIAL PACK, STA BUSY TONE	82	2.250	184.50	2.250	184.50	0.00	0.00	GET	018	014 0/0
4	INTERCOM 6A, DIAL TONE	4	14.250	57.00	14.250	57.00	0.00	0.00	GET	018	011 85/85
Y	INTERCOM 6A, 2 LINK, ADD'L STA	826	5.100	4,212.60	5.100	4,212.60	0.00	0.00	GET	018	011 30/30
Y	INTERCOM 6A, ADD ON CONF	1	4.900	4.90	4.900	4.90	0.00	0.00	GET	018	011 25/25
V	JACK IN CALL DIRECTOR	4	2.300	9.20	2.300	9.20	0.00	0.00	GET	018	0(007)
3	COMKEY 1434, 20 BUTTON	28	16.700	467.60	16.700	467.60	0.00	0.00	GET	018	048 25/20
1G	COMKEY 2152, POWER PANEL C	1	49.750	49.75	44.500	44.50	5.25	11.80	GET	018	069 45/45
1H	COMKEY 2152, POWER PANEL D	1	19.500	19.50	18.000	18.00	1.50	8.33	GET	018	069 40/35
1U	COMKEY 2152, POWER CONN UNIT	1	87.250	87.25	80.000	80.00	7.25	9.06	GET	018	069 45/55
1V	COMKEY 2152, CONN UNIT SUPPL	1	57.500	57.50	53.000	53.00	4.50	8.49	GET	018	069 45/55
21	COMKEY 2152, BASIC FEATURE PANEL	1	43.500	43.50	39.500	39.50	4.00	10.13	GET	018	069 210 [illegible] 70
22	COMKEY 2152, LINE EQUIP	10	2.500	25.00	2.500	25.00	0.00	0.00	GET	018	069 2/2

CAPITOL CENTREX
COMPARISON OF CURRENT SWB RATES VS RATES FILED JUN 21, 1982
DOCKET 4545
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			PROPOSED		-CURRENT-				REFERENCE		
OC	DESCRIPTION	QTY	RATE	COST	RATE	COST	DIFF	% CHG	TARIFF	SEC	SHEET
5	COMKEY 2152, POWER FAILURE RING	1	2.150	2.15	2.100	2.10	0.05	2.38	GET	018	[illegible](072) 15/15
6	COMKEY 2152, LAMP EXTENDER	2	4.400	8.80	4.400	8.80	0.00	0.00	GET	018	069 3/3
7	COMKEY 2152, OPTIONAL FEATURE	1	8.500	8.50	8.500	8.50	0.00	0.00	GET	018	071 3/3
8	COMKEY 2152, OPTIONAL FEATURE	2	5.250	10.50	5.250	10.50	0.00	0.00	GET	018	071 3/2
H	COMKEY 2152, 3 PATH INTERCOM	1	10.900	10.90	10.250	10.25	0.65	6.34	GET	018	069 3/2
N	COMKEY 2152, PAGING AMPLIFIER	1	4.900	4.90	4.600	4.60	0.30	6.52	GET	018	[illegible](072) 3/3
U	COMKEY 2152, TT COMM EQUIP	1	15.250	15.25	15.250	15.25	0.00	0.00	GET	018	072 3/2
X	COMKEY 2152, SUPPL FEATURE PANEL	1	27.100	27.10	24.350	24.35	2.75	11.29	GET	018	069 25/25
T	COMKEY 2152, TONE RINGING GEN	1	2.800	2.80	2.800	2.80	0.00	0.00	GET	018	069 2/2
[illegible]	COMKEY 416, COMM EQUIP	2	26.500	53.00	26.500	53.00	0.00	0.00	GET	018	087 30/25
LV6	COMKEY 416, STATION SET	2	15.500	31.00	15.500	31.00	0.00	0.00	GET	018	087 16/18
N	COMKEY 416, BUSY LAMP	2	5.650	11.30	5.250	10.50	0.80	7.62	GET	018	088 18/16
P	COMKEY 416, POWER FAILURE RING	2	4.300	8.60	4.300	8.60	0.00	0.00	GET	018	088 20/18
X	COMKEY 416, PRIVACY FEA	2	0.950	1.90	0.950	1.90	0.00	0.00	GET	018	088 18/18
2	COMKEY 2152, 14 LINE INST	32	12.500	400.00	12.500	400.00	0.00	0.00	GET	018	069 25/25
2	COMKEY 2152, 14 LINE INST	3	14.000	42.00	14.000	42.00	0.00	0.00	GET	018	069 25/25
5366	COMKEY 2152, 7 LINE INST	3	10.800	32.40	10.500	31.50	0.90	2.86	GET	018	069 19/17
5466	COMKEY 2152, 14 LINE INST	30	12.750	382.50	12.750	382.50	0.00	0.00	GET	018	069 25/20
5666	TOUCHTONE, ICM ONLY	1	6.500	6.50	6.500	6.50	0.00	0.00	GET	018	069 13/11
58	TOUCHTONE, ANS POS	6	12.500	75.00	12.500	75.00	0.00	0.00	GET	018	070 25/19
5H	TOUCHTONE, MSG WTG CONSOLE	2	11.500	23.00	9.750	19.50	3.50	17.95	GET	018	070 25/17
50	TOUCHTONE, MSG WTG CONSOLE W/DDS	1	87.000	87.00	87.000	87.00	0.00	0.00	GET	018	070 110/85
[illegible]	COMKEY 2152, HANDS FREE INTERCOM	3	5.000	15.00	5.000	15.00	0.00	0.00	GET	018	071 18/17
5U	COMKEY 2152, ADD'L RING TRANSFER	1	2.200	2.20	2.200	2.20	0.00	0.00	GET	018	071 60/55

STATE OF TEXAS
STATE TELECOMMUNICATIONS SYSTEM

CAPITOL CENTREX
COMPARISON OF CURRENT SWB RATES VS RATES FILED JUN 21, 1982
DOCKET 4545
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BILLING MONTH USED AS BASE -- MAY 82

