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NATIONAL VOICE RESPONSE SYSTEM (VRS) IMPLEMENTATION PLAN ALTERNATIVES STUDY

U.S. DEPARTMENT OF TRANSPORTATION
RESEARCH AND SPECIAL PROGRAMS ADMINISTRATION
Transportation Systems Center
Cambridge MA 02142

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16. Abstract

This study examines the alternatives available to implement a national Voice Response System (VRS) for automated preflight weather briefings and flight plan filing. Four major hardware configurations are discussed. A computerized analysis model was developed and used to determine relative merits, costs, and sensitivities of key factors such as centralized vs. decentralized networks, demand levels, average call duration, partial implementation, fail-soft operations, WATS vs. FX telephone service, VRS channel sizing and projected demand growth.

The study shows that excessive communication costs predominated the centralized configuration alternatives. The minimum cost system, which is also the recommended one, is a distributed processor configuration with 20 Data Base Processor sites and 134 VRS sites.

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PREFACE

The Federal Aviation Administration (FAA) is currently implementing a program to modernize and automate the Flight Service Station (FSS) system through the application of high-speed data communications and computer processing techniques. The new system is called the Flight Service Automation System (FSAS) and will incorporate the concept of Direct User Access which allows the pilot to directly communicate with the aeronautical and weather data base.

One concept under consideration for Direct User Access is the use of a computer-generated voice response system (VRS) for disseminating weather products and filing flight plans. The report presented herein was prepared by the Office of Air and Marine Systems of the Transportation Systems Center (TSC) for the FAA. It presents the results of a study performed by TSC to define the national VRS operational needs and to provide design alternatives with respect to cost and service for implementing the VRS Direct User Access Concept in the FSAS.

The work reported herein, under the direction of M. F. Medeiros, was performed by the TSC staff with programming support from S. Pergola and C. Schweinhart of Kentron International LTD. J. Sigona was lead technical person in the VRS specification development, J. Richards in estimating user demand, H. Glynn in alternative design considerations, I. Englander in communication network analysis, R. Wright in computerized model development, G. Wang in trade-off analysis. This work could not be accomplished without the advice and assistance of V. Constantino, C. Weigel, E. VanVlaanderen and C. Murray of ARD-441. In addition, the superlative quality of the typing and editing in this report was due to the effort of Elaine Grandoit of the Automation Branch.

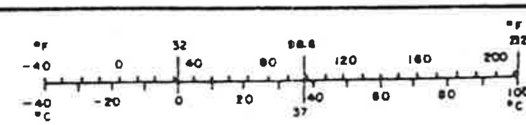
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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LIST OF ACRONYMS AND ABBREVIATIONS

ADPCM	Adaptive Differential Pulse Code Modulation
ARTCC	Air Route Traffic Control Center
AT&T	American Telephone & Telegraph Company
AWP	Aviation Weather Processor
AWW	Alert Weather Watch
CARF	Central Altitude Reservation Facility
DAA	Direct Access Arrengement
DBP	Data Base Processor
DUAT	Direct User Access Terminals
EPROM	Erasable PROM
FAA	Federal Aviation Administration
FDC	Flight Data Center
FPF	Flight Plan Filing
FSAS	Flight Service Automation System
FSDPS	Flight Service Data Processing System
FSS	Flight Service Station
FX	Foreign Exchange
FY	Fiscal Year
ID	Identification
IFR	Instrument Flight Rules
LDM	Linear Delta Modulation
LPC	Linear Predictive Coding
MTBF	Mean Time Between Failures
MTTR	Mean Time To Restore
NADIN	National Airspace Data Interchange Network
NAFEC	National Aviation Facilities Experimental Center
NAS	National Airspace System
NDRO	Non-Destructive Readout
NOTAM	Notice to Airmen
PATWAS	Pilot Automatic Telephone Weather Answering Service
PCM	Pulse Code Modulation
PIREP	Pilot Report of Weather Conditions

LIST OF ACRONYMS AND ABBREVIATIONS (Continued)

PROM	Programmable Read Only Memory
RAM	Random Access Memory
ROM	Read Only Memory
SIGMET	Significant Meteorological Information
SP	Special Surface Weather Observation
SW	Supplementary Surface Weather Observation
SYNS	Synopsis
TSC	Transportation Systems Center
TWEB	Transcribed Weather Broadcast Route Forecast
U.S.	United States
USP	Urgent Special Surface Weather Observation
UUA	Urgent Pilot Report
UWS	Urgent SIGMET Message
VFR	Visual Flight Rules
VOR	Very High Frequency Omni Directional Radio Range
VRS	Voice Response System
WATS	Wide Area Telecommunications Service
WFT	Terminal Forecast Message
WFT AMD	Aviation Terminal Forecast Amendment
WFT COR	Aviation Terminal Forecast Correction
WGF	Grid Winds Forecast Message
WMSC	Weather Message Switching Center
WSA	Surface Aviation Weather Observation
WSO	Severe Weather Outlook Message
WUA	Pilot Report Message
WW	Severe Weather Forecasts, Bulletins, and Status Reports
WWA	AIRMET Message
WWH	Hurricane Advisories
WWS	SIGMET Message

EXECUTIVE SUMMARY

This study was commissioned to examine the alternatives available to pursue a national implementation of an automated preflight briefing Voice Response System (VRS) plan for Flight Service Station (FSS) Automation. In order to phase this study with the Model I FSS automation development, the study was scoped to be completed within six months. Initially, VRS functional requirements were developed and user demand analyzed. This report presents six national implementation alternative networks. Four major hardware configurations are discussed. A computerized analysis model was developed and used to determine relative merits, costs, and sensitivities of key factors such as centralized versus decentralized networks, demand levels, average call duration, partial implementation, fail-soft operations, long distance telephone rate tariffs, WATS versus FX telephone circuit approaches, VRS channel sizing and projected demand growth effects.

The study showed that excessive communication costs predominated the centralized configuration alternatives. The study recommended that the requirement for voice recognition capability be waived in the initial implementation due to high equipment costs. The availability of economical tone input equipment provides a reliable input capability for the functions required. The resulting minimum cost system based upon a ten-year equipment amortization and including communication, operational and maintenance costs was a decentralized, distributed processor configuration with 20 Data Base Processor (DBP) sites co-located with (or integrated into) the FSDPS installations at the 20 ARTCC's and with 134 telephone answering and servicing sites (VRS sites, 20 of which are at the DBP sites). These VRS sites would be co-located at FSS facilities and would require minimum operator attention and simple facility accommodations. This alternative configuration proved to be minimal in total system cost for both FX/TELPAK and FX/AT&T rates). The services to be provided covered pilot briefings, flight plan entry, PATWAS, TEL-TWEB and TWEB functions common to today's FSS's. The level of service demand growth to 1995 examined shows linear predictable consistencies.

The conclusions and recommendations support the minimum cost configuration for a national VRS implementation.

1. INTRODUCTION

1.1 Background

A pilot preflight weather briefing is an essential part of planning a safe flight. The desire for increased capacity, rapid access and updating of essential aviation weather products has prompted the U.S. Department of Transportation, Federal Aviation Administration (FAA), to embark on a program to automate the Flight Service Stations through the application of high-speed data communications and computer processing techniques. The new system, called the Flight Service Automation System (FSAS), will be established in a time-phased development program producing Model 1, Model 2, and Model 3, with increasing systems automation and pilot self-service capability.

One future system enhancement considered for Model 3 implementation is the use of a computer generated voice response system (VRS) for disseminating weather products and automating flight plan filing. Using the Adaptive Differential Pulse Code Modulation (ADPCM) technique for voice encoding, the Transportation Systems Center (TSC), also of the U.S. Department of Transportation, has developed such a VRS which is currently being publicly tested in the greater Washington D.C. area. Responses from user pilots are so positive that the FAA is considering an earlier implementation of an operational VRS before the Model 3 time frame. TSC has been asked by the FAA to conduct a National VRS Implementation Plan Alternatives Study to define the VRS operational needs and to analyze national VRS system configurations. The recommendations and conclusions of the study will provide a basis for the FAA to establish its final National VRS Implementation plan.

1.2 Approach

Although many technical and operational questions have to be addressed before the final national voice response system can be realized, this study is intended to address the major aspects in implementing a national VRS capability. The study focuses on a number of critical issues such as the most promising VRS alternative configurations designed to satisfy future pilot demand, the potential communication networks, and the associated cost trade-offs. Where necessary, expedient decisions and assumptions will be made in order to avoid excessive effort in details which have low order effects on the alternative trade-offs. The study results produced should aid the FAA in narrowing the field of alternatives upon which their implementation plan can be based.

Prior to commencing the study effort, a survey of current documentation relative to the Flight Service Station (FSS) automation program was conducted to gather applicable data for consideration in this study. Then, a number of parallel but related activities were carried out. These activities are: (1) Functional Requirement Determination, (2) Pilot Briefing Demand Forecast Analysis, (3) VRS Alternative Configurations Development, (4) Communications Network Analysis, and (5) System Trade-off Analysis. Each of these activities will be addressed in subsequent sections in this report. The last section summarizes the results from all activities into a set of conclusions and recommendations.

1.3 VRS Operational Overview

In order to develop a good understanding of the operational functions involved in configurations studied in this report, a brief scenario of pilot interactions, system responses and system support activities is required. There are three categories of service envisioned for this Voice Response System (VRS). The first is a selected weather, preflight briefing service. The second is a mass weather dissemination service combining the Pilot Automatic Telephone Weather Answering Service (PATWAS) and Transcribed Weather Broadcast Route Forecast (TWEB). The last is a telephone flight plan entry service based upon using voice or push-button telephone input mode. In addition to these automated services, the pilot can elect to receive the services of an FSS specialist at any time. Although push-button and voice data entry are envisioned in the operational concept, the latter entry mode may be limited in scope or unavailable until voice recognition has become a cost competitive and feasible mode of data entry.

Let's examine in a hypothetical case the selected weather service first. A pilot would call a common telephone number for access to the three services discussed above. This number is dedicated to the automated services and is not the same as the local Flight Service Station specialist telephone number, although it is located at the FSS. The automated system will utilize as many lines, through a normal hunting telephone service, as is needed to satisfy the peak-hour demand forecasted for the combined automated service at the FSS. When the computer system, located at the FSS or remotely, answers the caller, it will announce the time and an introductory message offering the three services. The pilot selects the selected weather preflight briefing mode by entering the proper voice or push-button command. The specific protocol for selecting the weather products will most likely have two modes, a prompted mode and a brief mode. The prompted mode is similar to the present VRS demonstration system, asking for each input in voice or tone form as needed. This mode, if used with push-button entry, will permit the pilot to enter the answers via tone input as soon as the prompt message starts. This feature saves time if the pilot recognizes the request and does not need to hear it through. The second mode, designed specifically for push-button entry, allows the pilot to enter in all the input data via tone inputs in one sequence, according to a specified protocol. The VRS computer will then conduct all the briefing activities requested until it requires further instructions or offers additional service. During either of these modes, special interactive control tones associated with push-button entry can be used to stop the briefing, repeat, jump ahead, continue, or be switched to an FSS specialist. The selected weather products offered will be the full range of weather products and NOTAMS normally available through the FSS. The scope of reporting points covered by this automated system will include the continental United States and maybe selected Canadian, Mexican, and Caribbean regions. The caller may elect to enter a flight plan following the selected weather service.

The next category of service examined is the PATWAS/TWEB service. As mentioned previously, the pilot calls a local FSS special telephone number and is given an introductory message. If the pilot does not select an option within a specified time period, a local PATWAS briefing is automatically initiated. If a local PATWAS service is not required, a regional PATWAS briefing may be implemented as needed. The pilot would be given a fixed sequence of weather reports and NOTAMS comprising the PATWAS report. The interactive features of control would still be available to the caller by using the special tone inputs associated with push-button entry. Thus, the pilot can stop, repeat, continue, etc., the PATWAS briefing as desired. If a route-related PATWAS briefing was desired initially, the pilot would select the desired report by voice or tone input or if telephone service permits by dialing the selection number. This latter input technique would count the "clicks" from the dial. The appropriate route-related PATWAS briefing would be presented. Using voice or tone inputs, the caller has the additional option of switching to the selected weather mode, flight plan entry mode, or specialist.

The TWEB service available via telephone would be essentially the same as PATWAS differing only in the report composition. The radio TWEB service would be implemented automatically with the sequence of segments comprising the report being continuously repeated into the radio transmitter for mass dissemination.

The last category of service is flight plan entry. The caller can select this service using an appropriate voice or tone input initially when the call is made or after either the selected weather or PATWAS/TWEB service. As in the selected weather service, both a prompted and an unprompted (i.e., brief) mode are offered. The pilot enters each element of the flight plan using voice or push-button inputs. The pilot will have the capability of recalling for editing purposes any entry made during the flight plan entry sequence. The pilot will also have the option of reviewing the entire flight plan prior to commanding its submission for automatic FSS processing. During individual flight plan element entry, error messages may be given for unknown inputs, missing information and invalid entries. The pilot can switch to an FSS specialist at any time; however, if the pilot had not submitted the flight plan for automated FSS processing, the specialist will not have recall of the flight plan since this recall is a separate function of the specialist's automation system, that is, the Flight Service Data Processing System (FSDPS).

To complete the operational overview of these VRS automated services, the support requirements must be discussed. The major source of weather and aviation information is through the FSDPS or Aviation Weather Processor. This information will be automatically processed as encoded voice messages by these systems or if necessary by separate Data Base Processors. Therefore, all of the messages offered by these services will be completely automatic. However, special messages can be created, if needed, through direct input to the Data Base Processor using keyboard input devices. The projected vocabulary in the automatic voice generating subsystem is designed to supply sufficient dictionary for this capability.

As mentioned in several previous paragraphs, FSS specialist support is available in conjunction with the automated services. This support is supplied by the local FSS associated with the pilot's local area (i.e., the called exchange). This FSS would be equipped with an extension for each line connected to the VRS computer. When the pilot requests the specialist's service, the computer will signal the specialist and transfer the call accordingly. The caller will then hold until serviced by the specialist. No further automation service is offered the pilot once he is transfered to the specialist.

1.4 VRS System Concept

The system concept described in this section has been derived from the results of this study. The description is presented in this introductory chapter in order to aid in understanding the alternative analysis presented in the subsequent chapters.

The VRS concept is based upon digital encoding schemes to store human utterances in a compact form within a digital computer system for later recall, decoding and voicing by the system. The future equipment needed to implement a national Voice Response System will vary from the current hardware in specific detail, but conceptually will be similar in information processing function. Based upon the results of this study, the communications costs were found to be higher for centralized equipment configurations than for decentralized networks. The most promising alternatives involved distributing hardware throughout the nation. Two types of hardware subsystems evolved. The first was a Data Base Processor (DBP) and the other was a Voice Response System (VRS) Processor. The processing and flow of information between these subsystems must be examined to understand their roles.

The DBP subsystem was assigned the role of converting raw weather and aviation information reports into special vocabulary encoded message units. This raw information is obtained through the Model I/II automation system from the Aviation Weather Processor (AWP) and other FSDPS's. The encoded message units are stored on DBP peripheral storage devices (disk storage units) for later access and transmission to VRS processor subsystems when requested. This real-time conversion of raw information to vocabulary encoded information is a substantial processing task. The DBP is therefore positioned more centralized than the VRS processor subsystems which interact with the pilots/callers and perform the various telephone and voice input and output tasks. The information desired by the pilots is requested of the VRS processor by voice or tone input. The VRS processor then passes the request to the DBP subsystem through a dedicated inter-computer communication line. The vocabulary codes are returned to the VRS processor which then uses these codes to access the digital form of the associated utterances. The digital utterance data is converted to analog form to voice the word or words through the voice generation device associated with the VRS processor. The digital utterance data is stored within the VRS processor subsystem and only the identifying vocabulary codes are sent over the inter-computer communication lines to minimize the flow of information between the two processors.

The functions described above encompass the selected weather as well as the PATWAS/TWEB services. The remaining servce to be discussed is flight plan entry. This service is implemented within the functions of the DBP subsystem with the VRS processor serving only to pass the flight plan entries and responses between the pilot and the DBP. This assignment of tasks was developed to concentrate the sizable flight plan entry analysis and storage tasks in the larger DBP subsystem and to reduce the complexity and associated costs of the VRS processors which are more numerous in the alternatives studied.

This study examines arrangements of DBP's and VRS processors in conjunction with the associated communication networks to determine cost and performance tradeoffs. A variety of network configurations from centralized to decentralized are studied. In addition, several alternatives of VRS processor hardware configurations are included to assess costs of partial service implementations, several voice technology applications and different vocabulary storage devices. Throughout all of these alternatives a fundamental concept of failsoft performance is presented as the level of operational reliability appropriate for this national implementation. Failsoft performance for this study is defined as the level of performance which continues full operational services but permits reduced capacity in terms of the available caller telephone lines and/or response delays when an element of the system fails. To achieve this failsoft operation, it is simply required that no less than two similar subsystems be co-located at a site. If one fails, the other can assume some of its load in addition to its own service until the failed unit is repaired or replaced. This failsoft approach may permit less stringent requirements for timely replacement of the failed equipment to 24 hours. Thus, maintenance costs can be reduced below rates for on-line computerized equipment. The failsoft concepts expressed in these alternatives are essentially automatic for VRS processor sites if an interlaced telephone line hookup is employed. The DBP sites may be configured with automatic switch-over of inter-computer communication lines to the active DBP or may be performed manualy upon failure alarm. If a fail-safe concept is desired, an extra (redundant) processor subsystem is required at each processor site. The fail-safe extra unit may be on-line to share some of the service load even when no units have failed.

Such a configuration facilitates peak operational performance and reduces instantaneous impact of a failed unit if it should occur.

One last system variable must be discussed. All of the alternative communication networks studied use voice grade telephone lines for minimum cost except for one. This special case was designed to evaluate the use of digital communication networks to assess the costs of remoting specific voice generation devices with input devices via high data rate digital transmission lines. The fewer digital lines required for this concept, although individually more expensive, may permit reductions in processor site costs through combined hardware utilization.

2. NATIONAL VRS FUNCTIONAL FEATURES

The current TSC VRS operation in the greater Washington D.C. area provides only three weather products for the pilot briefing function. A multitude of flight service functions and system requirements will have to be analyzed and determined before a nationwide VRS could be implemented. To this end, frequent meetings and work sessions between TSC and the FAA/Systems Research and Development Service were conducted in which preliminary requirements were developed and drafted. The functional requirements document was transmitted to the FAA in the beginning of the first quarter of fiscal year 1979 (FY79) and circulated among the FAA/Air Traffic Service and the FAA/Airway Facilities Service soliciting comments. By the end of the first quarter of FY79, the document was approved with minor modifications.

2.1 Voice Response System with Full Capability

The functional requirements determination activity concluded that a multi-channel Direct User Access-Voice Response System shall be incorporated in the FSAS to provide the pilot and specialist users with simultaneous, non-interfering (independent) access to weather briefing and flight plan filing services using push-button and voice commands. The VRS will automatically generate all messages without manual intervention except where specifically noted otherwise in the requirements (i.e., 2.1.2, para. C). The VRS shall include:

- a set of commands to control the selection and output of the briefing such as: STOP, GO, REPEAT, SKIP, BEGIN OVER, FILE, SPECIALIST, ROUTE, LOCAL.
- a natural sounding voice with appropriate cadence and inflections.
- user data entry editing capabilities and data entry read-back.
- a set of time-outs to prevent system abuse.

Described below are the major functional features for the VRS. Many are long-range goals which may require intermediate stages of implementation until the technology required to implement them fully is available commercially (i.e., "off-the-shelf"). For example, flight plan filing may initially be implemented similar to a "fast file" capability then expanded at a later time to include amendments, status inquiries, and, in general, an interactive mode of operation between the user and the VRS. (NOTE: "Fast file" is a system whereby a pilot files a flight plan via telephone that is tape-recorded and then transcribed for transmission to the appropriate air traffic facility [Ref. 11].

2.1.1 Ground Rules and Assumptions - the following rules and assumptions were applied to bound the scope of the VRS capabilities and to facilitate sizing and trade-off analysis:

A. No record will be maintained within the VRS for specialist access of any data transactions between the pilot and the VRS. If any questions come up from the user, the user can relay to the specialist the data that was received.