			PROPOSED		-CURRENT-				REFERENCE			
SOC	DESCRIPTION	QTY	RATE	COST	RATE	COST	DIFF	% CHG	TARIFF	SEC	SHEET	
JX	TOUCHTONE, OPT FEA/SPKR CABINET	6	2.150	12.90	2.150	12.90	0.00	0.00	GET	018	072	55/50
M	KEY, MULTILINE CONF COMM EQUIP	10	1.550	15.50	1.550	15.50	0.00	0.00	GET	018	007	15/12
P	BLF CONS SUPPL POWER	12	5.000	60.00	5.000	60.00	0.00	0.00	GET	018	010	45/45
T	BLF CONS, 13 BUTTON INST	19	9.500	180.50	9.500	180.50	0.00	0.00	GET	018	039	19/17
X	BLF CONS, 13 BUTTON INST	46	8.750	402.50	8.750	402.50	0.00	0.00	GET	018	039	18/16
6	RESTRICTED STATION FEATURE	1	0.800	0.80	0.800	0.80	0.00	0.00	GET	018	14	25/14
S	COMKEY 718, AUX SIG ACTUN	2	2.400	4.80	2.400	4.80	0.00	0.00	GET	018	039	30/30
T66	COMKEY 1434, ATTND SET (K13+6)	1	16.700	16.70	16.700	16.70	0.00	0.00	GET	018	048	25/20
C	KEY, BUSY LAMP CONSOLE 19 STA	20	12.000	240.00	12.000	240.00	0.00	0.00	GET	018	010	45/35
D	KEY, BUSY LAMP CONSOLE 39 STA	29	18.600	539.40	18.600	539.40	0.00	0.00	GET	018	010	45/35
02	CALL DIRECTOR, 12 BUTTON	5	11.000	55.00	11.000	55.00	0.00	0.00	GET	018	007	40/30
02	CALL DIRECTOR, 12 BUTTON	82	12.300	1,008.60	12.300	1,008.60	0.00	0.00	GET	018	007	40/30
04	CALL DIRECTOR, 24 BUTTON	3	17.000	51.00	17.000	51.00	0.00	0.00	GET	018	007	60/50
04	CALL DIRECTOR, 24 BUTTON	40	18.400	736.00	18.400	736.00	0.00	0.00	GET	018	007	60/50
0L	CALL DIRECTOR, 30 BUTTON	47	20.750	975.25	20.750	975.25	0.00	0.00	GET	018	007	70/55
0S	CALL DIRECTOR, 18 BUTTON	2	12.500	25.00	12.500	25.00	0.00	0.00	GET	018	007	55/45
0S	CALL DIRECTOR, 18 BUTTON	147	15.200	2,234.40	15.200	2,234.40	0.00	0.00	GET	018	007	55/45
0U	CALL DIRECTOR, 18 BUTTON W/JACK	5	17.500	87.50	17.500	87.50	0.00	0.00	GET	018	007	55/45
0V	CALL DIRECTOR, 30 BUTTON W/JACK	11	24.500	269.50	24.500	269.50	0.00	0.00	GET	018	007	70/55
EJ	KEY, 6 BUTTON, EXT KEY UNIT	10	3.150	31.50	3.150	31.50	0.00	0.00	GET	018	009	25/25
EL25	6/11 BUTTON STA LINE	6919	1.150	7,956.85	1.150	7,956.85	0.00	0.00	GET	018	009	18/13
EL5A	12 BUTTON STA LINE	3	2.400	7.20	2.400	7.20	0.00	0.00	GET	018	009	18/13
EL50	20 BUTTON STA LINE	593	2.050	1,215.65	2.050	1,215.65	0.00	0.00	GET	018	009	51/[illegible]
EL75	12/18 BUTTON STA LINE	243	2.900	704.70	2.900	704.70	0.00	0.00	GET	018	009	51/35

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OC	DESCRIPTION	QTY	RATE	COST	RATE	COST	DIFF	% CHG	TARIFF	SEC	SHEET
LAX	24/30 BUTTON STA LINE	109	4.200	457.80**	4.200	457.80	0.00	0.00	GET	018	009 75/55
L02	NO/1 BUTTON STA LINE	38	0.600	22.80	0.600	22.80	0.00	0.00	GET	018	009 6/4
R	CALL DIRECTOR, 12 BUTTON W/JACK	5	16.500	82.50	16.500	82.50	0.00	0.00	GET	018	~~008(007)~~ 007 40/30
X	TELEPHONE, ICM ACCESS ONLY	6	1.500	9.00	1.500	9.00	0.00	0.00	GET	018	~~011(012)~~ 012 0/0
X	TELEPHONE, ICM ACCESS ONLY	27	2.100	56.70	2.050	55.35	1.35	2.44	GET	018	011(012) 0/0
1	TELEPHONE, MULTILINE, BASE JACK	7	6.550	45.85	6.550	45.85	0.00	0.00	GET	018	008 12/12
E	COMKEY 718, COMM EQUIP	3	85.000	255.00	85.000	255.00	0.00	0.00	GET	018	039 150/120
G	COMKEY 718, LINE EQUIP	24	3.500	84.00	3.500	84.00	0.00	0.00	GET	018	039 2/2
L	COMKEY 718, TT PER SYS	3	14.000	42.00	14.000	42.00	0.00	0.00	GET	018	040 3/2
	COMKEY 718, NIGHT TRANSFER	3	0.950	2.85	0.950	2.85	0.00	0.00	GET	018	040 2/2
Y	KEY, PL TERM, CB	190	5.000	950.00	5.000	950.00	0.00	0.00	GET	018	013 3/3
1	COMKEY 718, SPEAKER, WALL	1	4.200	4.20	4.200	4.20	0.00	0.00	GET	018	040 55/50
6	COMKEY 718, BL CONSOLE W/DSS	2	10.900	21.80	10.900	21.80	0.00	0.00	GET	018	039 19/15
7	COMKEY 718, BL CONSOLE W/MSG WTG	2	9.900	19.80	9.900	19.80	0.00	0.00	GET	018	039 25/17
A	COMKEY 1434, COMM EQUIP	1	156.450	156.45	154.000	154.00	2.45	1.59	GET	018	048 200/200
G	COMKEY 1434, CONSOLE W/MSG WTG	2	22.150	44.30	20.500	41.00	3.30	8.05	GET	018	048 30/25
4	AUTO CUTOFF	6	7.500	45.00	7.500	45.00	0.00	0.00	GET	018	010 40/40
3B	OPX KEY CTL EQUIP	42	12.750	535.50	12.750	535.50	0.00	0.00	GET	018	013 35/35
3C	KEY, 11 BUTTON	46	8.750	402.50	8.750	402.50	0.00	0.00	GET	018	007 14/30
3K	KEY, 20 BUTTON	121	12.450	1,506.45	12.450	1,506.45	0.00	0.00	GET	018	007 25/35
U2	EXTERNAL KEY TEL, 12 BUTTON	4	8.050	32.20	8.050	32.20	0.00	0.00	GET	018	008 35/30
UM	24 BUTTON CALL DIRECTOR W/JACK	12	23.250	279.00	23.250	279.00	0.00	0.00	GET	018	007 60/50
UMXX	24 BUTTON CALL DIRECTOR W/JACK	1	19.000	19.00	19.000	19.00	0.00	0.00	GET	018	007 60/50
V1	KEY, 10 BUTTON, Rotary	53	7.150	378.95	7.150	378.95	0.00	0.00	GET	018	007 14/18

CAPITOL CENTREX
COMPARISON OF CURRENT SWB RATES VS RATES FILED JUN 21, 1982
DOCKET 4545
AS PROPOSED BY SWB

BILLING MONTH USED AS BASE -- MAY 82

			PROPOSED		-CURRENT-				REFERENCE		
OC	DESCRIPTION	QTY	RATE	COST	RATE	COST	DIFF	% CHG	TARIFF	SEC	SHEET
1	KEY, 10 BUTTON, TT	2025	7.500	15,187.50	7.500	15,187.50	0.00	0.00	GET	018	007 14/18
2	~~12~~ 30 BUTTON CALL DIRECTOR	446	11.400	5,084.40	11.400	5,084.40	0.00	0.00	GET	018	007 25/25
X	KEY, 6 BUTTON, Rotary	68	3.150	214.20	3.150	214.20	0.00	0.00	GET	018	006 12/10
X	KEY, 6 BUTTON, TT	4625	4.250	19,656.25	4.250	19,656.25	0.00	0.00	GET	018	006 12/10
G	COMKEY 1434, LINE EQUIP	8	3.900	31.20	3.900	31.20	0.00	0.00	GET	018	048 2/2
L	COMKEY 1434, TOUCHTONE EQUIP	1	14.500	14.50	14.500	14.50	0.00	0.00	GET	018	049 3/2
N	COMKEY 1434 PRIVACY PER SET	1	1.350	1.35	1.350	1.35	0.00	0.00	GET	018	~~047~~ 049 (049) 15/5
R	COMKEY 1434, RINGING OPTION	21	0.300	6.30	0.300	6.30	0.00	0.00	GET	018	049 4/5
V	COMKEY 1434, NIGHT TRANSFER	1	0.700	0.70	0.700	0.70	0.00	0.00	GET	018	049 2/2
7	BUTON PER PATH INTERCOM	1	23.500	23.50	23.500	23.50	0.00	0.00	GET	018	010 40/17
9	BUTTON PER PATH INTERCOM	1	20.250	20.25	20.250	20.25	0.00	0.00	GET	018	010 35/15
7	BUTTON PER PATH INTERCOM	1	26.850	26.85	26.850	26.85	0.00	0.00	GET	018	010 65/30
M	ICM, MANUAL, INC BUSY LAMP	11	5.750	63.25	5.750	63.25	0.00	0.00	GET	018	013 18/18
T	BUTTON PER PATH INTERCOM	3	11.750	35.25	11.750	35.25	0.00	0.00	GET	018	010 2/2
M	INTERPHONE LINE, MANUAL	119	2.550	303.45	2.550	303.45	0.00	0.00	GET	018	013 0/0
N	INTERCOM, MANUAL, 2 PT	22	3.000	66.00	3.000	66.00	0.00	0.00	GET	018	013 12.50/12.50
A	DIALOG ICM COMMON CONTROL	22	118.000	2,596.00	105.000	2,310.00	286.00	12.38	GET	018	095 250/200
CAL	DIALOG ICM CODES 30-54	20	12.250	245.00	12.250	245.00	0.00	0.00	GET	018	095 120/85
CAS	DIALOG ICM CODES 55-61	10	6.250	62.50	6.250	62.50	0.00	0.00	GET	018	095 40/30
D	DIALOG ICM STA UNIT-4 CODES	228	7.800	1,778.40	7.000	1,596.00	182.40	11.43	GET	018	095 75/65
E	DIALOG ICM ADD'L LINK PATH	21	6.000	126.00	5.750	120.75	5.25	4.35	GET	018	095 10/11
G	DIALOG ICM LIVE ACCESS UNIT	3	8.150	24.45	6.750	20.25	4.20	20.74	GET	018	095 15/14
H	DIALOG ICM TOUCH TONE REG	22	10.000	220.00	9.250	203.50	16.50	8.11	GET	018	095 [illegible]
37	COMMON SIGNAL POWER SUPPLY	4	5.500	22.00	5.500	22.00	0.00	0.00	GET	018	014 30/16

CAPITOL CENTREX
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			PROPOSED		-CURRENT-				REFERENCE			
OC	DESCRIPTION	QTY	RATE	COST	RATE	COST	DIFF	% CHG	TARIFF	SEC	SHEET	
4	CONFERENCE EQUIP	7	4.350	30.45	4.350	30.45	0.00	0.00	GET	018	010	50/20
6	CONFERENCE EQUIP, PBX	1	1.250	1.25	1.250	1.25	0.00	0.00	GET	018	010	35/16
V	STA BUSY LAMP CONT UNIT	563	3.100	1,745.30	3.100	1,745.30	0.00	0.00	GET	018	014	45/25
A	EXCLUSION, AUTO	1	4.600	4.60	4.600	4.60	0.00	0.00	GET	018	010	30/30
L	EXCLUSION, MANUAL	28	1.050	29.40	1.050	29.40	0.00	0.00	GET	018	010	30/11
X	AUTO CUTOFF	4	3.750	15.00	3.750	15.00	0.00	0.00	GET	018	010	20/20
	GET SECTION 018 SUB TOTAL			108,524.35		107,991.45	532.90					
M	25 FT MOUNTING CORD	1	1.500	1.50	1.500	1.50	0.00	0.00	GET	021	006	0/0
	OPERATOR HEADSET	1	5.350	5.35	5.350	5.35	0.00	0.00	GET	021	025	14/14
:A	OPERATOR HEADSET	47	5.350	251.45	5.350	251.45	0.00	0.00	GET	021	025	25/14
5C	ATTENDANT HEADSET W/QUICK DISCNT	1	5.750	5.75	5.750	5.75	0.00	0.00	GET	021	025	25/14
:D	SUPERVISOR HEADSET	2	7.000	14.00	7.000	14.00	0.00	0.00	GET	021	025	25/14
:S	OPERATOR HEADSET	10	8.750	87.50	8.750	87.50	0.00	0.00	GET	021	025	25/14
'B	NO. 7 BELL	17	2.350	39.95	2.350	39.95	0.00	0.00	GET	021	021	45/15
:X	TRANSFER KEY	385	2.900	1,116.50	2.900	1,116.50	0.00	0.00	GET	021	031	40/15
:5	TRANSFER KEY	20	5.600	112.00	5.600	112.00	0.00	0.00	GET	021	031	130/15
'B	PUSH BUTTON PAD, 4 BUTTON	26	2.750	71.50	2.750	71.50	0.00	0.00	GET	021	021	55/15
'C	PUSH BUTTON PAD, 8 BUTTON	6	3.200	19.20	3.200	19.20	0.00	0.00	GET	021	021	75/15
IR	EXTENSION RINGER, INDOOR	24	2.250	54.00	2.250	54.00	0.00	0.00	GET	021	021	50/20
RU	EXTENSION RINGER OUTDOOR	16	2.850	45.60	2.850	45.60	0.00	0.00	GET	021	021	55/25
9M	BUSY OUT ARRANGEMENT	3	3.400	10.20	3.400	10.20	0.00	0.00	GET	021	04B	65/10
	AMPLIFIER, OPERATOR HEADSET	10	1.900	19.00	1.900	19.00	0.00	0.00	GET	021	05A	5/5
TX	OPERATOR HEADSET	2	2.600	5.20	2.600	5.20	0.00	0.00	GET	021	025	25/0.