B. There will be no data edit position dedicated for the VRS. This assumes that the source data will be error-free and standardized in some type of computer processable format. Should source data require correction or editing, the capability is available at the Aviation Weather Processor (AWP) to edit, correct or reformat the AWP weather data base. The type of editing to the source data that needs to be done for the VRS involves garbled, misspelled, and ambiguous items. The VRS vocabulary editing and updating will be provided as a separate feature.

C. Flight plans will not be recallable through the VRS. The specialist, however, will be able to access all of the functions concerning flight plans using the Model 2 FSAS services.

D. There will be no legal recordings of transactions between the user and the VRS. This is consistent with the current Pilot Automatic Telephone Weather Answering Service (PATWAS) briefing mode of operation. Data recordings for test and analysis purposes shall be available as a selectable option.

E. Prompted and unprompted user data entry modes shall be available for all modes of operation.

F. For the purposes of this study, all VRS sizing will be based on digitized voice technology using ADPCM.

G. All cost estimates used in this study are based on constant dollars since this study is primarily concerned with relative costs only, for various alternative configurations. Also, costs to the pilot for using the VRS including the acquisition of tone-generating telephones or pads are excluded.

2.1.2 Functional Features

A. Pilot Briefing - The specialist and the pilot shall have the means to retrieve the following products:

1. Surface Weather Observations - Surface weather observations include weather elements pertinent to flying. The types of reports available include: Surface Aviation Weather Observation (WSA), Special Surface Weather Observation (SP), Urgent Special Surface Weather Observation (USP), and Supplementary Surface Weather Observation (SW). All of these reports are collectively referred to as WSA reports. The following data, if present in the report, will be voiced: location, time of observation, sky conditions, visibility, weather and obstructions to visibility, temperature, dew point temperature, wind direction, wind speed, wind character, altimeter setting, and remarks.

2. Terminal Forecasts - A terminal forecast is a description of the weather expected at a specific airport. The types of reports available include: Terminal Forecast Message (WFT), WFT Amendment (WFT AMD), and WFT Correction (WFT COR). All of these weather report types are referred to as WFTs. The following data, if present, will be voiced: location, date/time group, height of sky cover, amount of sky cover, visibility, weather and obstructions to visibility, surface wind, remarks, and categorical forecast.

3. Grid Winds - The grid wind forecast message (WGF) consists of numerically derived upper-wind and temperature information in a digital form. The data voiced shall include: the wind speed, wind direction, and temperature for any valid location identifier in the data base. The data delivered shall be for the requested altitude, the altitude plus 4,000 feet, and the altitude minus 4,000 feet for a forecast interval of 0-30 hours.

4. Notice to Airmen - Notice to Airmen (NOTAM) advise of unanticipated or temporary changes to components of, or hazards in the National Airspace System (NAS), or permanent changes in these components or hazards until the permanent base-line data (aeronautical charts and/or publications) is amended. The types of NOTAM reports include: Flight Data Center (FDC) NOTAMS, Central Altitude Reservation Facility (CARF) NOTAMS, and International NOTAMS. The following data contained in the NOTAM may be voiced: identifier of accountable station, serial number, location or facility identifier affected, NOTAM type, valid time, and variable length textual data describing the specific service limitation or hazard.

5. Weather Warnings - Weather warnings and forecasts advise pilots of the development of potentially hazardous weather. The advisories include: Severe Weather Forecasts, Bulletins and Status Reports (WW), Hurricane Advisories (WWH), Significant Meteorological Information (SIGMET) message designated (WWS), Urgent SIGMET (UWS), Convective SIGMET (WST), Severe Weather Outlook Message (WSO), Airmet Message (WWA), and Alert Weather Watch (AWW). The following data contained in the reports may be voiced: Header information, States affected, alphanumeric series identifier , issuance and valid times, and variable length textual data.

6. <u>Density Altitude</u> - Density altitude is equivalent to that altitude in the U.S. Standard Atmosphere where air density is equal to that of the air in question. It is used as an index to tell the pilot how well the plane will take off or climb. The data voiced shall include the density altitude, temperature, time and location (airport).

7. <u>Pilot Report (PIREP)</u> - A PIREP is a report of meteorological phenomena encountered by aircraft in flight. These include both a Pilot Report Message (WUA), and an Urgent Pilot Report (UUA). The following data, if present, shall be voiced: location of the phenomena, type of aircraft , sky condition, temperature, wind velocity (direction and speed), turbulence (intensity and altitude), icing (intensity, type and altitude) , and remarks.

8. <u>Synopsis (SYNS)</u> - The synopsis report is a brief statement of frontal and pressure systems and circulation patterns. The data voiced shall include the location, date/time group, and variable length textual data.

9. <u>Transcribed Weather Broadcast Route Forecast (TWEB)</u> - The TWEB service provides continuous aeronautical and meteorological information on Low and Medium Frequencies and VOR (Very High Frequency Omnidirectional Radio Range) facilities. The data voiced shall include the TWEB route number identifier, date/time group, route identifier (a series of 2-5 alpha numeric location identifiers which uniquely identify the route), and variable length textual data such as information relating to synopsis, flight precautions, route forecasts, outlook, winds, radar reports, surface weather, pilot reports, and NOTAMS.

10. <u>Pilot Automatic Telephone Weather Answering Service (PATWAS)</u> - The PATWAS provides a continuous recording accessible by telephone of aeronautical and meteorological information. The PATWAS products may include such

information as surface observations, terminal forecasts, winds aloft forecasts, synopsis, weather warnings, and NOTAMS.

11. Local Weather - The data voiced shall include a predefined set of products (e.g., WSA, WFT, WGF, NOTAM reports) within a prescribed distance of a location.

12. Route-Related - The data voiced shall include a predefined set of products (e.g., WSA, WFT, WGF, NOTAM reports) along a corridor of a user-entered route (e.g. Boston to Washington D.C.).

13. Other Products - Additional products shall be incorporated into the VRS as they become available and are found suitable for voice output (e.g., weather trend reports, tropical depression advisories).

B. Flight Data Handling - The VRS shall provide for the entering, closing, amending, canceling, and status checking of flight plan data. Acceptance, rejection or error messages shall be returned to the VRS from the Flight Service Data Processing System (FSDPS) which will perform the major flight data and error processing. Initially, this flight data handling capability may be limited to a "fast file" or flight plan entry mode of operation. All types of flight plans (e.g., Instrument Flight Rules (IFR), Visual Flight Rules (VFR), military, defense) shall be handled by the VRS.

C. PATWAS/TWEB Generation and Updating - The VRS shall provide immediate generation and updating of message segments for PATWAS/TWEB reports without interference to preceding or succeeding segments. The process shall be performed automatically by the VRS or manually by the specialist until all products become available. All message updating shall be performed without disruption to any callers currently accessing the system.

D. Voice Vocabulary Maintenance - The VRS shall provide for on-line and off-line vocabulary updating and maintenance. One function shall be the capability to define new vocabulary items (i.e., words or phrases) and manually generate them. However, an extensive vocabulary shall be created initially by one speaker. This will minimize the need to add words on-line which may result in a message composed of different voices.

E. Menu Selection - The user shall be able to obtain upon request to the VRS a list of available products and features including instructions for selecting them.

F. System Recording - The VRS shall provide as an optional feature (i.e., the feature can be turned on or off) time correlated data recording on the system performance and usage. The data collected shall include, but not be limited to, data to determine:

1. VRS activity on a per user, hourly and daily basis (e.g., functions requested, number of simultaneous users).

2. the voice storage capacity required.

3. for each weather report type: the number of reports received, processed and rejected. In addition, a file of erroneous reports shall be maintained for subsequent error analysis.

G. System Performance - The VRS shall be capable of servicing 90% of the expected peak- hour voice demand in FY86. The data base shall be designed to handle at least a 50% increase in each type of data. The system shall be capable of supporting additional compatible hardware , incorporating new products and software functions, and modifying existing system modules. The VRS shall also provide response times consistent with those of the Model 2 system for the FSAS. The response time is defined as the time interval from when the ENTER button (or equivalent) is depressed until the first portion of response information is received by the user. For example, mean response times for user-VPS interaction, or weather briefings are typically 2-2.5 seconds. For fail-soft operations, the response time numbers shall not be increased by a factor greater than 2. Appropriate messages to the user shall be provided for system outages or unavailable data.

H. <u>System Reliability</u> - The VRS shall be designed to <u>operate continuously 24 hours a day, 7 days a week</u>. Equipment redundancy and switching shall provide recovery from partial or total failures. Automatic reconfiguration is not a requirement; however, operator control procedures shall be accomplished through fast, easy operations, such as throwing switches. Physically moving equipment units and manually interchanging cables are not allowed. <u>The availability of the VRS shall not be less than 0.995</u> and the Mean Time Between Failures (MTBF) shall not be less than 1500 hours. The mean time to restore the VRS to full operational capability in the event of failures that prevent the system from providing current weather briefings or flight plan filing shall have a mean time of not more than 2.5 minutes.

I. <u>Specialist Interaction</u> - The VRS shall provide for transfer by the user to an attended specialist position by means of a push-button or voice command. Calls to the specialist shall be assigned to a non-busy specialist on a fixed rotational basis.

2.2 <u>Voice Response System with Initial Capability</u>

A multi-channel VRS shall be incorporated in the FSAS providing, as a minimum, the capabilities and products currently under demonstration in the Washington D.C. area. These include:

A. A set of commands to control the output of the briefing (e.g., STOP, GO, REPEAT).

B. A natural sounding voice with appropriate cadence and inflections.

C. Deletion and change of the latest entry by the user. User data entry read back.

D. A set of time-outs to prevent system abuse.

E. Prompted and unprompted push-button interaction between the user and the VRS for the selection of weather products and services.

F. The three weather products:

1. Surface Weather Observations (WSA)

2. Terminal Forecasts (WFT)

3. Grid Winds (WGF)

G. Menu selection (per Section 2.1.2, para. E)

H. System recording (per Section 2.1.2, para. F)

I. System performance (per Section 2.1.2, para. G)

J. Off-line voice vocabulary updating and maintenance.

K. System reliability (per Section 2.1.2, para. H)

L. Specialist interaction (per Section 2.1.2, para. I)

Items A-D, F, H, and J are currently part of the demonstration system. The remaining items are either easily incorporated or deemed necessary (e.g., those for performance and reliability) and shall be included in the initial system. Other capabilities may be included in the initial VRS specification if they have been thoroughly tested and found acceptable for implementation (e.g., voice recognition, "fast file" of flight plans). The goal for the initial system is to be able to use the same hardware and software in subsequent expansions and enhancements for Model 2.

3. VOICE RESPONSE SYSTEM DEMAND

Introduction

In order to support the National VRS Implementation Alternatives Study, a demand model is required. To determine communication line requirements and equipment sizing, the demand model must specify the peak-hour demands for the various VRS functions and their respective time requirements. These demand components are discussed in the following paragraphs.

3.1 Baseline Demand Data

Forecasted demand data used by the FAA for their FSAS Specification has been transmitted to TSC (Ref. 2). The demand data, which is included in this report as Appendices A-E, consists of the following:

- FY86 and FY95 peak-hour demand forecasts for a consolidated 138-facilities system (Appendices A, B).
- FY86 and FY95 peak-hour demand forecasts for the 20 FSDPS's (Appendices C, D).
- Annual FY86 demand forecasts for all facilities (Appendix E, Tables E-1 through E-20).

The FY95 data are linear extrapolations of the FY86 data and can be found by applying a constant multiplier of 1.4 to the FY86 data. A constant multiplier of 0.000286 relates peak-hour demand to annual demand (Ref. 3).

3.1.1 Baseline Demand Data Verification

The forecasted annual demands were derived from September 1976 FAA forecasts. The total annual demands forecasted for FY86 were:

Pilot Briefings - 30.3 million

Flight Plans Originated - 13.4 million

The above forecasts were updated using September 1977 data (Ref. 4). The results are:

Pilot Briefing - 31.4 million

Flight Plan Originated - 13.1 million

There is less than a 4% difference in the two forecasts. Therefore, the original annual forecast data will be used for the demand model.

For sizing purposes, peak-hour demands are necessary. The peak-hour demand forecasts were obtained by multiplying annual demand forecasts by 0.000286. A peak-to-average hour demand ratio of 2.5 was obtained from the average of 7 days of data at Chicago in 1970. The same ratio for 29 days of data at Washington D.C. was 2.544. Thus, a ratio of 2.5 was considered a good approximation (Ref. 3).

From the 1978 FAA Indianapolis FSS Automation Evaluation Study data (Ref. 5), the average peak-to-average hour ratio was calculated to be 2.40. FSS logs collected by TSC in 1978 were also used to calculate peak-to-average hour ratios for four facilities with the following results:

FSS FACILITY	PEAK-TO-AVERAGE HOUR
Denver	2.13 (3 days)
St. Louis	2.52 (3 days)
Boston	2.32 (4 days)
Dallas	2.66 (4 days)

This 1978 data verifies analyses performed by the MITRE Corporation that a peak-to-average hour ratio of 2.5 is a good approximation. Using this ratio, the peak-hour to annual demand ratio of 0.000286 can be derived (Ref. 3).

For communication line requirements and equipment sizing, the question arose whether peak-hour demands from various time zones are additive if the VRS's are concentrated in a small number of facilities. Figure 3.1.1-1 shows diurnal plots of pilot briefings for the four facilities. These figures reveal that possibly a 10% reduction in peak-hour demand can

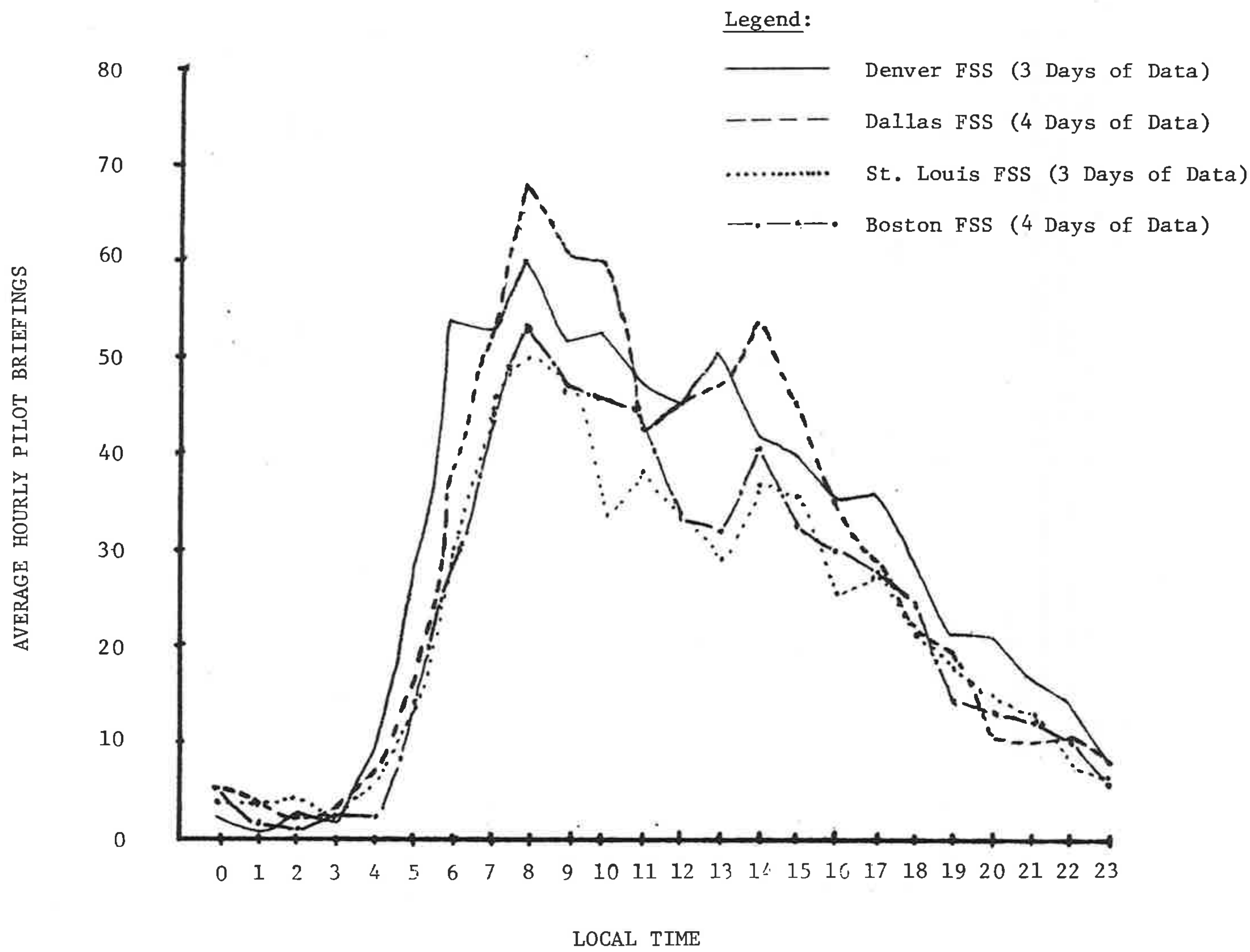


FIGURE 3.1.1-1 - AVERAGE HOURLY PILOT BRIEFINGS

be expected when adding demands for various time zones. However, in centralized VRS equipment configurations, when aggregating the demands from many locations, the reductions caused by time zone differences becomes insignificant. For example, MITRE (Ref. 6) calculated the peak hour demands at 50 hub configurations and the composite demand at one central facility located in Kansas City, MO. The pilot briefing demand at the one central facility was within 3% of the summation of the 50 hubs' pilot briefing demand.

3.2 Voice Response System Pilots Demand

The VRS product requirements are delineated in Section 2. For the purpose of a pilot demand model, the VRS messages are:

Pilot Briefings
Flight Plan Filings
PATWAS
TWEB

Pilot Briefings, Flight Plan Filings, and PATWAS are products which will be requested on the same telephone lines. Therefore, each of these messages has a forecasted pilot demand. TWEB "demand" consists only of the communication lines from the VRS to the TWEB transmitters.

The data in Appendices C and D show that the same peak-to-average hour ratio of 2.5 applies to both Pilot Briefings and Flight Plan Filings. It is assumed that the same ratio will apply to PATWAS.

The baseline forecast demand data now has to be applied to the three products. An analysis by the FAA of 1978 Washington DC data indicated that for every FSS/Weather Service Office (WSO) pilot briefing, there were 0.86 VRS pilot briefings and 1.78 PATWAS briefings. The present VRS has only three products. With the addition of more products and an increase in pushbutton phones, the FAA has estimated that the proportion of VRS pilot briefings will increase, with a decrease in the proportion of PATWAS briefings. An overall national average of the proportion of PATWAS and VRS pilot briefings to FSS/WSO pilot briefings in 1986 have been estimated by the FAA to be:

VRS Pilot Briefings = 1.2 X FSS/WSO Pilot Briefings
PATWAS = 1.3 X FSS/WSO Pilot Briefings

(Although the specialist workload is not part of this study, it should be emphasized that with the implementation of the VRS, the number of FSS/WSO pilot briefing requests and average length of the briefings will decrease.)

The FAA has also estimated that 12% of flight plans will be filed using the VRS. On a national basis for FY86, the ratio of flight plans filed to pilot briefings is 13.4/30.3 or 0.44 (see Section 3.1.1). Thus, flight plans filed by the VRS can be expressed as:

VRS Flight Plans Filed = (0.12)(0.44) FSS/WSO Pilot Briefings (PB's)

= 0.05 X FSS/WSO PB's

Since the VRS flight plan filings are only 2% of the total demand (i.e., .05/2.55), this factor has essentially no effect and has not been included in the model calculations.

Hence, the total VRS demand becomes:

1.2 X FSS/WSO PB's (for VRS PB's)
+ 1.3 X FSS/WSO PB's (for PATWAS)
2.5 X FSS/WSO PB's

The total VRS Peak-Hour Demand is as follows:

for FY86:

= 2.5 X 9078.8 Peak-Hour PB's (see Appendix C)

= 22,697 PB's

for FY95:

= 2.5 X 12,784.5 Peak-Hour PB's (see Appendix D)

= 31,961 PB's

3.3 VRS Communication Connection Times

In order to determine the number of communication lines required, both the pilot demand and the telephone connection times are required. The connection times discussed below include user and system protocol interaction times:

3.3.1 VRS Pilot Briefing Connect Time

The present VRS demonstration system has three products. These are Surface Weather Observations, Terminal Forecasts, and Grid Winds Forecasts. The additional products to be added for pilot briefings are Notices to Airmen, Weather Warnings, Density Altitude, Pilot Reports and Synopsis.

At the present time, the average VRS connect time is 3.75 minutes. If the message contents of the additional products are considered, a total VRS message could increase to 15 minutes. The possibility of a 15-minute pilot briefing is rather remote as discussed below:

- Approximately a third of the present pilot briefing connect time is due to protocol. Shorter protocol times will exist in the future due to user proficiency and changes to the present protocol.
- Synopsis is a relatively short statement. For example, the Boston PATWAS Synopsis was 15 seconds on 1-22-79. Density Altitude is a short statement which all users do not require.
- Weather Warnings and PIREPS only exist when there are potential hazardous weather and meteorological phenomena.
- NOTAM'S are of variable length and unscheduled. It is assumed that future designs will have either or both of the following:

  (1) NOTAM'S will be entered by order or priority.

  (2) The skip function will be mechanized so that individual NOTAM's can be skipped.

- As discussed in the next section, the average PATWAS message will be approximately 6 minutes. Essentially, PATWAS and VRS pilot briefings will have the same information.

Considering the above, 6.0 minutes has been selected as a reasonable average connect time for a VRS pilot briefing of selected weather products.

3.3.2 VRS/PATWAS Connect Time

Ref. 7 gives the average message length of PATWAS during the New York City PATWAS test. The overall weighted average message length was 5.64 minutes. Therefore, approximately 6 minutes has been selected for PATWAS connect time. It should be noted that the overall weighted PATWAS connect time during this test was 3.75 minutes. Thus, using 6.0 minutes connect time is conservative.

3.3.3 VRS Flight Plan Filing Connect Time

An on-going VRS Flight Plan Filing Test at the National Aviation Facilities Experimental Center (NAFEC) (Ref. 8) under the nonprompt mode resulted in an average overall flight plan filing time of 8 minutes. Therefore, 8 minutes will be used for the average connect time for flight plan filing.

3.4 PATWAS and TWEB Locations

As part of the study, PATWAS and TWEB outlet locations are required. To expedite the communication network analysis modeling TEL-TWEB only locations are considered the same at PATWAS locations. The conterminous U.S. PATWAS located at National Weather Service facilities are assumed to be located at the nearest FSS within the same state for network modeling. The PATWAS and TWEB outlets were obtained from the FAA and are delineated in Tables 3.4-1 and 3.4-2.

TABLE 3.4-1

TWEB OUTLETS

New England Region

Boston, MA
Montpelier, VT

Northwest Region

Boise, ID
Redmond, OR
Walla Walla, WA
Seattle, WA

Central Region

Wichita, KS
Kansas City, MO
Springfield, MO
St. Louis, MO
North Platte, NE

Southwest Region

New Orleans, LA
Albuquerque, NM
Oklahoma City, OK
Fort Worth, TX
Houston, TX
Midland, TX

Eastern Region

Washington, DC
Teterboro, NJ
Philadelphia, PA
Roanoke, VA

Rocky Mountain Region

Denver, CO
Grand Junction, CO
Billings, MT
Great Falls, MT
Minot, ND
Huron, ND
Pierre, SD
Rapid City, SD
Cedar City, UT
Salt Lake City, UT
Casper, WY
Rock Springs, WY

Western Region

Tucson, AZ
Prescott, AZ
Arcata, CA
Los Angeles, CA
Oakland, CA
Red Bluff, CA
San Diego, CA
Las Vegas, NV
Reno, NV

Southern Region

Mobile, AL
Jacksonville, FL
Miami, FL
Pensacola, FL
Albany, GA
Atlanta, GA
Louisville, KY
Jackson, MS
Nashville, TN

Great Lakes Region

Decatur, IL
Quincy, IL
Chicago, IL
Indianapolis, IN
South Bend, IN
Hancock (Houghton), MI
Negaunees (Marquette), MI
Traverse City, NI
Freeland (Saginaw), MI
Detroit, MI
Hibbing, MN
Minneapolis, MN
Cleveland, OH
Findlay, OH
Columbus, OH
Cincinnati, OH
La Crosse, WI
Green Bay, WI
Milwaukee, WI

TABLE 3.4-2

PATWAS OUTLETS FOR VRS IMPLEMENTATION STUDY

New England Region

Boston, MA

Northwest Region

Seattle, WA*
Portland, OR***

Central Region

Wichita, KS
Kansas City, MO
Springfield, MO*
St. Louis, MO
Omaha, NE

Southwest Region

New Orleans, LA
Shreveport, LA***
Little Rock, AR***
Okalahoma City, OK
Tulsa, OK
Dallas, TX
Fort Worth, TX
El Paso, TX
Houston, TX
Albuquerque, NM

Eastern Region

Washington, DC**
Teterboro, NJ
Millville, NJ
Albany, NY
Buffalo, NY
Islip, NY (NYC)***
Poughkeepsie, NY
Philadelphia, PA
Harrisburg, PA
Pittsburgh, PA
Roanoke, VA

*Presently TEL-TWEB
**Presently PATWAS and TEL-TWEB
***PATWAS at National Weather Service

Rocky Mountain Region

Denver, CO**
Huron, SD*
Salt Lake City, UT

Western Region

Phoenix, AZ
Tucson, AZ
Los Angeles, CA*
Ontario, CA
San Diego, CA
Oakland, CA*
Las Vegas, NV**

Southern Region

Mobile, AL
Muscle Shoals, AL
Birmingham, AL
Jacksonville, FL
Miami, FL
Orlando, FL
Pensacola, FL
St. Petersburg, FL
Vero Beach, FL (West Palm Beach)***
Albany, GA
Atlanta, GA
Louisville, KY
Jackson, MS
Hickory, NC
Raleigh-Durham, NC
Charleston, SC
Florence, SC
Nashville, TN
Memphis, TN

Great Lakes Region

Chicago, IL
Indianapolis, IN
South Bend, IN
Detroit, MI
Hibbing, MN*
Minneapolis, MN
Cleveland, OH
Columbus, OH
Cincinnati, OH
Dayton, OH
Milwaukee, WI

4. VRS ALTERNATIVES CONFIGURATION DEVELOPMENT

4.1 System Considerations

4.1.1 System Performance

As previously stated in the functional requirement section, the VRS shall be capable of servicing 90% of the expected peak-hour voice demand in FY86. The expected peak-hour voice demand is based on projected specialist pilot briefings and flight plan filing demands as follows:

	DEMANDS	TIME DURATION
VRS Pilot Briefing (PB)	1.2 (FY86 PB's)	6 minutes
PATWAS	1.3 (FY86 PB's)	6 minutes
VRS Flight Plan Filing (FPF)	0.05 (FY86 PB's)	8 minutes

The VRS shall provide response times not greater than the values shown in Table 4.1.1-1. The response times are consistent with those of the Model 2 System for FSAS. They in turn will impact on the design alternatives in terms of viable mass storage candidates as well as interprocessor communication baud rates. During fail-soft operations, the response time numbers shall not increase by a factor greater than 2. The fail-soft operations requirement may possibly be achieved by a back-up system configuration. Its response time factor will be discussed in more detail in the System Reliability Section.

4.1.2 System Reliability, Maintainability, and Availability

A restatement of the system reliability, maintainability, and availability requirements are in order prior to discussions of their considerations. "The VRS shall be designed to operate continuously 24 hours a day, 7 days a week. Equipment redundancy and switching shall

TABLE 4.1.1-1

VRS RESPONSE TIMES

	MEAN (SEC.)	90th PERCENTILE	99.5th PERCENTILE
USER			
Interactive	2.0	3.9	7.4
Route-Oriented Briefings	2.5	4.9	9.3
Other Weather Briefings	2.0	3.9	7.4
PATWAS/TWEB Flight Plan Filing	2.5	4.9	9.3

provide recovery from partial or total failures as a fail-soft mode of operation. Automatic reconfiguration is not a requirement; however, operator control procedures shall be accomplished through fast, easy operations, such as throwing switches. Physically moving equipment units and manually interchanging cables are not allowed. The availability of the VRS shall not be less than 0.995 and the Mean Time Between Failures (MTBF) shall not be less than 1500 hours. The mean time to restore the VRS to operational capacity in the event of failures that prevent the system from providing current weather briefings or flight plan filing shall have a mean time of not more than 2.5 minutes."

In addition, the FSAS's Model 2 system reliability requirements for redundant applications are contained in Table 4.1.2-1. The system performance requirements for a fail-soft mode are best satisfied by dual computer configurations at each site. In the event that one computer malfunctions, the users of the failed computer receiving no service will call back and be answered by the other computers servicing that area. This is achieved by interlacing the hunting telephone system lines between the two or more VRS computers. When one computer fails, its lines are automatically placed out of service and give a busy signal, letting incoming calls skip to the next available line serviced by an active computer. This shall put an increased burden on the remaining operational computers absorbing the temporary loading of the malfunctioning computer and could result, during peak-loading, in reducing the overall system response time capability. The 90% servicing requirement for peak-hour operation could be factored into the design of the computer network configurations such that the requirement be met when a VRS computer malfunctions. However, since the frequency of failure is low and the equipment costs high for adding enough computers to preserve 90% answering service, this study will not attempt to design alternative configurations preserving the 90% level, but will allow a maximum of 50% reduction in service level in event of computer failure. The associated response time factors will be expected to increase but the VRS shall be able to adhere to the requirements for fail-soft operations.

TABLE 4.1.2-1

MEAN TIME BETWEEN FAILURES (MTBF)

MEAN TIME TO RESTORE (MTTR)

EQUIPMENT TYPE	MTBF	MTTR
Processor	5000 Hours	0.5 Hour
Memory Units		
Disc Control	5000 Hours	0.5 Hour
Disc Drive	3000 Hours	0.5 Hour
Main Storage		
Magnetic		
One Megabyte	5000 Hours	0.5 Hour
Solid State		
One Megabyte	5000 Hours	0.5 Hour
Data Modem	10000 Hours	0.5 Hour

The reliability requirement to restore a failed back-up element and to have it back into service within one-half hour (see Table 4.1.2-1) substantially improves the effective MTBF of a dual system as follows:

> Given that two or more units are combined in simple active redundancy and with maintenance (i.e., all failures fixed or replaced), the failed unit is put in service within the Mean Time to Restore (MTTR) period:
>
> > MTBF = 1500 hours;
> >
> > MTTR = 1/2 hours;
> >
> > no interruption of service occurs if one unit fails:
> >
> > MTTR includes failure detection time, troubleshooting time, restore time either by repair or replacement, and checkout time.
>
> Under these conditions, the effective MTBF of the combination is:
>
> $$\text{Duplex} = \text{MTBF}^2/(2 \times \text{MTTR})$$
>
> $$= (1500^2)/(2 \times 1/2)$$
>
> $$= 2,250,000 \text{ hours}$$

Obviously, with this high level of back-up computer reliability (i.e., an effective MTBF which is greater than 250 years), we should check other elements of the system such as power, communication lines, and telephone equipment, to find the weakest link in the chain. Having the reliability of one of the elements of a serial system more than two or three orders of magnitude greater than the other elements does not materially affect the reliability of the entire system. However, it could provide us the latitude of relaxing the MTTR requirement (e.g., if it were changed from 1/2 hour to 24 hours, the effective MTBF would be 5.6 years) and possibly result in savings in system maintenance costs.

The reliability figures for the solid state VRS components are quite high. The telephone equipment has reliability values in the range of one failure in approximately every 500,000 calls. The communication lines (data lines) between computers are about as reliable as their modems, with a MTBF of 10,000 hours. However, noise problems on these lines are likely to be more frequent than hardware failures. Regarding power, the FAA has requirements for a stand-by power unit. Commercial power failures are not a common occurrence. Typical commercial dual feeder system power failures are on the order of 100×10^{-6} failures per hour with a Mean Time to Repair of 2 hours. This availability factor together with a redundant power unit with a starting probability of 90 percent provides an effective power availability of 99.998%. For this study, it is assumed that stand-by power service will be utilized if already available at VRS sites; no separate provisions will be factored into these alternatives.

In summary, the Proposed Hardware Configurations (see Section 4.4) adhere to the system reliability, maintainability, and availability requirements, assuming that the fail-soft concept is adequate.

4.1.3 Ground Rules and Assumptions

Consistent with the functional requirements section, the following rules and assumptions bound the scope of the VRS capabilities and will be used to facilitate sizing and trade-off analysis:

1. No record will be maintained within the VRS for specialist access of any data transactions between the pilot and the VRS.
2. There will be no data edit position.
3. Flight plans will not be recallable through the VRS.
4. There will be no legal recordings of transactions between the user and the VRS.
5. Prompted and unprompted user data entry modes shall be available for all modes of operation.

6. For the purposes of this study, all VRS sizing will be based on the digitized voice technology using ADPCM.

7. Each VRS computer can handle 32 simultaneous lines (channels). This capacity is based upon current VRS technology, projected to 1983 production.

8. Each VRS Weather Data Base Processor can support up to 8 VRS computers.

9. The VRS computers shall not need operators, i.e., it shall be a simplified start button operation.

4.1.4 Specialist Interaction

The VRS shall provide for transfer per request of the user to an attended specialist position. Transfer between the VRS computer and the specialist shall be accomplished by a simple telephone extension, with a hold button, at the specialist position. The VRS will put the caller on hold when he requests specialist service. The specialist extension will blink on hold until the call is serviced.

4.1.5 Computer Network Configurations

There are two major aspects of the computer network configurations which must be examined in this study. One aspect addresses the trade-offs in centralization versus decentralization. The other aspect addresses implementation phasing. Within any given configuration, there are two major demand considerations: the number of peak-hour callers, and the average duration of each call. Within the peak-hour calls there are several levels of service and several forecast years to consider. All of these factors produce a multidimensional matrix of possibilities to examine. In order to limit the examinations to that which can be accomplished within a reasonable schedule and resources, a preliminary manual analysis of network configurations was performed and the results were used in formulating a table of major computer network configurations requiring more investigation. Table 4.1.5-1 presents these selected configurations. Portions of the matrix of configurations have been eliminated because the configurations do not make sense or they are

TABLE 4.1.5-1

MAJOR COMPUTER NETWORK CONFIGURATIONS

DATA BASE PROCESSOR NETWORK CONFIGURATIONS	DEMAND LEVELS (AVG. CONNECT TIME 6 MIN)		VRS NETWORK CONFIGURATIONS							
			NATIONAL IMPLEMENTATIONS						PARTIAL IMPLEMENTATIONS	
	FORECAST YEAR	DEMAND RELATIONSHIP TO PILOT BRIEFS	A. CENTRALIZED (WMSC)	B. DUAL SITE (NADIN: ALT SLC)	C. FSDPS'S (20 ARTCC'S)	D. LEVEL III FSS'S (43 SITES)	E. CONSOLIDATED FSS SITES (134 SITES)	F. ALL FSS'S (293 SITES)	G. 3 ARTCC AREAS (LEVEL III FSS CONFIGURATION)	H. 14 ARTCC AREAS (LEVEL III FSS) CONFIGURATION)
1. CENTRALIZED (WMSC)	1986	1.2								
		2.5	X							
		1.2 + CURRENT PATWAS								
	1995	1.2								
		2.5	X							
2. DUAL SITE (NADIN)	1986	1.2								
		2.5		X	X					
		1.2+ CURRENT PATWAS			X					
	1995	1.2								
		2.5		X	X					
3. FSDPS SITES (20 ARTCC'S)	1986	1.2				X				
		2.5			X	X*	X	X	X	X
		1.2+ CURRENT PATWAS				X			X	X
	1995	1.2				X				
		2.5			X	X	X	X		

*EVALUATE CHANGES IN AVERAGE CONNECT TIME FOR THIS CONFIGURATION.

inherently more expensive than the other alternatives or because the factors involved are covered by other configurations. Although the preliminary manual analysis will be discussed in the communications analysis section later in this report, it is helpful at this point to highlight the configuration trade-off characteristics evidenced in this kind of a national implementation. Figure 4.1.5-1 illustrates the cost behavior as the alternatives vary from centralized to decentralized networks. These results, recognizing that the user demand and equipment cost estimates were based on rough estimates to expedite this simplified desk top analysis, show the minimal cost system falls between the FSDPS equipment site configuration and the more distributed FSS VPS equipped configuration. As will be seen in the latter part of this study (i.e., Section 5.4), this minimal cost region was further validated by the more extensive computerized analysis. The computerized runs indicated by the X's in Table 4.1.5-1 explore the most sensitive parameters of the VRS national implementation alternatives.

4.1.6 Speech Digitization and Compression Methods

The key factor in the design of a digital voice response system is the choice of the form of digital representation for the speech utterance. The scientific and engineering field has matured in recent years, and it can offer abundant possibilities ranging from Linear Delta Modulation (LDM) to Formant Frequency Synthesis techniques. These techniques, classified into waveform coding analysis/synthesis categories, are summarized in the following figure in terms of four major characteristics:

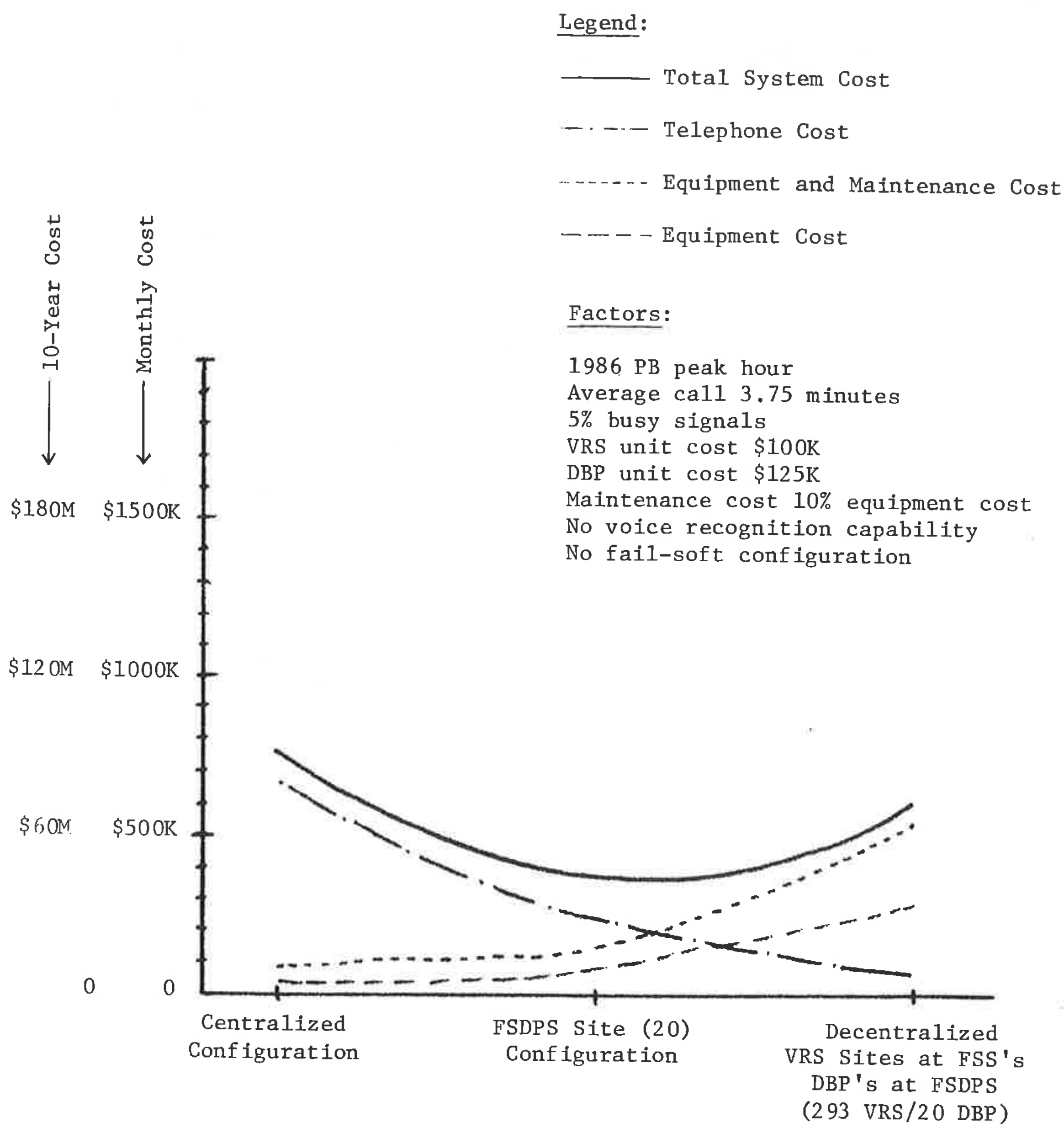
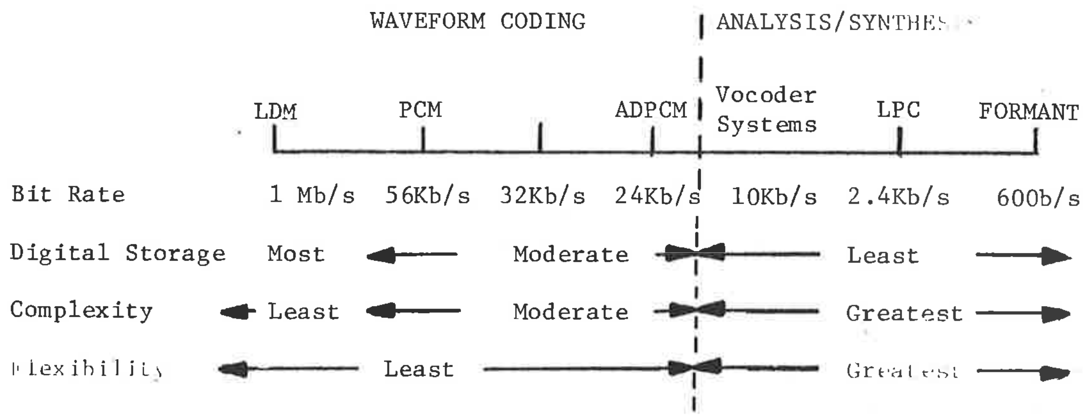