STATE OF TEXAS
STATE TELECOMMUNICATIONS SYSTEM

CAPITOL CENTREX
COMPARISON OF CURRENT SWB RATES VS RATES FILED JUN 21, 1982
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BILLING MONTH USED AS BASE -- MAY 82

			PROPOSED		-CURRENT-				REFERENCE		
OC	DESCRIPTION	QTY	RATE	COST	RATE	COST	DIFF	% CHG	TARIFF	SEC	SHEET
C	BELL CHIMES	1	1.100	1.10	1.100	1.10	0.00	0.00	GET	021	021 5/5
6	BELL, INDOOR	1	5.550	5.55	5.550	5.55	0.00	0.00	GET	021	022 50/15
N	SPEC BILLING NUMBER (GRP OF 50)	76	6.150	467.40	6.150	467.40	0.00	0.00	GET	021	020
Y	CL7 10 INCH OUTDOOR BELL	1	6.500	6.50	6.500	6.50	0.00	0.00	GET	021	022 11/11
T	PUSH BUTTON, INT	111	1.200	133.20	1.200	133.20	0.00	0.00	GET	021	021 8/15
T	PUSH BUTTON, EXT	203	1.650	334.95	1.650	334.95	0.00	0.00	GET	021	021 25/15
Z	BUZZER, INDOOR	128	1.200	153.60	1.200	153.60	0.00	0.00	GET	021	021 25/14
Z	BUZZER, OUTDOOR	375	1.850	693.75	1.850	693.75	0.00	0.00	GET	021	021 35/16
J	CHIME TONE	1	3.000	3.00	3.000	3.00	0.00	0.00	GET	021	021 35/14
Y	CHIMETONE, W/KEY SYSTEMS	19	3.000	57.00	3.000	57.00	0.00	0.00	GET	021	021 35/
M	AUTO DIAL EQUIP	20	2.600	52.00	2.600	52.00	0.00	0.00	GET	021	004 35/15
R	DELAYED RINGING CONT CKT	39	7.000	273.00	7.000	273.00	0.00	0.00	GET	021	012 36/36
B	EXT BELL W/O VOL CONT	1	2.400	2.40	2.400	2.40	0.00	0.00	GET	021	021 12/12
B	EXT BELL W/VOL CONT	24	2.500	60.00	2.500	60.00	0.00	0.00	GET	021	021 40/25
G	EXT GONG	2	1.200	2.40	1.200	2.40	0.00	0.00	GET	021	021 9/9
D	ELEVATOR TEL	38	8.700	330.60	8.000	304.00	26.60	8.75	GET	021	024 0/12.50
DBT	ELEVATOR TEL	6	8.700	52.20	8.700	52.20	0.00	0.00	GET	021	024 10/12.5
DXW	TEL, ELEVATOR	12	8.000	96.00	8.000	96.00	0.00	0.00	GET	021	024 0/12.50
R	TEL, ELEVATOR	12	6.750	81.00	6.750	81.00	0.00	0.00	GET	021	024 0/0
R	ELEVATOR TEL	1	7.350	7.35	7.350	7.35	0.00	0.00	GET	021	024 0/0
U	HANDSET, PUSH TO TALK	20	1.050	21.00	1.050	21.00	0.00	0.00	GET	021	030 0/0
2	HORN, INDOOR, KS16	3	4.100	12.30	4.100	12.30	0.00	0.00	GET	021	022 50/15
J	TRANSMITTER CONFIDENCER	26	1.950	50.70	1.950	50.70	0.00	0.00	GET	021	030 2
S	CONTROL IN HANDSET, WEAK SP TEL	4	1.200	4.80	1.200	4.80	0.00	0.00	GET	021	05A 0/0

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BILLING MONTH USED AS BASE -- MAY 82

			PROPOSED		-CURRENT-				REFERENCE			
OC	DESCRIPTION	QTY	RATE	COST	RATE	COST	DIFF	% CHG	TARIFF	SEC	SHEET	
1X1	HEADSET JACK 18 INCH CORD	1	4.050	4.05	4.050	4.05	0.00	0.00	GET	021	025	36/20
E	AUTO-CARD DIALER, 6 BUTTON	4	20.750	83.00	20.750	83.00	0.00	0.00	GET	021	003	12/12
ME6	AUTO-CARD DIALER, MULTILINE	2	9.250	18.50	9.250	18.50	0.00	0.00	GET	021	003	20/20
P	SPEAKERPHONE 3A, CALL DIRECTOR	2	12.500	25.00	12.500	25.00	0.00	0.00	GET	021	020	15/15
W	ONE BUTTON TEL	13	3.700	48.10	3.700	48.10	0.00	0.00	GET	021	028	0/0
WBG	ONE BUTTON TEL	1	3.100	3.10	3.100	3.10	0.00	0.00	GET	021	028	0/0
C	RELAY CONTROL EQUIP	9	3.100	27.90	3.100	27.90	0.00	0.00	GET	021	021	25/10
6	4 LAMP INDICATOR	2	3.050	6.10	3.050	6.10	0.00	0.00	GET	021	021	55/15
7	ONE LAMP INDICATOR	32	1.900	60.80	1.900	60.80	0.00	0.00	GET	021	021	40/15
	TYPE 21 LAMP SET	31	3.000	93.00	3.000	93.00	0.00	0.00	GET	021	021	35/15
D	LINE STATUS INDIC, 8 LINE	23	15.100	347.30	15.100	347.30	0.00	0.00	GET	021	045	79/79
S	LINE STATUS INDICATOR,16 LINE	7	23.400	163.80	23.400	163.80	0.00	0.00	GET	021	045	115/115
T	LINE STATUS INDIC, 32 LINE	11	38.500	423.50	38.500	423.50	0.00	0.00	GET	021	045	180/180
YVX	LINE STATUS INDIC, 12 LINE	4	19.500	78.00	19.500	78.00	0.00	0.00	GET	021	045	94/94
ZET	LINE STATUS INDIC, 24 LINE	1	31.800	31.80	31.800	31.80	0.00	0.00	GET	021	045	150/150
4BX	SPEAKERPHONE, DELUXE, ROTARY	1	18.750	18.75	18.750	18.75	0.00	0.00	GET	021	026	60/60
9	BUSY OUT ARRGMT, CONT EQ	3	18.350	55.05	18.350	55.05	0.00	0.00	GET	021	04B	0/10
Q	REMOTE ACCESS UNIT	3	52.000	156.00	52.000	156.00	0.00	0.00	GET	021	19E	/105
C	MULTI FUNCTION TEL	7	4.000	28.00	4.000	28.00	0.00	0.00	GET	021	11B	0/5
P	SPEAKERPHONE 4A	159	9.950	1,582.05	9.950	1,582.05	0.00	0.00	GET	021	020	75/35
V	LOUDSPEAKER 107A	7	4.300	30.10	4.300	30.10	0.00	0.00	GET	021	018	45/20
M	AUTO DIALER ATTCH, SPEAKERPHONE	16	1.450	23.20	1.450	23.20	0.00	0.00	GET	021	004	30/5
2	HEADSET JACK	21	4.050	85.05	4.050	85.05	0.00	0.00	GET	021	025	36/20
3	SPEAKERPHONE 3A	6	12.500	75.00	12.500	75.00	0.00	0.00	GET	021	020	15/15

CAPITOL CENTREX
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SOC	DESCRIPTION	QTY	PROPOSED RATE	PROPOSED COST	CURRENT RATE	CURRENT COST	DIFF	% CHG	REFERENCE TARIFF	REFERENCE SEC	REFERENCE SHEET	
RH	SIGNAL MAN RELAY	2	2.800	5.60	2.800	5.60	0.00	0.00	GET	021	05B	0/6
5JGT	TOUCH-A-MATIC 16#,NON BUTTON	1	14.350	14.35	14.350	14.35	0.00	0.00	GET	021	004	35/35
AJ	TOUCHMATIC 32 W/TT	12	19.350	232.20	19.350	232.20	0.00	0.00	GET	021	004	40/40
AJ	SIX BUTTON INST W/TOUCHMATIC ROT	3	21.500	64.50	21.500	64.50	0.00	0.00	GET	021	004	30/30
AJ	SIX BUTTON INST W/TOUCHMATIC TT	56	21.850	1,223.60	21.850	1,223.60	0.00	0.00	GET	021	004	30/30
AX	32 NUMBER ADJUNCT DIALER ROT	8	18.500	148.00	18.500	148.00	0.00	0.00	GET	021	004	30/30
AX	32 NUMBER ADJUNCT DIALER TT	190	18.850	3,581.50	18.850	3,581.50	0.00	0.00	GET	021	004	30/30
EL	SINGLE LINE INST TT	74	1.250	92.50	1.250	92.50	0.00	0.00	GET	021	028	0/0
IL	SINGLE LINE INST ROT	751	1.800	1,351.80	1.800	1,351.80	0.00	0.00	GET	021	028	0/0
F3	NOISY LOCATION TELEPHONE	2	1.600	3.20	1.600	3.20	0.00	0.00	GET	021	030	0/0
JE	TEL W/JACK IN BASE TT	2	4.300	8.60	4.300	8.60	0.00	0.00	GET	021	025	0/0
JEBC	TEL W/JACK IN BASE ROT	1	3.800	3.80	3.800	3.80	0.00	0.00	GET	021	025	0/0
IL	TRIMLINE TEL	1	2.900	2.90	2.900	2.90	0.00	0.00	GET	021	028	6.25/6.2
IL	TRIMLINE TEL	3	3.600	10.80	3.600	10.80	0.00	0.00	GET	021	028	6.25/6.2
N	TEL W/VOL CONTROL	71	0.650	46.15	0.650	46.15	0.00	0.00	GET	021	05A	0/0
N	TEL W/VOL CONTROL	1	1.200	1.20	1.200	1.20	0.00	0.00	GET	021	05A	0/0
33	EXT BELL W/VOL CONT & CUTOFF	6	2.650	15.90	2.650	15.90	0.00	0.00	GET	021	021	40/25
	GET SECTION 021 SUB TOTAL			15,034.25		15,007.65	26.60					
												no change
3Y	PAGING AMP, 35 WATT	5	10.500	52.50	10.500	52.50	0.00	0.00	GET	022	006	
YG	SPEAKER, WALL MOUNTED	12	2.800	33.60	2.800	33.60	0.00	0.00	GET	022	006	
D	AMPLIFIER, 100 WATT	1	14.300	14.30	14.300	14.30	0.00	0.00	GET	022	006	
O	SPEAKER, PAGING	7	3.250	22.75	3.250	22.75	0.00	0.00	GET	022	006	
0	SPEAKER, CEILING MOUNTED	22	2.600	57.20	2.600	57.20	0.00	0.00	GET	022	006	

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OC	DESCRIPTION	QTY	RATE	COST	RATE	COST	DIFF	% CHG	TARIFF	SEC	SHEET
T	SPEAKER, INDOOR/OUTDOOR HORN	14	3.350	46.90	3.350	46.90	0.00	0.00	GET	022	006
X	SPEAKER, BI-DIRECTION	1	5.600	5.60	5.600	5.60	0.00	0.00	GET	022	006
D	PAGING SYSTEM, ACCESS ARRGMT	2	4.200	8.40	4.200	8.40	0.00	0.00	GET	022	006
F	HORIZON, DIALOG, ACCESS ARRGMT	3	7.000	21.00	7.000	21.00	0.00	0.00	GET	022	006
	GET SECTION 022 SUB TOTAL			262.25		262.25	0.00				
Z	SVC OBS EQUIP JACK	1	0.450	0.45	0.450	0.45	0.00	0.00	GET	030	003
	GET SECTION 030 SUB TOTAL			0.45		0.45	0.00				
	CONCEN IDENT BRIDGE CHARGE	29	6.300	182.70	6.300	182.70	0.00	0.00	GET	036	005
	GET SECTION 036 SUB TOTAL			182.70		182.70	0.00				
M	TT INTERCOM COMM EQUIP 2 LINK	65	18.500	1,202.50	18.500	1,202.50	0.00	0.00	GET	037	002(018)
P	TT INTERCOMM COMM EQUIP 1 LINK	292	18.500	5,402.00	18.500	5,402.00	0.00	0.00	GET	037	002(018)
S	TT ITERCOM COMM EQ 20/40 DIAL PK	7	25.900	181.30	25.900	181.30	0.00	0.00	GET	037	002(018)
	GET SECTION 037 SUB TOTAL			6,785.80		6,785.80	0.00				
V	DATA SET 201C	7	69.000	483.00	69.000	483.00	0.00	0.00	GET	039	04A 150/100
P08	DATA SET 100 SERIES 300 BPS	1	20.750	20.75	20.750	20.75	0.00	0.00	GET	039	002 120/65
Z	DATA SET 100 SERIES	1	15.000	15.00	15.000	15.00	0.00	0.00	GET	039	002 25/25
C01	DATA SET 800 SERIES	1	43.000	43.00	43.000	43.00	0.00	0.00	GET	039	009 25/25
O	DATA SET 100 SERIES, 103J	7	32.500	227.50	32.500	227.50	0.00	0.00	GET	039	004 120/65
6	DATA SET 100 SERIES 300 BPS	8	27.000	216.00	27.000	216.00	0.00	0.00	GET	039	002 25/25