FIGURE 4.1.5-1 - PRELIMINARY MANUAL ANALYSIS SUMMARY



These characteristics govern the choice of the digital coding method for specific voice response applications. They are:

1. The information rate (or bit rate) required for producing acceptable speech quality;

2. Storage required to provide the set of vocabulary necessary for specific applications;

3. The complexity of the coding and decoding schemes which impact the computer requirements;

4. The flexibility of the representation and modification of the vocabulary elements.

The TSC's VRS prototype demonstration system uses the ADPCM coding scheme which lies in the middle of the technology spectrum. At present, the 750-utterance vocabulary is implemented on a fixed head disc. To implement the national VRS, using ADPCM technology, the risk is very low. The required 4000-utterance vocabulary could be implemented by a high-speed moving head disk servicing multiple users. Later in the near future, within 3 years perhaps, it is expected that the technology for the production of mass storage elements will be improved such that implementing the 4000-utterance vocabulary in a solid-state memory becomes feasible and cost competitive.

The LPC (Linear Predictive Coding) technique of speech synthesis is an advanced state-of-the-art. It is capable of providing extremely accurate estimates of the speech parameters with low input data rate, but the dynamic computation (number crunching) requirement is quite high. Only recently, an English language training aid in the form of an educational toy appeared on the market utilizing a proprietary LSI (Large-Scale Integration) speech synthesis chip. Its vocabulary is rather limited (approximately 250 utterances) and the speech quality although intelligible is noticeably inferior to the ADPCM speech produced at TSC. However, it is highly probable that within three years the LPC technology could be matured to a point which warrants serious consideration for the implementation of the national VRS.

The Formant Frequency method as shown in the far right of the spectrum possesses great features to be the ideal speech synthesis technique. However, it is still in the laboratory research stage, and it will not be considered for the national VRS at this time.

4.1.7 System Response Time

The automation response due to a 32-channel VRS service load is well within 20 percent of system instruction execution capacity. The users would see no delays due to processor backlog (small fractions of a second). This is true for both the VRS and the Data Base Processors, assuming that asyncronous servicing is used throughout. There are, however, two areas of system resources which may offer delay when loads increase. These areas are the inter-computer communications line and the Data Base Processor data file (assumed to be on a disk storage unit).

Looking first at the inter-computer communication line, it is desirable to keep this line within the range of a voice grade line to obtain the associated economies compared to digital data service lines. A 2400 baud level of service is assumed to operate reliably on this voice quality line. This baud rate will produce small delays due to queuing of reports transmitted from the Data Base Processor to the VRS unit.

First, the average call length is six minutes. Each caller requires 10 reports, each averaging about 35 seconds to utter, including prompts. About 0.95 seconds are required to transmit the vocabulary codes (pointers) and associated communication protocol (10-bit ASCII asynchronous mode). If 32 callers are on simultaneously, there will be 32 such transmissions per 36 seconds (1/10 of 6 minutes, the time required for a single report). Taking a Poisson random distribution function to examine this queuing problem, the delays caused by simultaneous requests for reports can be expressed as follows. Each user will experience a one-second delay, twice each call. One out of every two users will experience a two-second delay once per call. One out of every 9 callers will experience a 3-second delay, once per call. One out of 47 callers will see a 4-second delay, one out of 320 callers a 5-second delay, and one out of 2500 callers a 6-second delay. In practical terms, these delays due to communication queuing are tolerable and infrequent enough to adopt the voice grade line economies.

Next, let us examine the disk access loading at the Data Base Processor sites. Assuming that one Data Base Processor services eight VRS units of 32-channels each, it is possible to have 256 requests for data over a 36-second period (using the same loading discussed above). Using typical moving head disk performance, about 40 random accesses per second can be serviced with transfers of less than 512 bytes per access (this message block is adequate for this application). This means that 6.4 seconds are required to retrieve all 256 reports. Random distribution factors will spread the requests over the 36-second period such that delays will be within one second almost all of the time. It is assumed that the data base updating accesses will be of lower priority and less frequent such that negligible interference is caused.

One very important response time improvement over the current prototype VRS design is assumed for all alternatives. This improvement is based upon the voice decoding device having direct access to the digitized vocabulary storage device (e.g., PROM memory unit). This relieves the VRS processor from handling this flow of data through the computer. The voice decoding unit (the buffer management module) has adequate capacity in its microprocessors to perform this direct access with negligible delay.

In summary, the VRS response delays should remain within the 2.5 second requirement for most users except for one in 9 users who would see about a 3.5 second delay at peak loading, etc., as discussed above. These delays can be reduced if needed by increasing the inter computer communication baud rate or switching to the more efficient synchronous communication mode.

4.1.8 Facilities

A desire exists to constrain the VRS to the FSS automation facilities. This constraint will facilitate provision of the environmental conditions required for this equipment. However, if further decentralization of VRS equipment proves to be beneficial, the costs of facilities alteration will be included.

4.1.9 Operations

The VRS shall be designed to operate 24 hours a day, 7 days a week, with the exception of scheduled preventative maintenance periods. VRS computers shall have a simple push-button operation start up mode and shall not require special operators.

The flight service station specialist shall be able to perform start-up, restart, and shut-down procedures for VRS computers by means of simple push button procedures.

The VRS Weather Data Base Processor shall include monitoring functions and outputs at the Data Base Processor Terminal. These functions shall include system performance, status outputs and system error comments. The operation of the Data Base Processor will be kept very simple as in the VRS site with a minimal amount of additional training of operators for handling special processing such as dumping usage records to magnetic tape and running system analysis programs to measure performance and response.

4.2 Software Considerations

The software functional capacity is based upon the current prototype software and its extension to encompass additional VRS software functional features for this study (see Section 2). This activity is projected for the 1982-83 time period. For the purposes of software costing, estimates were generated in view of current software technology and no attempt was made to factor in the impact of software technological advancements occurring during the referenced time frame.

Therefore, our software development assumptions will be based on two key factors. First, that the computer architecture for the 1982-83 time period will be essentially the same as used in the VRS Prototype Demonstration System. And the second key factor is the availability and potential utilization of the prototype software designs and even source codes currently developed. The prototype software is designed in modular functional units. The current Data Base Processor software is implemented primarily in FORTRAN. To upgrade the software for the new Data Base Processor should constitute little or no problem since there is essentially minimal conversion between FORTRAN versions.

In the following sections, software modules will be identified with respect to a two-phased development approach and where applicable, some modules will be discussed briefly.

4.2.1 VRS Computer Software Development

Although coding for the current VRS computer has been implemented in machine language, nevertheless the software design and data base structure are effective and salvageable. Software sizing for the additional new VRS computer products not currently implemented in the prototype VRS will cause more impact in terms of expanding data base or memory requirements than on the amount of new software to be implemented. These new products could readily be implemented for the most part in FORTRAN, and make considerable use of existing product subroutines instead of redeveloping them.

In the case of flight plan data entry, a partial implementation such as a "fast file" mode of operation is available. When the mode is requested by the user, the VRS computer simply records the flight plan spoken by the pilot. This information is subsequently manually processed by a specialist at the VRS computer site.

Another partial implementation approach pertains to a manually augmented PATWAS real-time message capability. This capability may be necessary to PATWAS VRS computer sites during early phases of the national VRS development. It is during this time period that a limited VRS vocabulary is expected to exist. A real-time voice digitizing and encoding capability would permit special messages to be added to the automatic weather reports comprising PATWAS reports. These special messages would be adapted to the local VRS site and would physically reside there. When PATWAS is accessed by the users, these real-time voice messages would be appended to automated PATWAS voiced reports. In the final implementation, the local real-time PATWAS messages can be entered on a simple keyboard terminal. The messages will be sent to the Data Base Processor automatically and then be processed similar to other reports. The message would then be treated as any other PATWAS product and will be voiced automatically.

4.2.2 Data Base Processor Software Development

In the VRS Prototype Demonstration System, there is a master-slave relationship, with the master being the VRS Computer and the slave being the Data Base Processor.

For this study, the functions of Pilot Briefings and PATWAS/TWEB shall continue with the same computer master-slave relationship. However, for flight plan data entry, it appears that Data Base Processor should assume the master role. The reason for this approach to flight plan entry is to permit most of the buffers and processing load to be on the Data Base Processor and thus reduce the load on the VRS computer.

During the course of this alternatives study, there have been references to the possibility that the Data Base Processor functions be incorporated into the FSDPS and/or the Aviation Weather Processor. However at this time, for this study, there is insufficient information regarding contractor proposed design for the FSAS to intelligently size this alternative. As a result, this study will size a separate Data

Base Processor for all data base processing and support functions (including flight plan handling). It is also assumed that there will be a local link connecting the Data Base Processors to the FSDPS's or Aviation Weather Processors.

4.2.3 Software Sizing and Costing

Software sizing for the national VRS programs and modules were generated by comparisons with the current prototype system wherever possible. The complexity of a module and its sizing can be estimated in terms of the associated prototype software products. In this manner, estimates were generated for FORTRAN source statements, machine language instructions, and total memory requirements including data base allocations as summarized in Tables 4.2.3-1 and 4.2.3-2. These tables enumerate estimates for the VRS computer and the Data Base Processor respectively. Actual sizing figures for current VRS prototype programs and modules for the respective processors are denoted in Tables 4.2.3-3 and 4.2.3-4.

Various methods for estimating costs are currently being used throughout the industry. Before we discuss the approach we used for costing, we should briefly address the major factors affecting software costs.

Too often the magnitude and complexity of large software activities are underestimated or their requirements change such that they are not developed within the initial budgetary and time estimates. Other factors more germane to VRS affecting software costs include scheduling requirements, phased developments, software reliability, and quality of documentation. These factors will be addressed shortly.

The approach chosen for estimating future software costs is a quantitative-analytic method (Ref. 9). The parameters used, as adapted for the VRS, are listed in Table 4.2.3-5. These items must consider: estimated instruction counts; level/category of complexity; programmer productivity; percentages of analysis and design, coding, and checkout accomplished in previous efforts; percentages of programmer cost for remaining analysis and design, coding, and debugging; and a break-out of percentages for module testing and

TABLE 4.2.3-1

NEW SOFTWARE SIZING ESTIMATES - VRS COMPUTER

Functional Area	FORTRAN Source	Machine Instructions	Memory
1. Pilot Briefing Operations	---	700	30.0 KW
2. Flight Plan Entry	---	300	8.3 KW
3. PATWAS/TWEB Operations	---	400	1.4 KW
4. Voice Vocabulary Maintenance	---	1000	10.0 KW
5. Menu Selection	---	100	0.2 KW
6. Support Functions	---	200	1.0 KW
TOTALS		2700	50.9 KW

TABLE 4.2.3-2

NEW SOFTWARE SIZING ESTIMATES - DATA BASE PROCESSOR

Functional Area	FORTRAN Source	Machine Instructions	Memory
1. Pilot Briefing Data Programs			
• Notice to Airmen (NOTAMS)	1400	5390	14.8 KW
• Pilot Reports (PIREP)	1100	4235	11.6 KW
• Weather Warnings			
-- Severe weather forecasts and bulletins	900	3465	9.5 KW
-- Hurricane advisories	800	3080	8.5 KW
-- Significant meteorological information			
SIGMET	900	3465	9.5 KW
urgent SIGMET	500	1925	5.3 KW
convective SIGMET	1600	6160	16.9 KW
-- Severe weather outlook	800	3080	8.5 KW
-- AIRMET	1000	3850	10.6 KW
-- Alert weather watch	900	3465	9.5 KW
• Density Altitude	1000	3850	10.6 KW
• Synopsis	900	3465	9.5 KW
• Transcribed Weather Broadcast -- TWEB	1850	7123	19.6 KW
• Pilots Automatic Telephone Weather Answering Service -- PATWAS	500	1925	5.3 KW
• Local Weather	250	962	2.6 KW
• Route-Related	1500	5775	15.9 KW
PILOT SELF BRIEFING SUBTOTAL	15900	61215	168.2 KW
2. Flight Data Handling	500	1925	9.5 KW
3. PATWAS/TWEB Generation and Updating	1500	5775	15.9 KW

TABLE 4.2.3-2 (Continued)

NEW SOFTWARE SIZING ESTIMATES - DATA BASE PROCESSOR

Functional Area	FORTRAN Source	Machine Instructions	Memory
4. Voice Vocabulary Maintenance	500	1925	9.5 KW
5. Support Functions	400	1540	2.5 KW
GRAND TOTALS	18800	72380	205.6 KW

TABLE 4.2.3-3

PLUS PROTOTYPE VRS SOFTWARE ACTUAL SIZING

Functional Area	FORTRAN Source	Machine Instructions	Memory
1. Pilot Briefing Operations	0	6010	62.9 KW
2. Flight Plan Entry	Not Implemented Yet		
3. PATWAS/TWEB Operations	Not Implemented Yet		
4. Voice Vocabulary Maintenance	0	300	0.3 KW
5. Menu Selection	0	120	0.2 KW
6. Support Functions	0	550	0.6 KW
TOTAL	0	6980	64.0 KW

TABLE 4.2.3-4

PLUS PROTOTYPE DATA BASE PROCESSOR SOFTWARE ACTUAL SIZING

Functional Area	FORTRAN Source	Machine Instructions	Memory
1. Pilot Briefing Data Programs	17690	48946	134.4 KW
2. Flight Data Handling	Not Implemented Yet		
3. PATWAS/TWEB Generation and Updating	Not Implemented Yet		
4. Voice Vocabulary Maintenance	860	3300	4.0 KW
5. Support Functions	1050	4060	4.0 KW
TOTAL	19600	52306	142.4 KW

dynamic/integration testing. This data must be accumulated on a per product/module basis with appropriate values being assigned. The reference codes in Table 4.2.3-5 have been included to relate the following discussion of these factors in the VIS context:

(a) Real time programming is on the order of 2-3 instructions per day.

(b) Programmer productivity is the biggest variable among programmers and can be represented only by average numbers for the respective computer type (see Table 4.2.3-6a). Productivity is also a function of module difficulty and schedule duration and its index factors are presented in Table 4.2.3-6b. To calculate the number of instructions/statements per day, select the appropriate index factor (e.g., for a project duration of 12-24 months and a program module of medium difficulty the value is 1.2) and multiply it by the computer type value (e.g., DBP-9.0).

(c) Generally the programmer's respective time percentages for software development breakdown are:

Analysis and design	35%
Coding	20%
Debugging	45%

Again, there is a good deal of variance here. For example, if it is a long-term project, then later in the development the analysis and design factor could be expected to decrease significantly, perhaps as low as 10%. Other factors include programmer's familiarity with the computer, the support software, the operating system, debugging aids, and availability of computers for software debugging.

(d) The percentages of analysis and design, coding, and debugging for the respective modules accomplished in previous efforts could vary a good deal from module to module. The new effort could be a simple add-on. Then again it could entail a

TABLE 4.2.3-5

PARAMETERS FOR SOFTWARE COSTING

Parameter Meaning	Reference
Predicted total executable instruction count	
Function of difficult instructions, such as operating system, real-time programming	(a)
Programmer productivity	(b)
Percentage of programmer cost allocated to analysis and design	(c)
Percentage of programmer cost allocated to coding	(c)
Percentage of programmer cost allocated to testing	(c)
Percentage of analysis and design effort accomplished in previous efforts	(d)
Percentage of coding accomplished in previous efforts	(d)
Percentage of module or program checkout accomplished in previous efforts	(d)
Percentage of testing allocated to module or program checkout	(e)
Percentage of testing allocated to integration testing	(e)

TABLE 4.2.3-6

PROGRAMMER PRODUCTIVITY

a

Computer Type	Productivity (Instructions/statements per day)
Data Base Processor	9.0
VRS Computer	4.5

b

PROGRAM DIFFICULTY	PROJECT DURATION (in months)		
	6-12	12-24	> 24
Easy	2	2.4	4
Medium	1	1.2	2
Difficult	0.6	0.7	0.7

complicated module modification requiring detailed knowledge of the existing program logic and design.

(e) The percentage of testing allocated to module checkout is generally 60% with another 40% for integration testing.

As previously stated, these parameter data were applied on a per-module basis resulting in a respective instruction/statement per day count.

The resulting projected software estimates are presented in Table 4.2.3-7. These costs are enumerated in terms of the software functional areas as a function of the VRS computer and the Data Base Processor. Each processor in turn is broken-out in terms of conversion software effort and new products effort and their estimates are listed in labor-weeks. For cost purposes, seventy thousand dollars is equated to one labor-year of effort.

Table 4.2.3-8 contains another cut at the projected software estimates, in this case, for software development in its entirety from scratch. Similarly, these costs are listed in labor-weeks and presented in terms of the software areas as a function of the VRS computer and the Data Base Processor.

Regarding documentation, the manuals to be supplied should be the same as those required for the FSAS software development, with the quality of documentation being equal to Level 4 as described in FIPS Publication 38 (Ref. 10).

The projected documentation costs are $130K which together with the two projected software costs amounts to $1,000K and $1,288K for the conversion and new products approach and the complete software development approach respectively.

4.2.4 Software Maintenance

Software maintenance should be minimal in nature since the operational functions are well defined. FAA assumes to handle this area of responsibility for these VRS systems upon acceptance at the respective sites. Any software changes will predominately be of an enhancement nature and will be implemented by FAA software personnel. For this reason, software maintenance costs are not included.