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OC	DESCRIPTION	QTY	RATE	COST	RATE	COST	DIFF	% CHG	TARIFF	SEC	SHEET
	GET SECTION 039 SUB TOTAL			1,005.25		1,005.25	0.00				
	GET TOTAL			197,743.70		194,126.90	3,616.80	1.86			
EHC	SPCL ASSEMBLY	1	19.700	19.70	19.700	19.70	0.00	0.00	0000	000	000
ETS	SPCL ASSEMBLY	1	189.600	189.60	189.600	189.60	0.00	0.00	0000	000	000
ETS	SPCL ASSBLY	2	31.500	63.00	31.500	63.00	0.00	0.00	0000	000	000
ETS	SPCL ASSEMBLY	1	240.500	240.50	240.500	240.50	0.00	0.00	0000	000	000
ETS	SPCL ASSEMBLY	1	290.000	290.00	290.000	290.00	0.00	0.00	0000	000	000
ETS	SPCL ASSEMBLY	1	310.000	310.00	310.000	310.00	0.00	0.00	0000	000	000
ETS	SPCL ASSEMBLY	1	330.000	330.00	330.000	330.00	0.00	0.00	0000	000	000
ETS	SPCL ASSEMBLY	1	342.000	342.00	342.000	342.00	0.00	0.00	0000	000	000
ETS	SPCL ASSEMBLY	1	404.650	404.65	404.650	404.65	0.00	0.00	0000	000	000
EUP	SPCL ASSEMBLY	1	280.800	280.80	280.800	280.80	0.00	0.00	0000	000	000
EVP	SPCL ASSEMBLY	1	165.000	165.00	165.000	165.00	0.00	0.00	0000	000	000
EVP	SPCL ASSEMBLY	1	165.600	165.60	165.600	165.60	0.00	0.00	0000	000	000
EVP	SPCL ASSEMBLY	1	210.000	210.00	210.000	210.00	0.00	0.00	0000	000	000
EVP	SPCL ASSEMBLY	1	221.750	221.75	221.750	221.75	0.00	0.00	0000	000	000
EVP	SPCL ASSEMBLY	1	273.600	273.60	273.600	273.60	0.00	0.00	0000	000	000
Z	SPCL ASSEMBLY	7	2.500	17.50	2.500	17.50	0.00	0.00	0000	000	000
Z	SPCL ASSEMBLY	2	5.900	11.80	5.900	11.80	0.00	0.00	0000	000	000
Z	SPCL ASSEMBLY	1	6.200	6.20	6.200	6.20	0.00	0.00	0000	000	000
Z	SPCL ASSEMBLY	1	10.450	10.45	10.450	10.45	0.00	0.00	0000	000	000
Z	SPCL ASSEMBLY	1	12.250	12.25	12.250	12.25	0.00	0.00	0000	000	000

CAPITOL CENTREX
COMPARISON OF CURRENT SWB RATES VS RATES FILED JUN 21, 1982
DOCKET 4545
AS PROPOSED BY SWB

BILLING MONTH USED AS BASE -- MAY 82

OC	DESCRIPTION	QTY	PROPOSED RATE	PROPOSED COST	-CURRENT- RATE	-CURRENT- COST	DIFF	% CHG	REFERENCE TARIFF	REFERENCE SEC	REFERENCE SHEET
Z	SPCL ASSEMBLY	3	17.300	51.90	17.300	51.90	0.00	0.00	0000	000	000
Z	SPCL ASSEMBLY	1	17.950	17.95	17.950	17.95	0.00	0.00	0000	000	000
Z	SPCL ASSEMBLY	2	19.700	39.40	19.700	39.40	0.00	0.00	0000	000	000
Z	SPCL ASSEMBLY	1	29.100	29.10	29.100	29.10	0.00	0.00	0000	000	000
Z	SPCL ASSEMBLY	1	41.650	41.65	41.650	41.65	0.00	0.00	0000	000	000
Z	SPCL ASSEMBLY	1	187.200	187.20	187.200	187.20	0.00	0.00	0000	000	000
Z	SPCL ASSEMBLY	1	220.800	220.80	220.800	220.80	0.00	0.00	0000	000	000
Z	SPCL ASSEMBLY	2	228.000	456.00	228.000	456.00	0.00	0.00	0000	000	000
Z	SPCL ASSEMBLY	1	330.000	330.00	330.000	330.00	0.00	0.00	0000	000	000
	0000 SECTION 000 SUB TOTAL			4,938.40		4,938.40	0.00				
	0000 TOTAL			4,938.40		4,938.40	0.00	0.00			
SE	INX ADD'L PT OF TERM SAME BLDG	18	1.500	27.00	1.500	27.00	0.00	0.00	PLST	001	13A(002)
	PLST SECTION 001 SUB TOTAL			27.00		27.00	0.00				
.3QR	INX LOCAL CHNL 1ST 1/4 TYPE 101	68	6.600	448.80	4.400	299.20	149.60	50.00	PLST	002	002 140/30
.3QR	INX LOCAL CHNL ADD'L 1/4 TYPE101	13	3.600	46.80	2.400	31.20	15.60	50.00	PLST	002	002 0/0
.6RY	CTX ATT CONS DATA LK TYPE 323	1	10.950	10.95	10.950	10.95	0.00	0.00	PLST	002	011 190/60
.6RY	CTX ATT CONS DATA LK TYPE 323	0	4.700	0.00	4.700	0.00	0.00	0.00	PLST	002	011 0
.HV4	IXC SCHED 2 < 200 QTR	224	0.850	190.40	0.950	212.80	-22.40	10.53	PLST	002	016 0
HV4	IXC SCHED 2 201-600 QTR	0	0.600	0.00	0.600	0.00	0.00	0.00	PLST	002	016 0
4	IXC SHCED 2 > 600 QTR	0	0.450	0.00	0.350	0.00	0.00	0.00	PLST	002	016 0
LLAY	IXC LCL CHNL 1ST TER TYPE 315	2	4.000	8.00	3.300	6.60	1.40	21.21	PLST	002	015 260/60

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OC	DESCRIPTION	QTY	PROPOSED RATE	PROPOSED COST	CURRENT RATE	CURRENT COST	DIFF	% CHG	REFERENCE TARIFF	REFERENCE SEC	REFERENCE SHEET
LAY	IXC LCL CHNL 1ST TER TYPE 315	34	2.650	90.10	2.650	90.10	0.00	0.00	PLST	002	015 0/0
LBE	INX LCL CHNL ON PREM EXT	2	0.750	1.50	0.750	1.50	0.00	0.00	PLST	002	013 0/0
LBM	INX LCL CHNL W/PASSAGE TYPE 315	705	7.400	5,217.00	1.600	1,128.00	4,089.00	62.50	PLST	002	012 260/30
LBR	SVC BTN BLDG < 1MI TYPE 315	2116	8.400	17,774.40	5.600	11,849.60	5,924.80	50.00	PLST	002	011 260/30
LBS	INX INTEROFC CHNL	4789	0.450	2,155.05	1.250	5,986.25	-3,831.20	64.00	PLST	002	012 0/0
LJR	SVC BTN BLDG < 1MI TYPE 315	525	4.800	2,520.00	3.100	1,627.50	892.50	54.84	PLST	002	011 0/0
LJY	INX LCL CHNL 1ST TER TYPE 312	132	6.250	825.00	5.700	752.40	72.60	9.65	PLST	002	011 185/30
LJY	INX LCL CHNL 1ST TER TYPE 312	735	2.500	1,837.50	2.500	1,837.50	0.00	0.00	PLST	002	011 0/0
LRY	INX LCL CHNL 1ST TER TYPE 315	421	4.000	1,684.00	3.300	1,389.30	294.70	21.21	PLST	002	011 260/60
LRY	INX LCL CHNL 1ST TER TYPE 315	2351	2.650	6,230.15	2.650	6,230.15	0.00	0.00	PLST	002	011 0/0
LSR	SVC BTN BLDG < 1MI TYPE 311	3	4.800	14.40	3.200	9.60	4.80	50.00	PLST	002	011 0/0
LUR	SVC BTN BLDG < 1MI TYPE 311	31	8.400	260.40	5.600	173.60	86.80	50.00	PLST	002	011 195/30
MCE	INX LCL CHNL DIFF BLDG SM PREM	0	0.750	0.00	0.750	0.00	0.00	0.00	PLST	002	003(000) 0/0
MCE	INX LCL CHNL (MINIMUM	2	3.000	6.00	3.000	6.00	0.00	0.00	PLST	002	003 75/30
MCR	INX LCL CHNL TYPE 101A	3	6.600	19.80	4.400	13.20	6.60	50.00	PLST	002	002 140/30
MCR	INX LCL CHNL TYPE 101A	0	3.600	0.00	2.400	0.00	0.00	0.00	PLST	002	002 0/0
PAY	INX LCL CHNL 1ST TER TYPE 311	2	4.800	9.60	4.800	9.60	0.00	0.00	PLST	002	011 195/30
PAY	INX LCL CHNL 1ST TER TYPE 311	0	2.400	0.00	2.400	0.00	0.00	0.00	PLST	002	011 0/6
PJE	INX LCL CHNL DIFF BLDG SM PREM	0	0.750	0.00	0.750	0.00	0.00	0.00	PLST	002	013 0/0
PJE	INX LCL CHNL (MINIMUM)	11	3.000	33.00	3.000	33.00	0.00	0.00	PLST	002	013 85/30
PJM	INX LCL CHNL W/PASSAGE	4	7.400	29.60	3.200	12.80	16.80	31.25	PLST	002	012 195/30
PJR	SVC BTN BLDG < 1MI TYPE 311	32	8.400	268.80	5.600	179.20	89.60	50.00	PLST	002	011 195/30
PJR	SVC BTN BLDG < 1MI TYPE 311	7	4.800	33.60	3.200	22.40	11.20	50.00	PLST	002	011 0/0
PJS	INX INTEROFC CHNL	0	0.450	0.00	1.250	0.00	0.00	0.00	PLST	002	013(002) 0/0

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			PROPOSED		-CURRENT-				REFERENCE		
OC	DESCRIPTION	QTY	RATE	COST	RATE	COST	DIFF	% CHG	TARIFF	SEC	SHEET
.VBR	SVC BTN PREM < 1MI TYPE 312	1	7.450	7.45	4.950	4.95	2.50	50.51	PLST	002	011(11A) 185/30
.VBR	INX SVC BTN PRM<1 MI TYPE 312	5	4.080 4.80	20.40	3.100	15.50	4.90	31.61	PLST	002	011(11A) d/o
'H	INX 2 PT SVC SAME BLDG	108	3.000	324.00	3.000	324.00	0.00	0.00	PLST	002	13A 85/30
E	INX ADD'L PT OF TERM SAME BLDG	27	1.500	40.50	1.500	40.50	0.00	0.00	PLST	002	013 70/0
NFS	INX INTER OFC CHNL TERM TYP FSO	806	10.500	8,463.00	0.000	0.00	8,463.00	0.00	PLST	002	012 0/0
	PLST SECTION 002 SUB TOTAL			48,570.20		32,297.40	16,272.80				
821	DATA SET 200 SERIES	1	135.000	135.00	135.000	135.00	0.00	0.00	PLST	003	12A 140/10
AWO	SIGNALING, INX W/O INTEROFC CHNL	320	5.250	1,680.00	4.800	1,536.00	144.00	9.38	PLST	003	025 75/10
	PRIVATE LINE INST	4	3.000	12.00	3.000	12.00	0.00	0.00	PLST	003	029 35/30
	PLST SECTION 003 SUB TOTAL			1,827.00		1,683.00	144.00				
	PLST TOTAL			50,424.20		34,007.40	16,416.80	48.27			
	GRAND TOTAL			253,106.30		233,072.70	20,033.60	8.60			

MULTIPLEXER VS. PACKET SWITCH

APPENDIX L

DATA ALTERNATIVE COMPARISON

This appendix provides a first-order cost comparison of the two alternatives for the backbone data network. Common equipment will not be included, i.e. multiplexers/concentrators at customers' premises * . The trade-off between alternatives is in data communications equipment (time division multiplexers (TDM) and packet switches) and transmission bandwidth. For both cases, 50% utilization is assumed at the access line level, using multiplexers or multi-point or cluster controller configurations. The packet switch provides more efficient net trunk bandwidth utilization (90%) than the time division multiplexer does (no utilization benefit beyond that provided on the "access lines"), while the packet switch is much more expensive than the multiplexer. The heaviest data traffic link, Austin-Dallas, was selected for comparison, because it is where the packet switch most possibly will prove in. The 1989 expected data circuits, derived from throughput requirements between Austin and Dallas (Section 3.3.2), are:

(1) Access lines (9.6 kbps) through the network: 190 (shown in Table 3.22);

(2) No trunk circuits required for the TDM multiplexer, because the output is a DS-1 signal which feeds into the muldem (which in turn combines DS-1 signals to a DS-3 signal). Since data traffic is small, the multiplexing technique may at most require one more DS-1 channel than that for a packet switch. The cost of one additional DS-1 channel is negligible for this study (approximate $900).

(3) Trunks (56 kbps) for packet network: 15, based on the throughput requirements, shown in Table 3.18, and 90% utilization factor, i.e.,

(911.0 x 90%) / 56 = 15.

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* In the packet network environment, if the existing multiplexers/concentrators are not compatible with the packet network, either they have to be replaced by the packet network vendors' equipment or the vendors have to customize their equipment to provide compatibility.

Packet Switch Cost

The following cost parameters are based on generic product pricing for existing packet switches:

(1) Start-up cost: $96K.

(2) 9.6 kbps line: $1,375.

(3) 56 kbps trunk: $6K.

The cost parameters for the channel banks are:

(1) Basic: $1,600 including installation;

(2) 56 kbps port: $650.

The cost for the Austin-Dallas link included the cost of a Dallas packet switch, the cost of Dallas-Austin transmission channels, and a portion of the Austin packet switch. The Austin switch was allocated according to the number of trunk terminations on it from the Dallas node relative to all of its trunk terminations, i.e.,

$96K x (190/544) = $33.5K.

For simplicity in calculating the packet switch cost, it is assumed that all of the Dallas-Austin traffic has Austin and Dallas as source/termination. (76% of Austin-Dallas data traffic is direct traffic based on the traffic requirements, shown in Tables 3.14 and 3.16, i.e., 148.1/195.5.) This assumption provides a lower bound packet network cost, because otherwise the start-up costs of switches at other locations should be allocated for this data traffic.

The allocated channel bank cost is

($1600 / 23) + $650 = $719.6.

The costs for the packet switches and channel banks at Dallas and Austin are:

	Packet Switch ($K)	Channel Banks ($K)	Total ($K)
Dallas	447.3	10.8	458.1
Austin (allocated)	384.8	10.8	395.6
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Total	832.1	21.6	853.7

Multiplexer Cost

The cost parameters for a generic TDM are:

(1) multiplexer from 9.6 kbps to up to 256 kbps:

(a) basic unit (22 input channels): $9,770;

(b) extension unit (16 incremental channels): $4,480;

(c) per channel additional cost: $410.