TABLE 4.2.3-7

SOFTWARE COST ESTIMATES - CONVERSION AND NEW PRODUCTS

FUNCTIONAL AREAS	VRS		DATA BASE PROCESSOR		TOTAL LABOR WEEKS	COST
	Prototype Software (Labor-Weeks)	New Products (Labor-Weeks)	Prototype Software (Labor-Weeks)	New Products (Labor-Weeks)		
1. Pilot Briefing	18.0	23.3	49.2	314.4	404.9	$545.0K
2. Flight Data Handling	---	10.0	---	20.8	30.8	$ 41.5K
3. PATWAS/TWEB Operations	---	13.3	---	62.6	75.9	$102.2K
4. Voice Vocabulary Maintenance	2.7	33.3	16.5	20.8	73.3	$ 98.7K
5. Menu Selection	1.0	3.4	---	---	4.4	$ 5.9K
6. Support Functions	4.0	16.0	20.3	16.7	57.0	$ 76.7K
TOTALS	25.7	99.3	86.0	435.3	646.3	$870.0K

TABLE 4.2.3-8

SOFTWARE COST ESTIMATES - SOFTWARE DEVELOPMENT

FUNCTIONAL AREAS	VRS (Labor-Weeks)	DBP (Labor-Weeks)	TOTAL LABOR WEEKS	COST
1. Pilot Briefing	71.6	622.0	693.6	933.7K
2. Flight Data Handling	9.9	9.3	19.2	25.8K
3. PATWAS/TWEB Operations	14.4	27.8	42.2	56.8K
4. Voice Vocabulary Maintenance	26.6	25.2	51.8	69.7K
5. Menu Selection	5.6	---	5.6	7.5K
6. Support Functions	21.3	26.9	48.2	64.9K
TOTALS	149.4	711.2	860.6	1158.4K

4.3 Hardware Considerations

The hardware functional capacity and cost estimates are based upon the current prototype system and projected technology for production about the 1982-83 period. These estimates consider several important factors. The current VRS developmental equipment, which is approximately two years old, costs about $100K and handles 20 callers; the Data Base Processor system costs about $150K and handles only one VRS unit but supports many other unrelated functions simultaneously. Sizing the hardware for 1982 represents about a five-year advance in technology over the current VRS computer and associated equipment. In addition, the current system was developed on general purpose computers possessing broader capabilities in both hardware and software than are required for VRS operational support. Thus, in projecting the number of callers which can be handled by the future VRS unit and its likely cost, it is necessary to consider only the specific capacity requirements for VRS and the new technology advances.

4.3.1 VRS Hardware

The composition of a VRS unit can be briefly described as a minicomputer, a vocabulary storage device, a voice generator and an input device. The choice of individual components should be carefully selected to suit the major functions of the VRS. It must be recognized that the current VRS prototype is less efficient in both hardware and software than could be achieved in a tailored national implementation. Recognizing this, let us examine the selection factors for the major hardware items comprising a VRS unit.

The minicomputer should be selected for its ability to efficiently asynchronously handle 32 VRS channels, buffering I/O data and commands with the peripherals such as the tone input and voice output units. This minicomputer may have a small memory requirement if the voice generation unit has its own digitized vocabulary storage unit, thus saving the requirement for buffering the digitized vocabulary to the voice generating unit as it is done in the prototype systems. In addition, if the design forwards all flight plan entry data to the Data Base Processor as it is input, the needs for buffering this data in the VRS computer is reduced. The need for VRS floating point hardware may be eliminated if integer precision is considered in the design, and all route conversions, etc., are relegated to the Data Base Processor. With these features, the VRS computer may be satisfied by a small minicomputer or even an advanced microprocessor computer of the 1982 era. However, for this study, a minicomputer similar to the current prototype system will be used as a low-risk selection.

The next major hardware consideration addresses the vocabulary storage unit. The current VRS prototype uses a fixed head disk for this purpose, with a fast moving head disk for back-up. The important consideration in selection is the ability to randomly retrieve 32 digitized voice data streams at a rate which services the voice generation unit without noticeable delays in utterances. The ADPCM data compression approach requires about ten times more data per utterance than LPC concepts. The LPC concepts suffer from poorer voice quality. The storage device selection therefore is sensitive to the selected data compression methodology. Since the LPC technology is in an early stage of proven capability for this VRS application, our study will focus on device selection around the ADPCM concept. This is a lower risk approach and it easily facilitates LPC storage capacity needs if chosen later in the implementatinon. A recent LPC innovation in games has illustrated the advantages of using read only memory (ROM) for digitized, compressed vocabulary storage. This approach is highly desired for the VRS unit since it eliminates the mechanical elements associated with the disk units and thus improves reliability to a level of solid state equipment. The recent advances in large capacity ROM, Programmable ROM (PROM), and Erasable PROM (EPROM) chips promise to fulfill the needs even for an ADPCM digitized vocabulary of 4K utterances (between 8 and 10 megabytes). The important factor in the economics of using these storage devices is the quantity of production since there is a significant initial cost for ROM mask development. The use of PROM's offers better economics for smaller production quantities but it has lower density characteristics, therefore requiring more chips. The improvements in EPROM's have actually produced significant capacity in each chip, comparing favorably to ROM's. Their cost, although higher than large production ROM's, will be competitive for small production quantities however. Since the number of VRS units will not be large in terms of ROM production economics, it is more likely that PROM or EPROM vocabulary storage units are more practical for national implementation. Lastly, it is likely that the PROM vocabulary storage unit will be more expensive than disk units, but the reliability advantages justify the increased costs and the ease of random access directly by the voice generation unit and high transfer rates associated with PROM's easily support 32 channels. Therefore, this study will focus upon the use of a solid state vocabulary storage unit for the full capacity national system.

The next hardware item of concern is the voice generation device. An earlier section discussed the digitization methods. Each channel must have a digital-to-analog capability plus the associated data accessing, buffering and logical control features to produce the utterances upon command of the VRS computer. As discussed in the previous paragraphs, the voice generation device should access the vocabulary storage device directly (e.g., by a DMA, Direct Memory Access, capability) to produce efficient and responsive performance. The conversion and expansion circuitry for processing the digitized voice, both ADPCM and LPC, are considered similar in cost in the light of the new LPC technology used in the LPC speaking games. The very complicated and heavy computational task of decoding the LPC voice data has been reduced to a single integrated circuit. A similar approach is possible for this application.

In the area of voice recognition, several devices are just becoming available which handle a small vocabulary for selected applications. This technology will be discussed in a later section. In terms of capability and costs used in this study, the existing systems have been projected to increase in capacity by four times the number of channels served and to reduce in price by 25% compared to the 1978 devices. Thus, an eight- channel system selling for $80K will support 32 channels and sell for $60K in 1983. The four-fold increase in capacity may be on the optimistic side, but is possible. Although the cost difference between voice recognition and tone decoder devices is significant (i.e., voice recognition unit costs are 20 times greater than tone decoder units (Ref. Table 4.3.1-1)), this study will use VRS hardware configuration costs which include the voice recognition capability in addition to the

Table 4.3.1-1

VRS 32-CHANNEL HARDWARE ELEMENTS
(Solid State Vocabulary Storage)

Element	Description	Estimated 1983 Cost
Processor	Minicomputer with 256K bytes of memory and I/O interfaces	$10K
Voice Management Unit	Multi-channel voice output control	$ 3K
Voice Generation Unit	Digital to analog voice output unit	$ 2K
Tone Decoder Unit	Tone recognition and input channel multiplexing	$ 3K
Voice Recognition Unit	Voice input recognition and channel multiplexing	$60K
Vocabulary Storage Unit	One of the following options:	
	PROM for 4K vocabulary (ADPCM)	$20K
	PROM for 1K vocabulary (LPC)	$ 4K
Terminal	PATWAS message entry	$ 1K
Telephone Interface	Interlaced connection and subsystem interface control	$ 1K

tone input unless stated otherwise.

The last major hardware area of concern is the PATWAS real-time message entry capability. In the early phases of implementation, when a limited VRS vocabulary may exist, it may be necessary to implement a real-time voice digitizing and encoding capability to permit special messages to be added to the automatic weather reports comprising PATWAS reports. Thus, it will be necessary to provide at the VRS site a voice digitizing input device and a means of storing and retrieving these reports by the VRS computer. The input device is relatively simple and inexpensive ($2K) for ADPCM encoding; however, the LPC approach requires a considerable amount of processing and conceivably might need a separate minicomputer comparable to that of the VRS unit itself. At the time when the VRS vocabulary is increased to support all types of weather products, only a simple computer input terminal will be needed to enter these real-time PATWAS messages. These messages will be transmitted to the Data Base Processor where it will be translated using the extensive existing vocabulary for all its voicing needs. This study assumes that a full vocabulary exists and adds only the simple terminal costs to the hardware estimates.

In summary, the VRS hardware elements are listed in Table 4.3.1-1 for the full implementation capability. Also shown are the projected costs by element. These costs have been estimated using available literature, discussions with manufacturers and experience with similar hardware items. The estimates assume that 100 or more units would be produced by a manufacturer with adequate production experience to develop specialized hardware tailored for this application.

For comparison, a simplified 20-channel version of the current VRS prototype would cost about $60K using 1978 hardware. The projected 32-channel system will cost $40K in 1983 (with no voice recognition capability). This difference reflects an increase of about 50 percent in channel capacity due to the elimination of general purpose software needed in the prototype, more efficient software and the selection of a minicomputer with characteristics better suited to the VRS functions. The 38% lower price reflects cost reductions due to five years of hardware advances and the highly competitive nature of the mini-and microcomputer industries. These estimates will be used as the basis of our computerized network analysis.

4.3.2 Maintenance of VRS Equipment

To simplify this alternatives study, maintenance cost estimates for a VRS site will be related to the equipment costs by a simple percentages of hardware cost. For this study, the FAA has established a 20% value per year for estimating associated hardware inventory, spare parts, and labor. This 20% value was derived by assuming that the hardware costs associated with 134 VRS sites was $80K per site. This 20% value established by the FAA compares on the high side of industrial maintenance contract estimates which run between 5% and 10% of equipment costs each year for such systems. It is assumed that one-day service is all that is required for VRS sites since each site will have a dual VRS unit at a minimum and will operate in a fail-soft mode in event of failure in one unit. Relaxing maintenance to one-day service may actually reduce maintenance costs closer to the 10% range by permitting a regional maintenance depot concept to be used.

4.3.3 Data Base Processor Hardware

This national VRS implementation alternatives study is based upon a network of distributed processors. The pilot interface with the automated system is with the VRS unit discussed earlier. This VRS unit requires support in supplying the encoded weather products and in handling flight plan filing information. These supporting services are relegated to the Data Base Processor. One Data Base Processor is estimated to have the capacity to service up to eight VRS units simultaneously. At this level of support, a minicomputer system with a capacity equivalent to the current prototype Data Base Processor (a Digital Equipment Corporation PDP 11/70) will adequately handle the workload without response delays. This number of VRS units is conservatively estimated. A single weather data base file on a single disk storage device will support approximately 20 weather report retrievals per second (256 byte reports, equates to about 35 seconds of utterance). This allows for an equal amount of access time for data base updates. Selecting 8 VRS units, the random service requests from 256 users (8 VRS units with 32 channels each), although averaging about 8 accesses per second would allow for queuing requests 2.5 times this average without any delay.

Table 4.3.3-1 presents the key elements in the Data Base Processor.

TABLE 4.3.3-1

DATA BASE PROCESSOR HARDWARE ELEMENTS

Element	Description	Estimated 1983 Cost
Processor	Large capacity minicomputer with 1.25 megabyte memory, control consoles, network interface, tape unit, and operating system	$100K
Storage Disks	Two large capacity disk storage drives and controller	$ 25K

An important consideration in the selection of the Data Base Processor hardware should be adequate memory for efficient buffering of user data and information. This Data Base Processor buffering capacity is needed to minimize the memory requirements in the VRS units. Associated with this large amount of memory is the need for easy addressing of the full memory. It may be desirable to consider the newer 32-bit word size minicomputer systems for their ease in accessing buffers anywhere in memory.

For comparison, the current prototype Data Base Processor costs about $160K. The projected 1983 costs are approximately 20 to 25% less, based upon competitive price reductions and technology advances. This price estimate will be used for this study analysis.

4.3.4 Maintenance of Data Base Processor Hardware

It is assumed that the Data Base Processor hardware will be co-located at the FSDPS sites. In fact, if the FSDPS has the available capacity and required features, it may perform all the functions of the Data Base Processor, thus eliminating a separate Data Base Processor purchase. However, for this study, we will assume a separate Data Base Processor is required and must be maintained. As in the VRS hardware maintenance, a 2[illegible]% of purchase price appears reasonable for estimating yearly maintenance costs. These costs may be reduced if the specific processor and disk drive are the same as those used for the FSDPS hardware. The commonality will permit shared inventory and reduced training requirements for maintaining other hardware.

4.3.5 Telephone Equipment

This alternative study is based upon minimizing the costs of telephone equipment wherever a simple beneficial approach can be found. For example, the VRS hardware is scoped to include the tone decoding function provided by the Dataphone 407C units in the prototype system. All that is required is a simple DAA (Direct Access Arrangement) device to connect the VRS to the telephone lines. The requirement for specialist interaction can also be solved simply by installing a push-button extension telephone (with a hold option) at the specialist's desk. When the VRS computer determines that the caller requests specialist service, it simply puts the caller on hold. The extension at the specialist's desk will blink until he services the caller. Neither call directors nor call forwarding equipment are anticipated for these alternatives.

4.3.6 Voice Recognition Hardware

This section is devoted to analyzing the role of voice recognition in this study. Although included in the requirements specification, this technology is not quite ready for immediate application to the VRS since the field of speech signal recognition is still in the infancy stage. Basic research and development work are being conducted at many laboratories and universities. This work can be classified into three categories: speaker verification, speaker identification, and speech recognition.

For speaker verification, an identity is claimed by the user, and the verification system is required to make a rather strict decision, to accept or reject the claimed identity. The notion of speaker identification differs significantly from the speaker verification problem, hence a more complex problem. In this case, the system is required to make an absolute identification among speakers in the user population. In the area of speech recognition, however, the problem is further complicated by the existence of a large number of options which must be specified before the problem can even be approached. Examples of major considerations are listed as follows:

1. Type of Speech - isolated words, connected speech.

2. Number of Speakers - single, designated speakers, unlimited user population.

3. Type of Speakers - male, female.

4. Environment - noisy, quiet.

5. Transmission System - microphone, telephone.

6. System Training - none, fixed, continuous.

7. Vocabulary size - small (e.g., 20 words); medium (e.g., 100 words); large (greater than 100 words).

8. Spoken Input Format - restricted text, free spoken format.

Associated with the above options, there are a number of practical difficulties described as follows:

Speech Pattern Variation

Variations in speech patterns are found even when the same person repeats a word, particularly over a period of time. This complexity is greatly magnified when different speakers say the same word. Such differences have made the design of accurate "universal" recognition system (unlimited user population) a formidable task. Consequently, most systems in practical use employ the speaker adaptation design, i.e., system training approach. However, this approach may degrade the applicability of a speech recognition feature in the national VRS.

Background and Breathing Noise

Background and breathing noise can be a real problem where systems may have to operate at noisy work sites. Experience indicated that this problem could be solved by using a noise-cancelling microphone on a lightweight headband as those used by air traffic controllers. However, this approach would not help the VRS users (pilots) using regular home or office telephones.

Extraneous User Sounds

Extraneous user sounds may occur as as a result of coughs, sneezes, throat clearings, or side conversations. These types of sounds can be eliminated to a great extent, if not completely, by the technique of using cued speech. This means that the recognition device is told to listen to the user only at precisely controlled times when the user is told to respond.

The above-mentioned difficulties can be minimized by clever designs and judicious selection of system options, and these are precisely the approaches taken by a few companies to market their speech recognition products. For example, one company has produced a voice data entry device with up to a 200-word vocabulary. This trainable unit can achieve high recognition level at 99.7% through the use of high quality microphones in a controlled environment. In using the regular telephone, the recognition accuracy has shown marked degradation to 80%, which, according to the company, will be improved via training. A single user unit sells for approximately $10.5K. Another company, on the other hand, taking the "universal approach," has produced a 25-word vocabulary voice recognition unit. The company claims that a 90% recognition level via regular telephone is attainable. An 8-channel unit has a price tag of $80K.

In summary, an operational voice recognition device applicable to the national VRS appears to be just beyond the present state-of-the-art. More research and experimentation needs to be done to solve the aforementioned problems as well as to answer some of the operational questions, such as optimal vocabulary size, acceptable recognition accuracy, pilot interface and acceptance, etc. Cost is a, if not the, major factor which impacts the applicability of the voice recognition to the VRS. Unless in three to five years the cost of a single-channel voice recognition unit is reduced to $2K - $4K, it would not be considered cost-effective for the national VRS implementation. However, for completeness, the cost of a voice recognition unit capable of servicing 32 users (i.e., $60K) has been included in all of the following hardware alternatives unless stated otherwise.

4.4 Proposed Hardware Configurations

It is proposed that the national VRS be structured in a hierarchical network configuration as shown in Figure 4.4-1. Each Data Base Processor can handle up to eight VRS computers, which in turn can handle up to 32 user calls simultaneously. Through the voice and tone input telephones, pilot users can either interface with the VRS computers or speak with the FSS specialists. This can simply be achieved by a push-button extension telephone with the hold option at the specialist's desk (See Section 4.3.5). Incoming telephone lines with extensions at the specialist's console are interleaved to a multiplicity of VRS computers at each site. This technique provides the VRS with the fail-soft feature so that the failure of any VRS computer will only partially degrade the VRS service in the areas covered by the failed computer. For the same reason, one or more back-up Data Base Processors are required for the access by VRS computer through the dial-up telephone lines in case a dedicated Data Base Processor and/or a dedicated data line fails.

Functionally, the VRS computer interacts with pilot users by interpreting user requests, obtaining the desired weather products from the Data Base Processor, converting these products into digitized speech data, and finally, generating the voice responses to the requesting users. In addition, it also provides the PATWAS and the TWEB services to users. The major function of the Data Base Processor include receiving the raw weather data periodically from the Weather Message Switching Center (WMSC) computer, converting

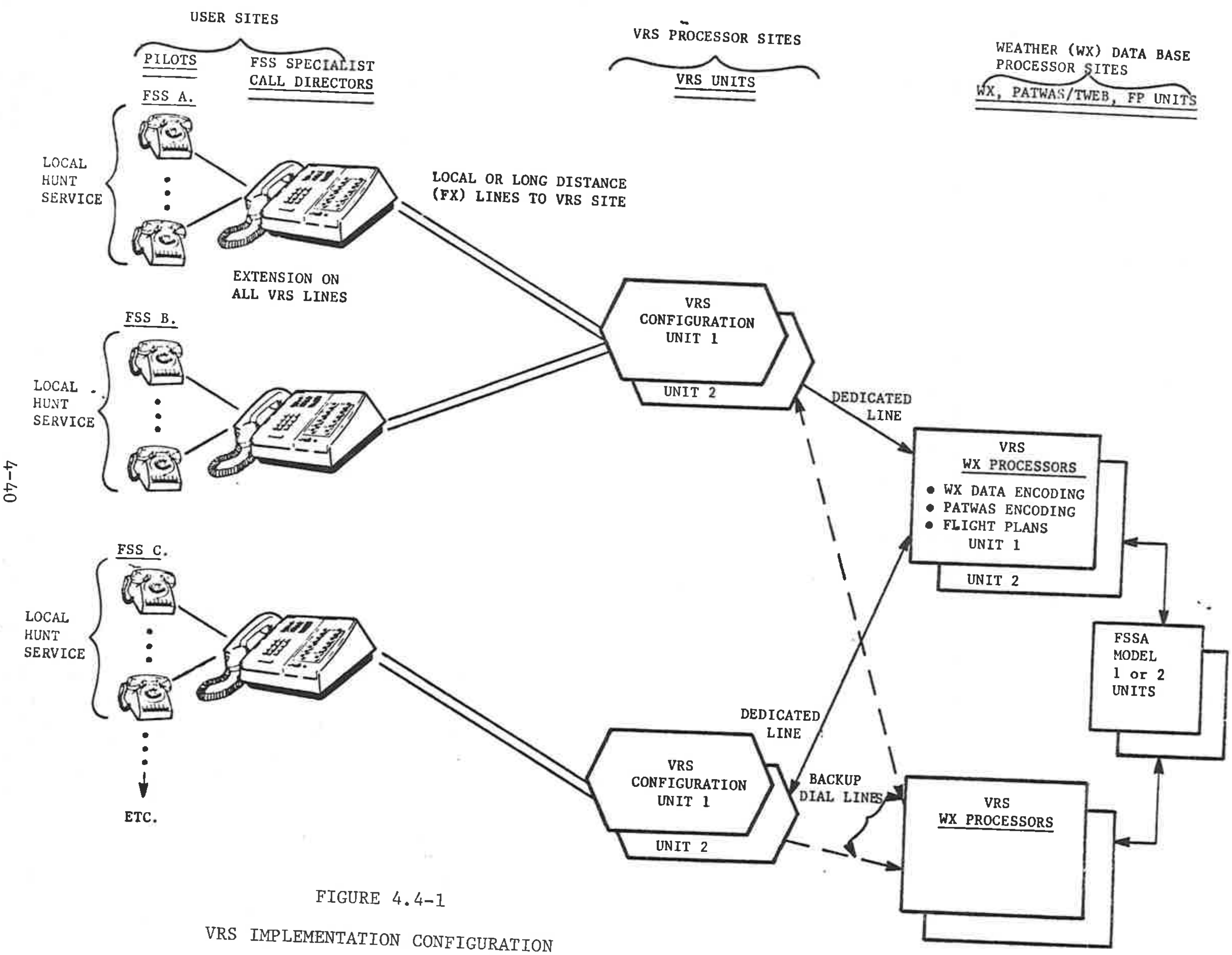


FIGURE 4.4-1

VRS IMPLEMENTATION CONFIGURATION

these raw weather data into binary representation suitable for use by the VRS computer, and processing flight plans submitted by pilots.

Physically, these VRS computer and Data Base Processors can range from being distributively co located at Flight Servce Stations or being centrally clustered into one or a few hub centers. This is the subject of a trade off study in Chapter 5, Communications Analysis, and will not be elaborated any further here.

4.4.1 Partial Implementation Alternatives

The purpose of the partial implementation alternatives is to provide a low risk quality VRS service to users without having to wait for the full capability system which may require a longer time to develop. To satisfy these requirements, it is desirable to develop the partial implementation alternative systems on the basis of the TSC VRS (ADPCM Technology) demonstration system with perhaps some added functionalities and enhancement features. This approach provides the shortest development cycle and lowest technical risk. In fact, most commercially available medium-to-high performance minicomputers with real-time system software could fill the roles of both the Data Base Processors and VRS Computers.

One partial implementation alternative for the national VRS configuration is shown in Figure 4.4.1-1. A moving head disk is used to store the 1,000-utterance vocabulary and the PATWAS messages. Due to the recent advance in disk technology, a moving head disk can provide more storage at less cost than a comparable fixed head disk as used in the TSC VRS demonstration system. Although the access time of the moving head disk is much longer than that of the fixed head disk, its data transfer rate is actually higher. In addition, an efficient design of the Multichannel Management Unit and the Voice Generation Unit should readily offset the slower access time inherent in the moving head disk. The projected cost for this system is $97K.

A second partial implementation alternative calls for the replacement of the moving head disk by a combination of solid-state memories. Erasable Programmable Read-Only Memory or Programmable Read-Only Memory of a moderate size for the storage of 1,000 utterances vocabulary is directly accessed by

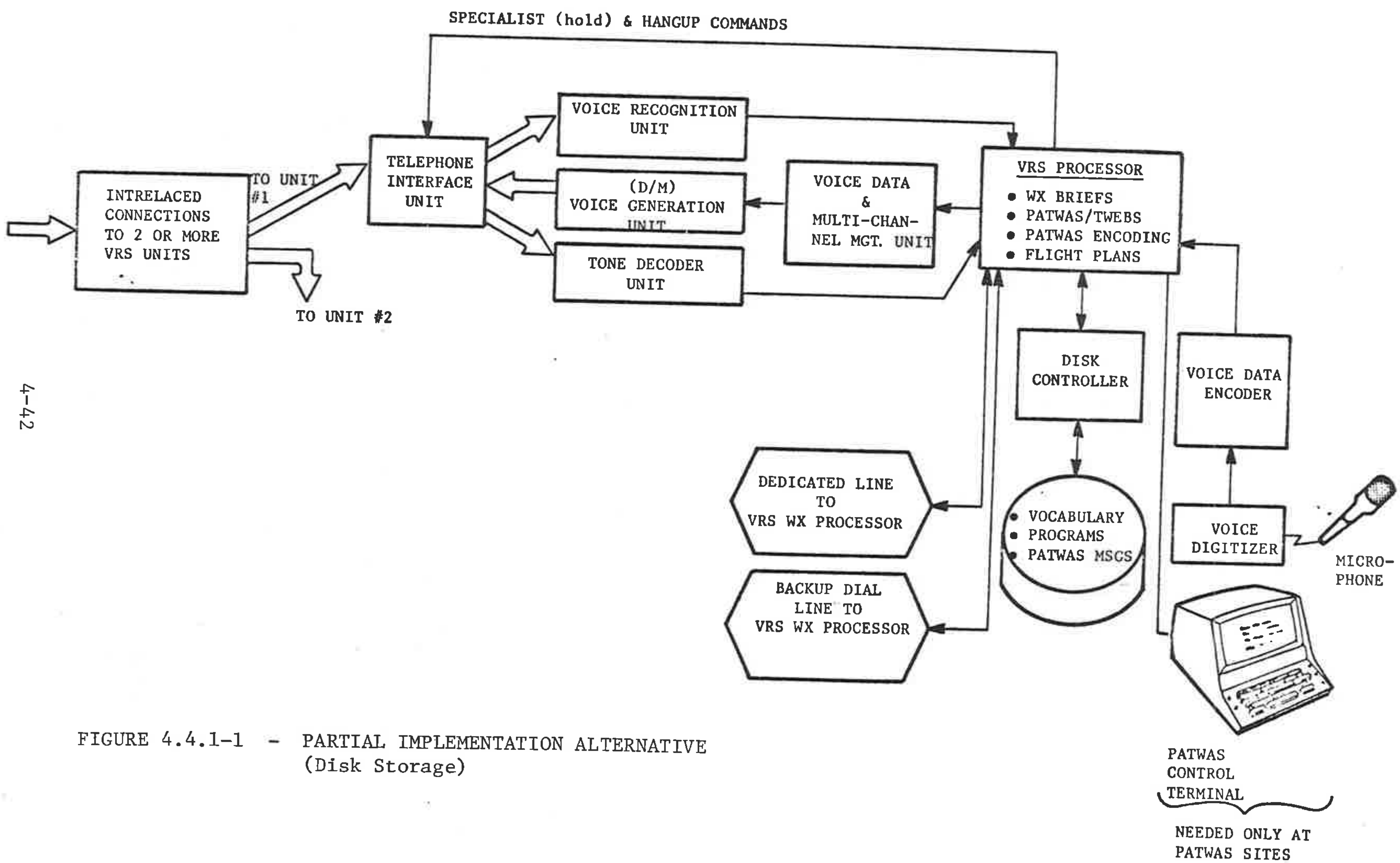


FIGURE 4.4.1-1 - PARTIAL IMPLEMENTATION ALTERNATIVE (Disk Storage)

the Multichannel Management Unit to yield fast system response and offload the VRS computer. Approximately 1 megabyte of solid-state Random Access Memory (RAM) is required to store locally digitized PATWAS message segments. This alternative is represented in Figure 4.4.1-2. The projected cost of this alternative is $93K.

Both alternatives require a facility for the FSS specialists at PATWAS sites to compose PATWAS messages and encode voice data not contained in the vocabulary.

4.4.2 Full Implementation Alternative

The full implementation alternative for a VRS computer configuration is illustrated in Figure 4.4.2-1. It is a natural evolution from the previous implementation alternatives. A full size vocabulary in the order of 4,000 utterances is implemented by PROM chips whose price is expected to decrease considerably in the next 3 to 5 years. With the implementation of a full vocabulary, there is no longer a need for the voice digitizer and encoder equipment at the PATWAS site. Only the PATWAS message data entry terminal is required. This full VRS configuration is feasible and desirable for a national VRS implementation and is the simplest and most reliable hardware configuration evaluated in this study. This therefore is the VRS unit used for the subsequent computerized analysis and costing estimates. This hardware configuration is projected to cost $100K.

4.4.3 Voice Encodng Alternatives

As discussed in Section 4.1.6, Speech Digitization and Compression Methods, Linear Predictive Coding is one of the most promising techniques for producing intelligible quality voice output with low input data rates. Further research and development work is needed before LPC techniques could be applied in any complex operational system such as the VRS. However, due to its potential in future VRS applications, the implication of LPC to the proposed system configuration is considered.

Figure 4.4.3-1 shows a special LPC arrangement of the full VRS alternate configuration. The VRS computer and its interfaces remain unchanged. The size of the vocabulary in terms

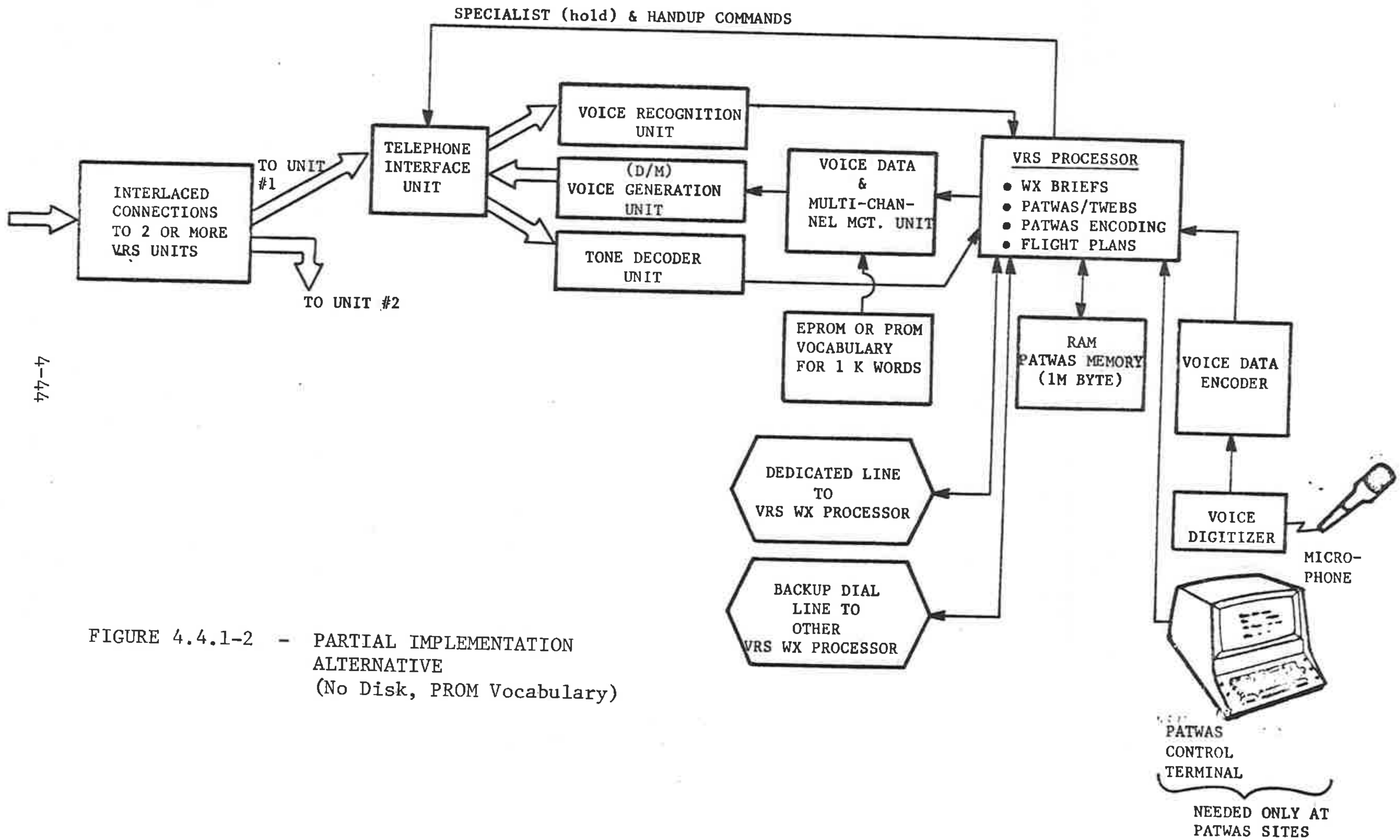


FIGURE 4.4.1-2 - PARTIAL IMPLEMENTATION ALTERNATIVE
(No Disk, PROM Vocabulary)

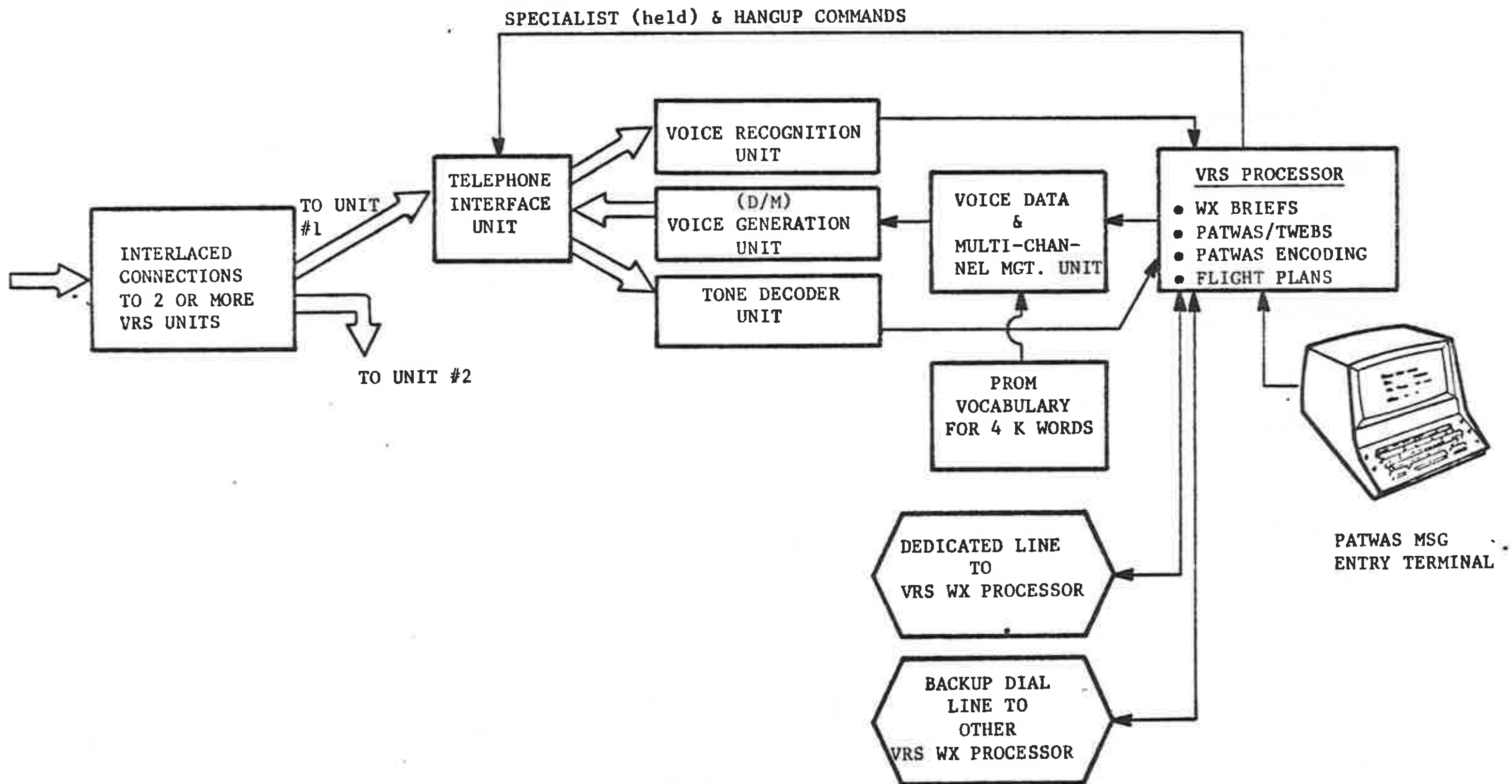


FIGURE 4.4.2-1 - FULL IMPLEMENTATION ALTERNATIVE
(No Disk, PROM Vocabulary)

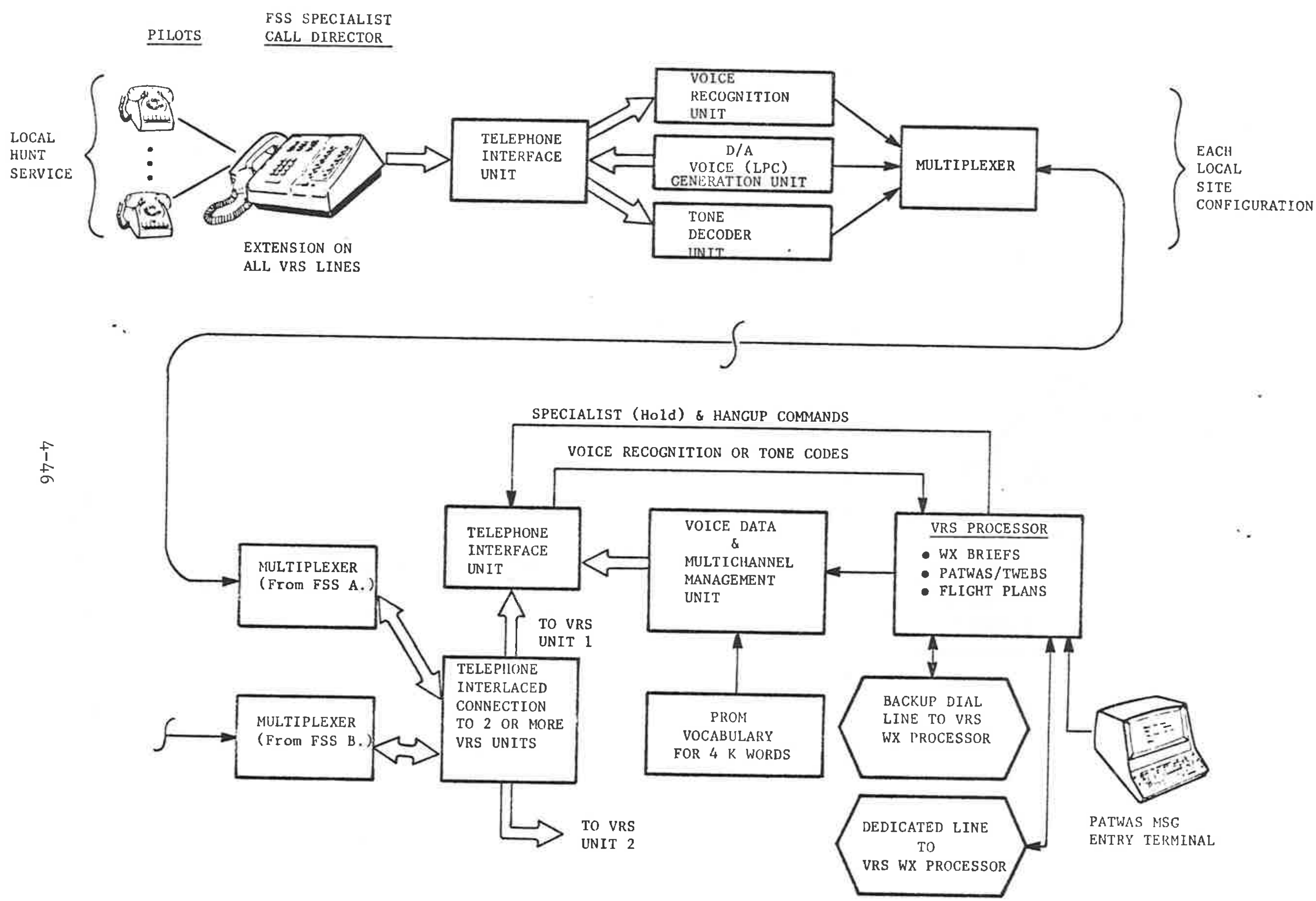


FIGURE 4.4.3-1 - ALTERNATE LPC CONFIGURATION

of digital bit storage should enjoy a sizable reduction as compared to the ADPCM approach for the same 4,000 utterances. Due to the low input data rate requirement, it is desirable to locate the LPC voice generation units close to users in order to reduce the length of the voice lines yielding savings in line cost. However, these savings are partially offset at least, by the complex requirements of high-speed multiplexors and modems for those data lines between the voice generation units and the VRS computers. The projected cost of this system is $92K.