(2) T1 multiplexer:

(a) basic unit (up to 22 channels): $12,470;

(b) extension unit (16 incremental channels): $4,480;

(c) per channel additional cost: $410.

A cost-effective way to engineer the multiplexers is:

(1) Fill a T1 multiplexer as much as possible (up to 49 channels so that five low-speed multiplexers can be cascaded to it for input channel expansion).

(2) Fill low speed multiplexer basic units. This simplifies the engineering procedure. In addition, the extension unit is not very efficient for the case in which all access channels are 9.6 kbps (Only eight channels can be filled in the extension unit compared to its 16-channel capacity).

The through traffic (46 - 9.6 kbps circuits, which is 24% of the total 190 circuits) originating at other source locations requires demultiplexing and multiplexing at Austin. The multiplexer cost for other source locations is calculated based on the allocated cost for T1 multiplexer, i.e.,

($12,470/22) + $410 = $977.

The costs for the TDM's at Dallas, Austin and other locations for the Dallas-Austin traffic are:

	TDM ($K)
Dallas	167.2
Austin	212.1
Others	44.9

Total	424.2

Conclusion

TDM is a much more cost-effective technique than packet switching to provide data transport on the backbone network. This is not surprising, because the major advantage of a packet switch is providing a switching function, which is not used in the STS data network. For data transport purposes, TDM is a much more reasonable approach. In addition, TDM is transparent to protocols, while a packet switch is not. Additional cost may be required in fitting a packet network to the existing customers' equipment.

MICROWAVE PATH CHECKS

APPENDIX M

COMPUCON, INC.
13749 Neutron Road, P.O. Box 401229
Dallas, Texas 75240 214/233-4380

November 11, 1982

BNR, Inc.
685A East Middlefield Road
Mountain View, CA 94043
Attention: Mr. Ken Myers

Subject: State of Texas Communications Study
Compucon Job Number 2306-2684

Dear Mr. Myers:

This letter is in responce to BNR's contract with Compucon regarding Communication Engineering Services outlined in Compucon's proposal dated October 29, 1982.

I. Feasibility of ingress/egress from selected locations

The following locations in Dallas, Austin, San Antonio and Houston were used to perform preliminary frequency engineering in the microwave industrial bands.

City	Latitude(N)	Longitude(W)	AMSL(*)(ft)	AGL(**)(ft)
Dallas	32° 48' 20"	95° 50' 18"	450	60
Austin	30° 16' 44"	97° 44' 18"	535	60
San Antonio	29° 22' 56"	98° 34' 31"	1020	60
Houston	29° 48' 17"	95° 27' 00"	75	60

(*) = Ground Elevation
(**) = Antenna Center Line

The above coordinates correspond to the selected site's addresses provided to me by Mr. Ken Myers over the phone.

In conducting the frequency congestion studies to determine the feasibility of ingress/egress at the chosen locations, hypothetical paths were constructed. The radio equipment, antennas, and associated data concerning radiated power, antenna gain, loading, etc., used in the models were those typical for the industrial bands.

1. From Dallas, probe of the 6 GHz band (6.525 - 6.875 GHz) indicates availability of at least 2 pairs of frequencies, both vertical and horizontal polarization, in the Austin direction.

2. From Austin, the study shows there are no paired frequencies available in the 6 GHz band in the Dallas and San Antonio direction. Some unpaired frequencies are available. It may be possible to clear more frequencies when more detailed frequency engineering is done using the actual (not hypothetical) components of the path. An alternative would be to use the 12 GHz industrial band for the first hop coming out of Austin. Because the 12 GHz industrial band may be displaced in the future due to direct broadcast satellite, the radios need to be tunable from 12.2 to 13.250.

   In the Abilene-Lubbock direction, preliminary analysis shows one pair of frequencies available in the 6 GHz band and some unpaired frequencies in the same band. In the Houston direction we found 2 paired frequencies available in the 6 GHz band.

3. From San Antonio in direction to Austin, we found one pair of frequencies in the 6 GHz band which can be used with either horizontal or vertical polarization. In the Harlingen direction, two paired frequencies - horizontal polarization - are available in the 6 GHz band. Some unpaired frequencies can possibly be used also.

4. The Houston area looks rather congested in the 6 GHz band. No available frequencies were found for the Houston - Austin direction. Nevertheless, with the use of high performance horn antennas, it might be possible to come in and out of Houston in this band.

   Another alternative would be to come in and out of Houston using 12 GHz radios for the first hop, and 6 GHz radios for the remaining of the path.

II. <u>Estimate of approximate number of hops per path</u>

The preliminary map study conducted for the proposed microwave system shows the following estimates of number of hops needed for each path:

1.	Austin to Dallas:	11 hops ± 2
2.	Austin to Houston:	9 hops ± 2
3.	Austin to Lubbock:	19 hops ± 2
4.	Austin to Harlingen:	17 hops ± 2

In doing the estimation of the number of hops for each path, we made the following assumptions:

1. The typical length of the hop would be between 15 and 25 miles, a rather conservative assumption to achieve high path reliability at 6 GHz. For the 12 GHz band, path length criteria would be less than 15 miles.

2. The typical location of each repeater would be such that it would not produce intra-system interference. To do the preliminary site selection, U.S. Geological Survey maps, scale 1:250,000 were used.

3. The ± 2 hops variance allowance is necessary to accomodate terrain variations which may appear when doing the more detailed final site selection, and to avoid high-low frequency violations.

4. Preliminary terrain availability considerations were also made in planning the necessary number of hops - this was also a determining factor in choosing the 15 to 25 miles limit per hop.

III. Impact of adding drop/inserts at selected locations

The following is a summary of the impact that might be caused by adding drop/insert repeaters at selected locations:

1. Austin to Dallas: Adding a drop at Waco will have no impact on the design of this path unless the selected site in Waco is blocked by buildings or in low terrain, in which case an extra hop would be needed.

   In order to have drops at Temple, Belton and Killeen it would be necessary to add a spur which would add two hops to this path.

   Corsicana would also require a spur which would add one hop to this path.

2. Austin to Houston: To serve College Station, a spur could be used or the path could be designed to go through College Station. In either case, 2 extra hops would be needed for a total of 11 $\pm$ 2 hops.

3. Austin to Lubbock: Adding drops at Abilene and Brownwood would have no effect in the number of hops for this path unless the selected sites in Abilene and Browswood are in low terrain or blocked by buildings.

4. Austin to Harlingen: Introducing drop/inserts at Corpus Christi, Kingsville and San Antonio in this route will increase the number of hops to 19 $\pm$ 2. If only San Antonio is chosen to have drop/insert, this could be done with a spur of one hop, for a path total of 18 $\pm$ 2 hops. If only Corpus Christi is chosen to have drops, it could be done with a spur of one hop. If only Kingsville is chosen, there will be no impact on the number of hops for the path.

If you have any questions regarding this preliminary report, please do not hesitate to call me.

Sincerely,

Gerardo Mejia
Communications Systems Engineer
Network Management Services

GM/ctg