4.4.4 Network Configuration Alternatives

As discussed in Section 4.1.5, a set of Major Computer Network Configurations was identified for further computer analysis. These configurations cover a wide spectrum, from centralization to decentralization, of network structures. Although the results in terms of various costs from the computer analysis will be discussed in Chapter 6, System Trade-Off Analysis, it is helpful to highlight the physical layout characteristics over the entire nation. Figures 4.4.4-1 through 4.4.4-8 depict the set of the Major Computer Network Configurations in a graphic representation. The graphics legend used is described as follows:

Small Dot	=	VRS demand node, i.e., FSS's without VRS computer
Large Dot	=	Computer site, either VRS computer or Data Base Processor
Thin Line	=	Voice line connecting VRS computer to demand node
Heavy Line	=	Data line connecting Data Base Processor to VRS computer

Figure 4.4.4-1 shows a centralized version where all the required Data Base Processors and VRS computers are located at the two NADIN Centers, i.e., Salt Lake City, UT, and Atlanta, GA. The division of VRS services between these two centers is based on ARTCC regions. All the telephone lines for VRS services, within one ARTCC region, will be connected to the same NADIN Center if the ARTCC region is on the

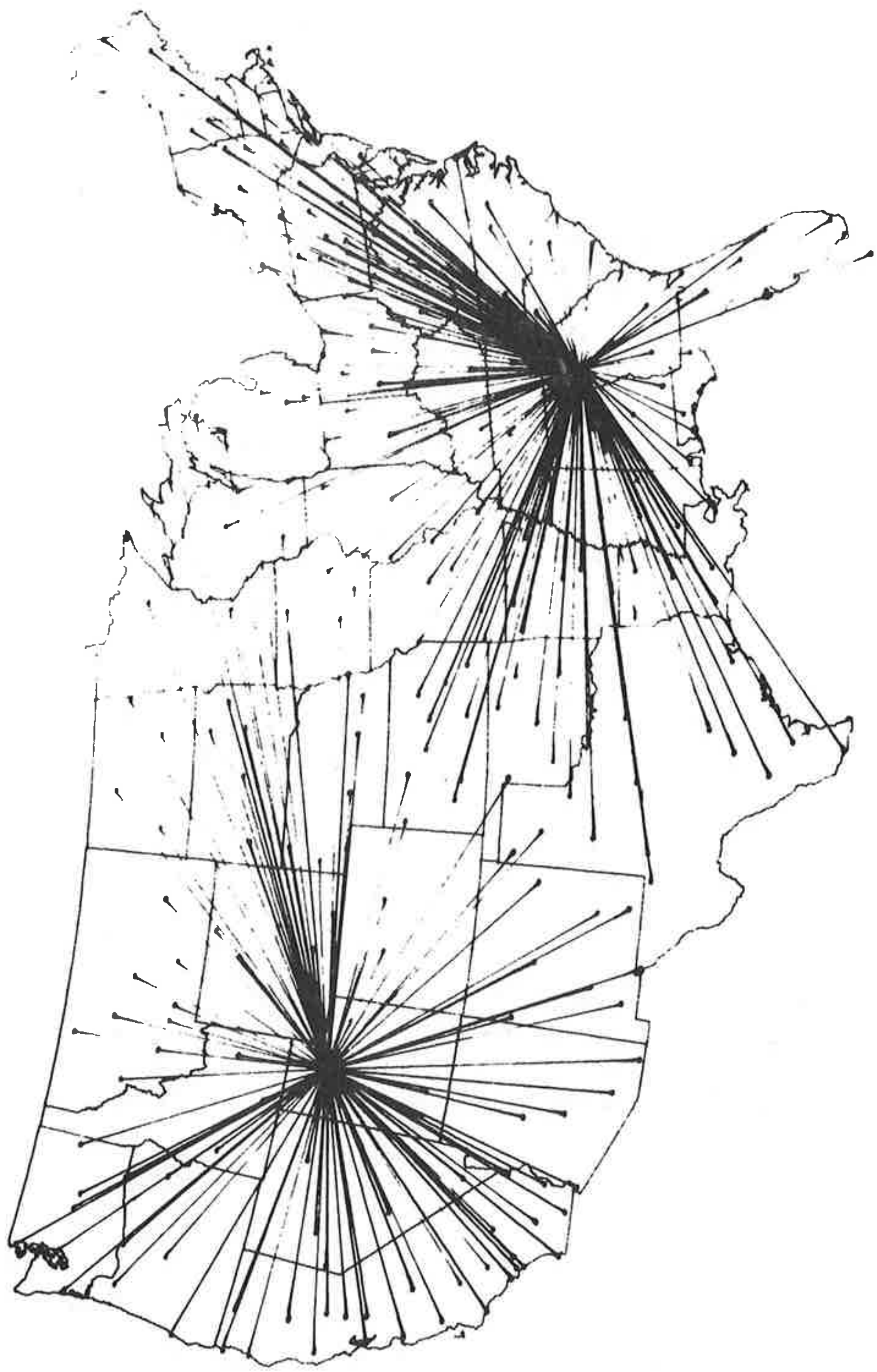


FIGURE 4.4.4-1. - NADIN CENTRALIZED CONFIGURATION (2 VRS/2 DBP)

average closer to this center than the other. Figure 4.4.4-2 illustrates the first step decentralization whereby Data Base Processors remain at the two NADIN Centers but the VRS computers are distributed among the 20 ARTCC's plus one FSS in Great Falls, MT. The cluster of FSS's in Montana are, for economic reasons, too far away from any ARTCC or the NADIN Center in Salt Lake City to be served by them. The required number of VRS computers at the Great Falls FSS service the users in the Montana area.

In Figure 4.4.4-3, the Data Base Processors are also distributed among the 20 ARTCC Centers co-located with the VRS computer. This network eliminates the need for the data line transmission between Data Base Processors and VRS computers. Please note the exception at Great Falls where data lines are still needed for the transmission of weather products from the Data Base Processors at the Salt Lake City ARTCC.

Keeping the Data Base Processors at the 20 ARTCC Centers, Figures 4.4.4-4, 4.4.4-5, and 4.4.4-6 demonstrate further decentralization of VRS computers among 45, 134, and 293 FSS's respectively. The decentralization occurs first at the 43 Level III FSS's which will be automated under the FSAS program, second at the 134 VRS automation consolidated FSS's, and finally at the 293 FSS level for the entire nation. It is interesting to note the shift of balance between the data lines connecting between computers and the voice lines between computers and users as the network configuration becomes more and more distributed in nature.

Lastly, two partial implementation networks will be examined in order to evaluate factors in phased installation. The first network, Figure 4.4.4-7, shows the 3 busiest ARTCC regions with the same network decentralization as Figure 4.4.4-4 (43 VRS/20 Data Base Processor). Figure 4.4.4-8 shows a 14-center level of installation for this configuration. The results of the analysis of these partial implementations are presented in Section 6.9.

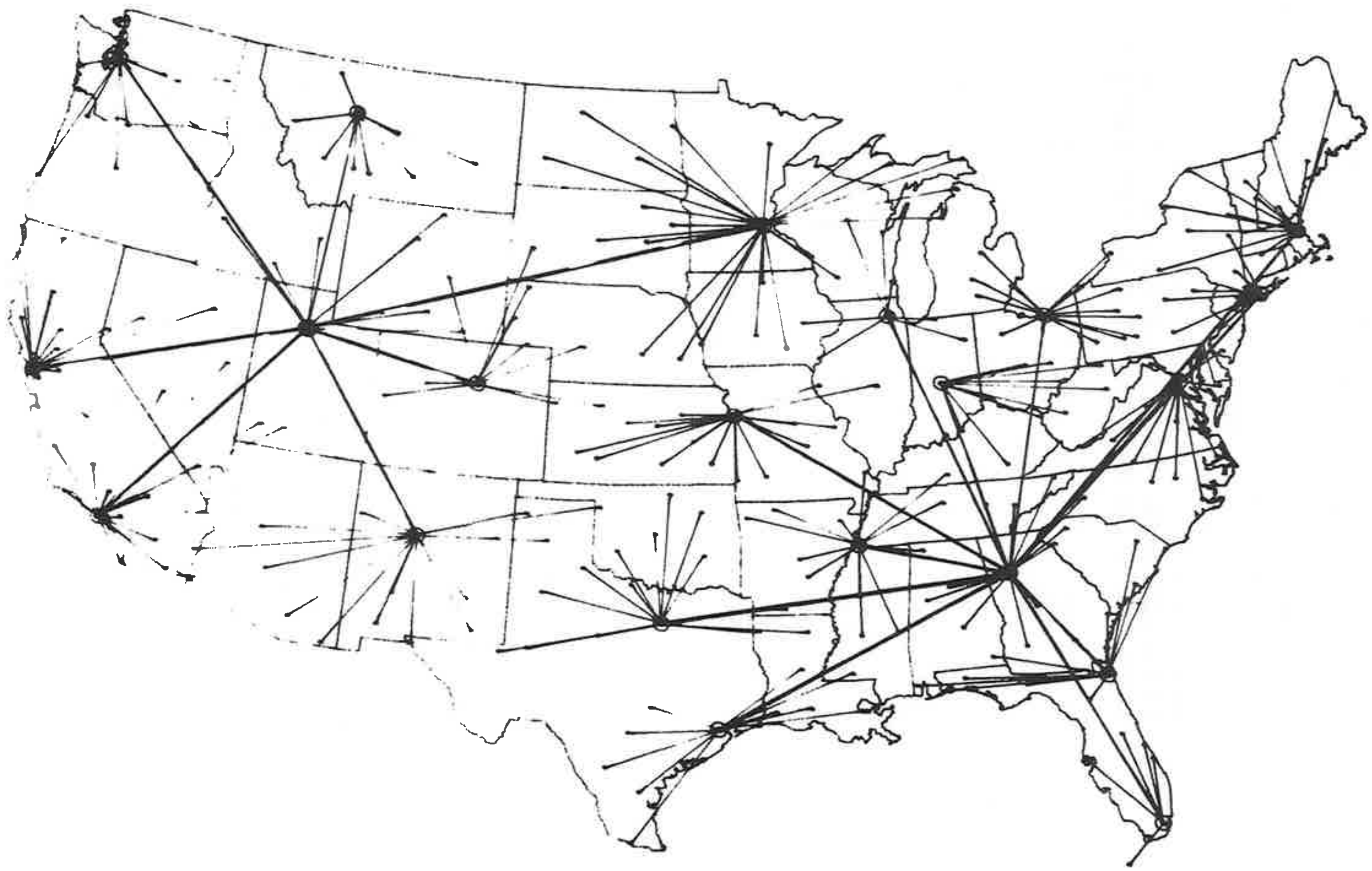


FIGURE 4.4.4-2. — FSDPS VRS/SITES (21 VRS/2 DBP)

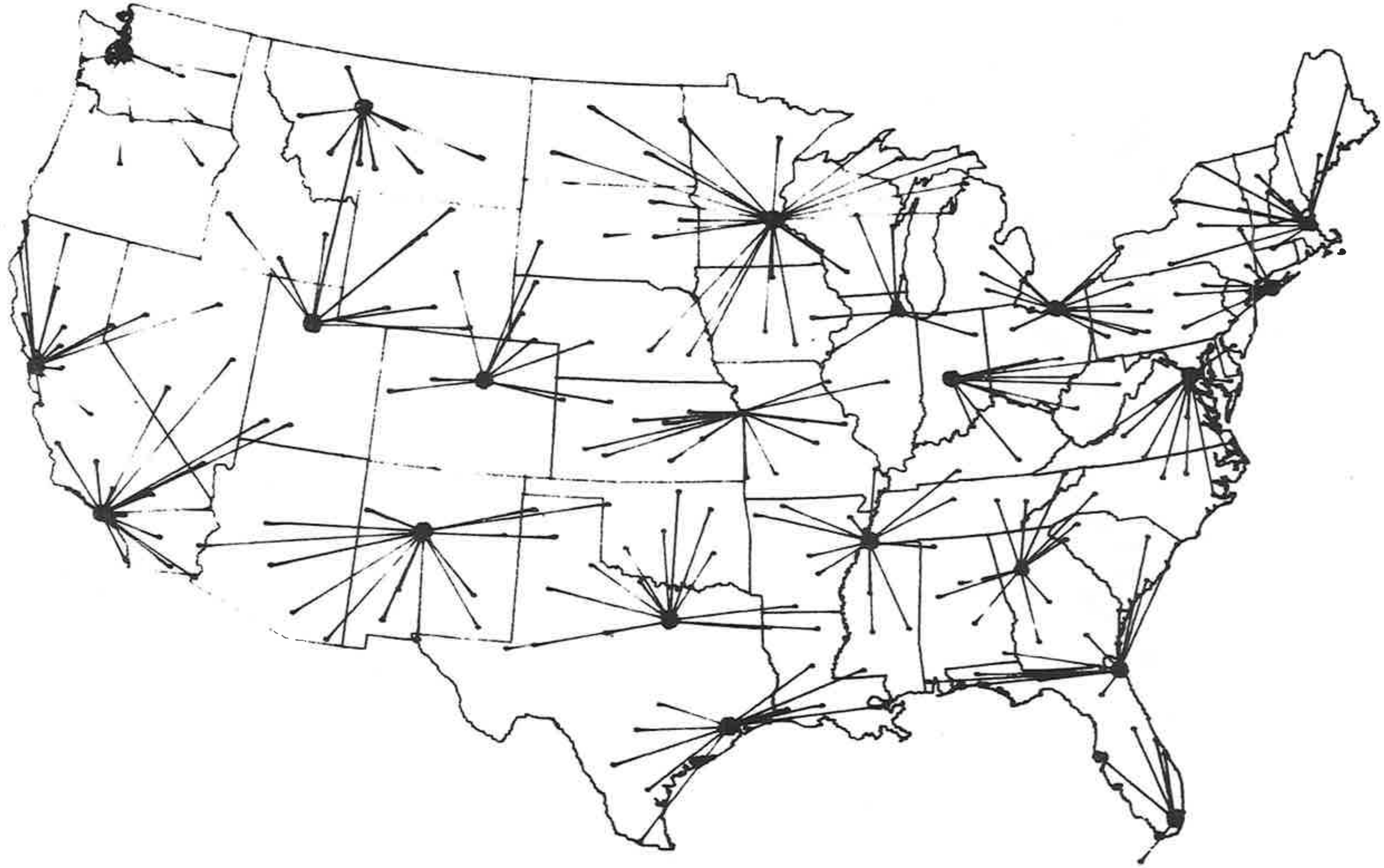


FIGURE 4.4.4-3 - FSDPS SITES (21 VRS/20 DBP)

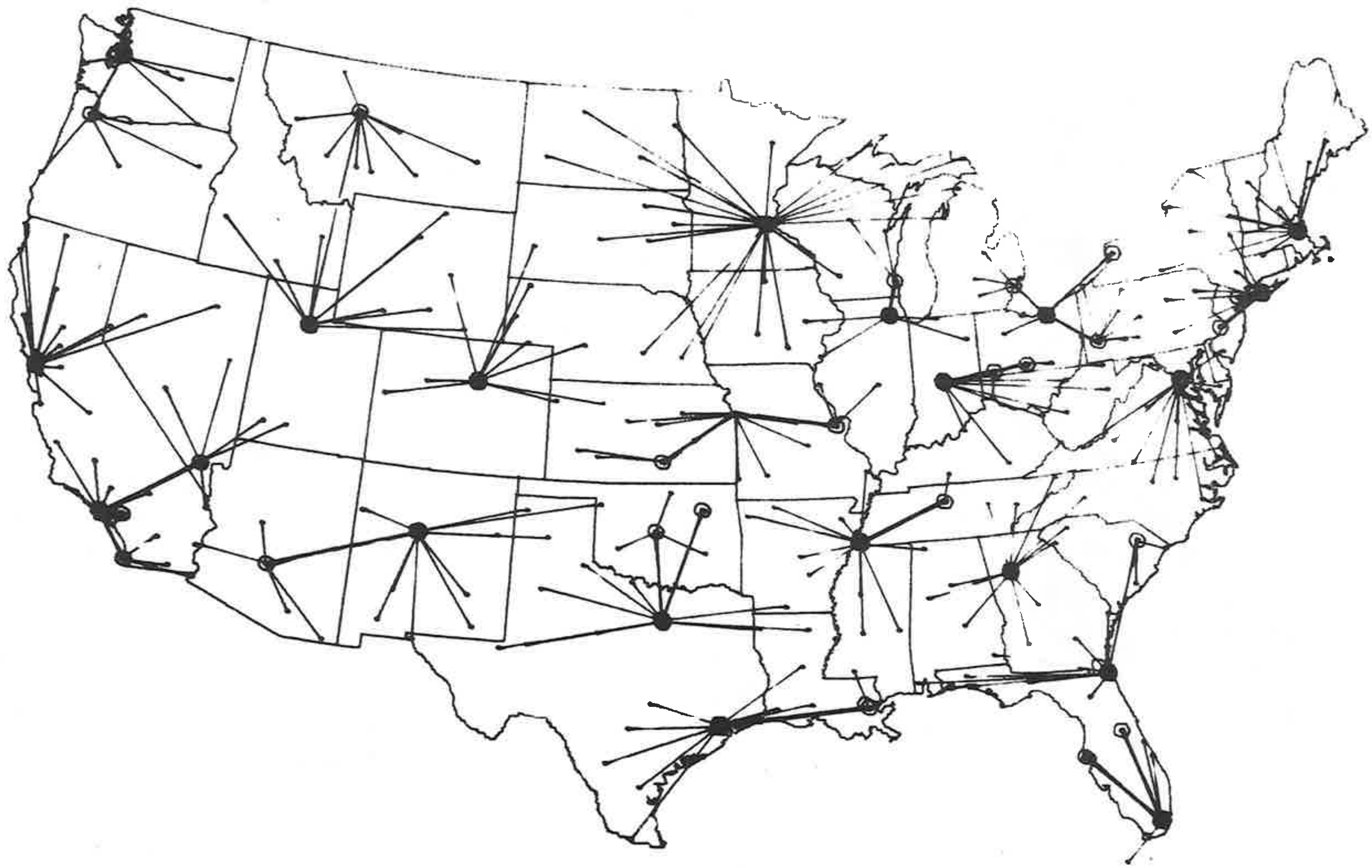


FIGURE 4.4.4-4 - LEVEL III FSS VRS/FSDPS DBP SITES (43 VRS/20 DBP)

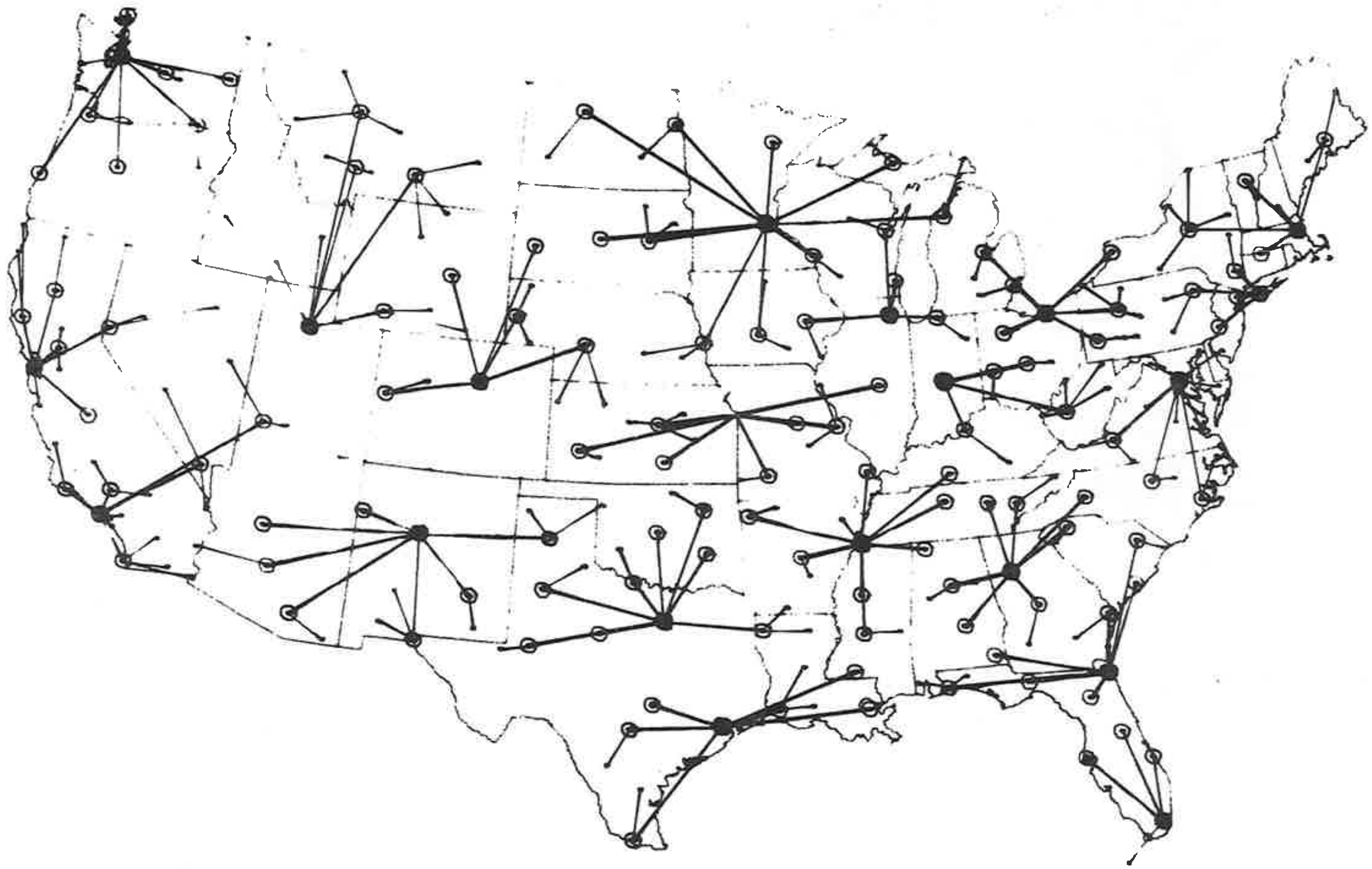


FIGURE 4.4.4-5 - CONSOLIDATED FSS VRS/FSDPS DBP SITES (134 VRS/20 DBP)

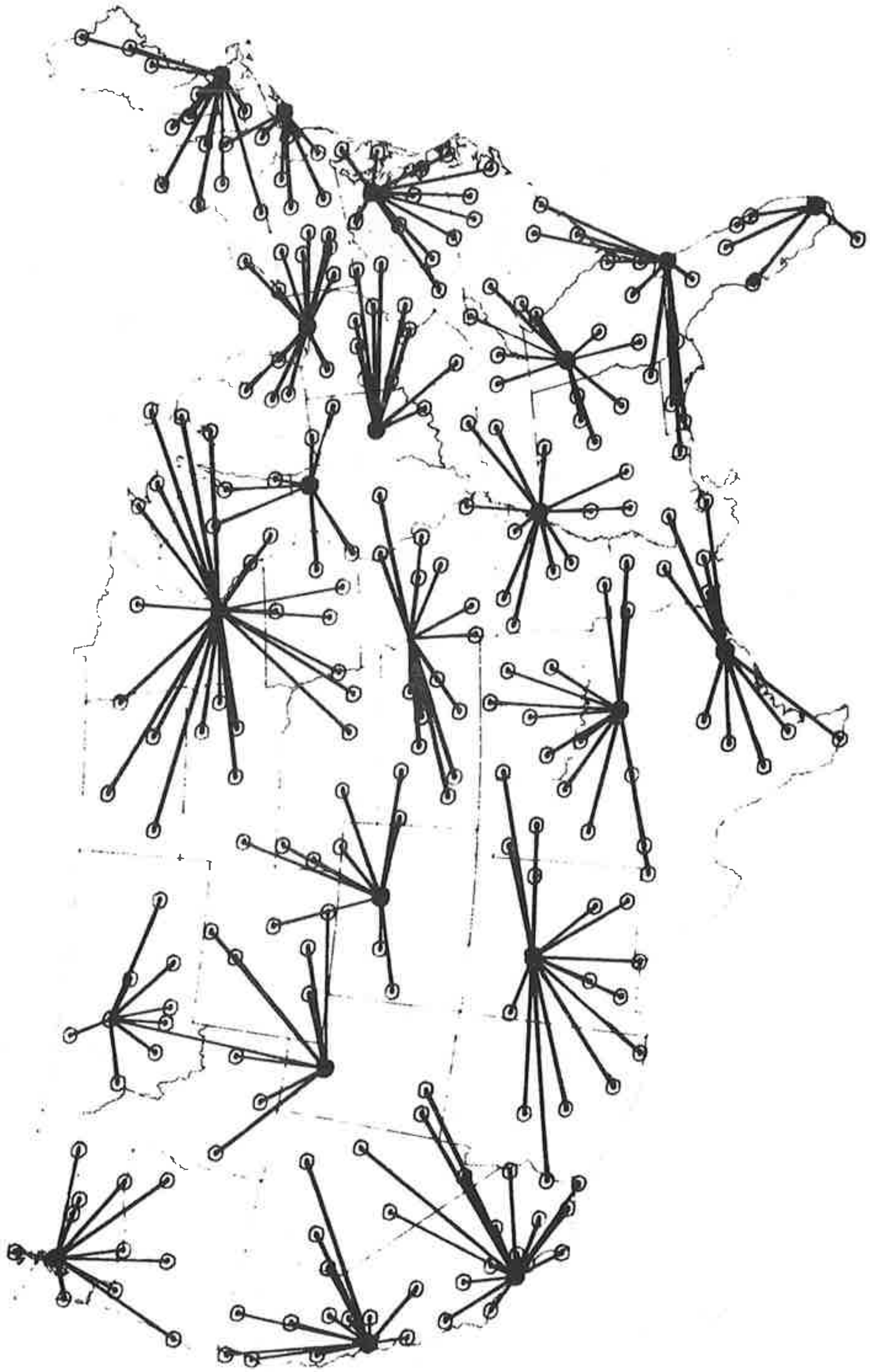


FIGURE 4.4.4-6. — ALL FSS VRS/FSDPS DBP SITES (293/20)

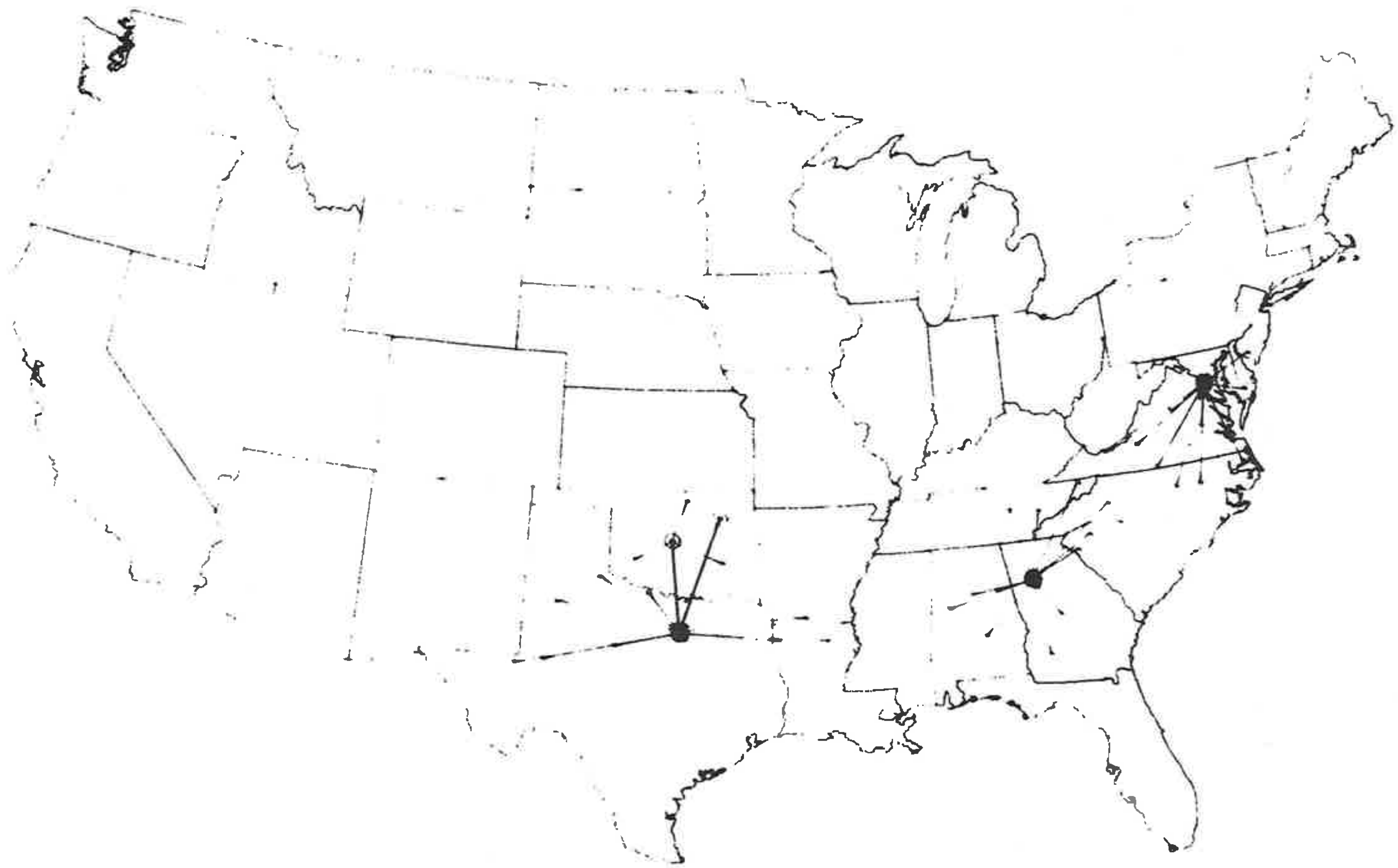


FIGURE 4.4.4-7 — 3 ARTCC AREAS (LEVEL III FSS VRS/FSDPS DBP SITES) PARTIAL IMPLEMENTATION

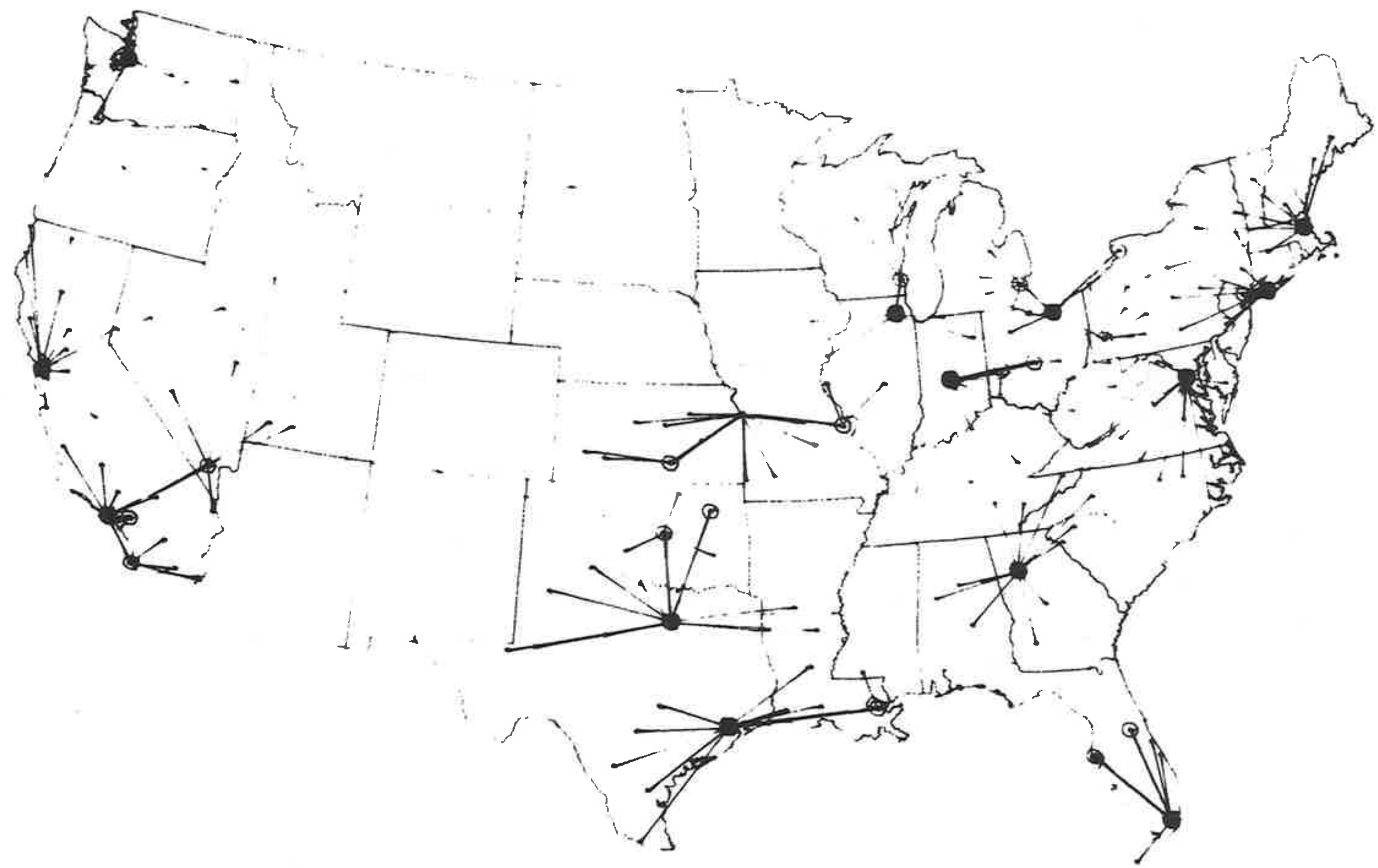


FIGURE 4.4.4-8 — 14 ARTCC AREAS (LEVEL III FSS VRS/FSDPS DBP SITES) PARTIAL IMPLEMENTATION

5. COMMUNICATIONS ANALYSIS

5.1 Introduction

The basic VRS, as shown in the block diagram in Figure 5.1-1, consists of a Data Base Processor which keeps up-to-date national weather data and a VRS computer which accepts pilot demands and generates voice responses. The VRS is a hierarchical system whereby one Data Base Processor may handle a number of VRS computers each of which in turn may handle a number of users interacting with the VRS simultaneously. Data lines are used to interface between computers, whereas voice lines are used to communicate between pilot users and the VRS computers.

To satisfy the pilot demands on a national basis, it is apparent that the VRS required would be a hierarchical computer network interconnecting computers by data and voice lines typically as shown in Figure 5.1-2. Consistent with the FAA Flight Service Station organization, these Data Base Processors and VRS computers may be either centrally located in major facilities, such as NADIN centers or ARTCC's, or distributed among automated flight service stations.

The degree of centralization (or decentralization) of computers has a profound impact on both the cost and utilization of computers and the cost of the communication lines. In general, a higher degree of centralization yields higher computer utilization, lower computer cost and higher line cost. In contrast, a higher degree of decentralization tends to produce lower computer utilization, higher computer cost, and lower cost of communication lines. The purpose of the communications analysis task is to seek a better understanding of how the system cost varies with network configuration, and to identify a number of alternative configurations with minimal system cost.

5.2 Analytic Approach

The analytic approach used in this study is straightforward. The basic data used in this approach is the forecasted pilot briefing demand (Section 3.0). A mathematical model was developed which processes these data and maps and computes the number of voice lines needed to satisfy the pilot demands at a predetermined level of service. From the number of lines to be serviced in a region, one can determine the number of VRS computers required and in turn dictate the number of Data Base Processors and data lines needed to satisfy these regional demands.

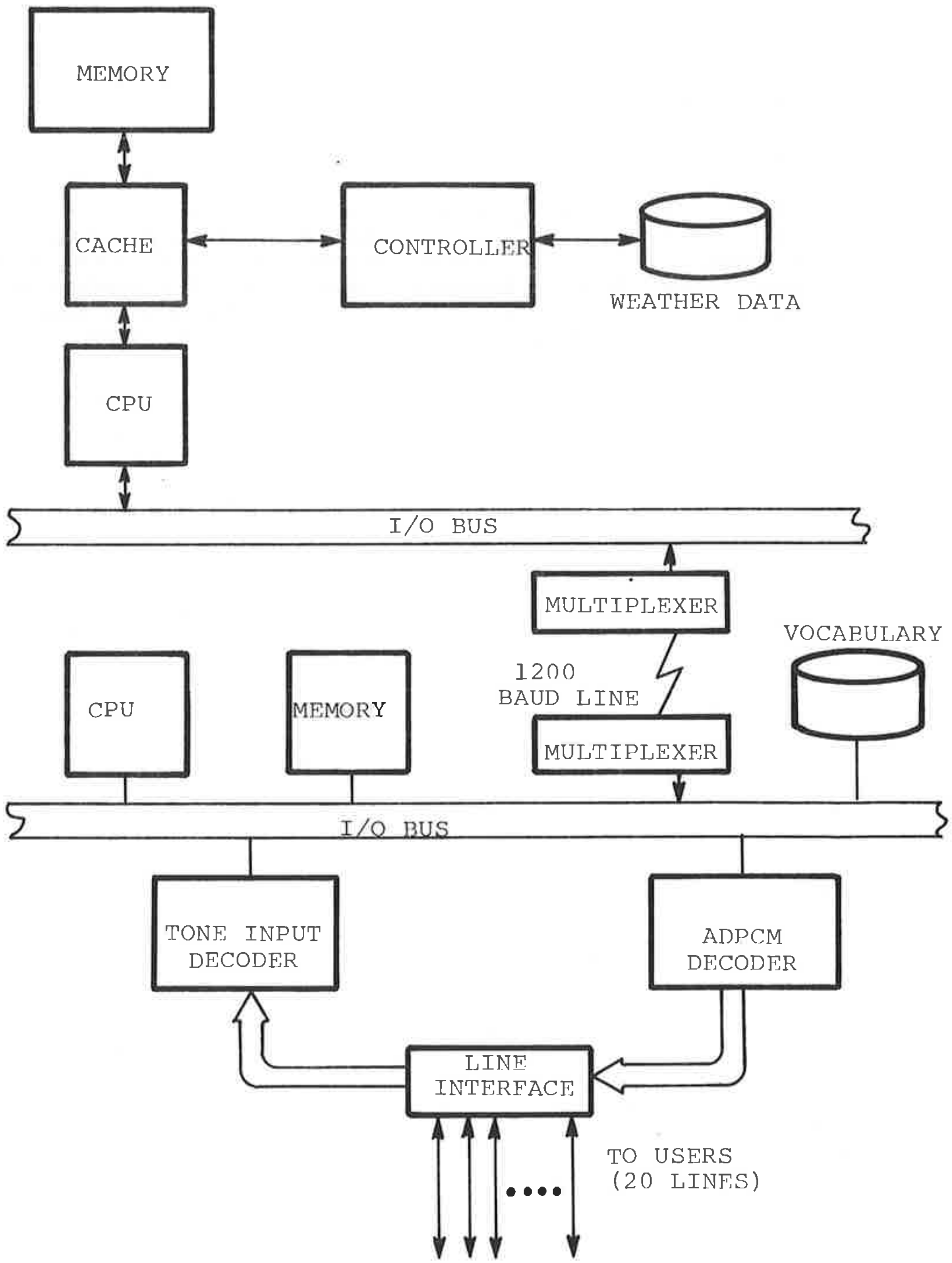


FIGURE 5.1-1 - VRS WASHINGTON DEMONSTRATION SYSTEMS

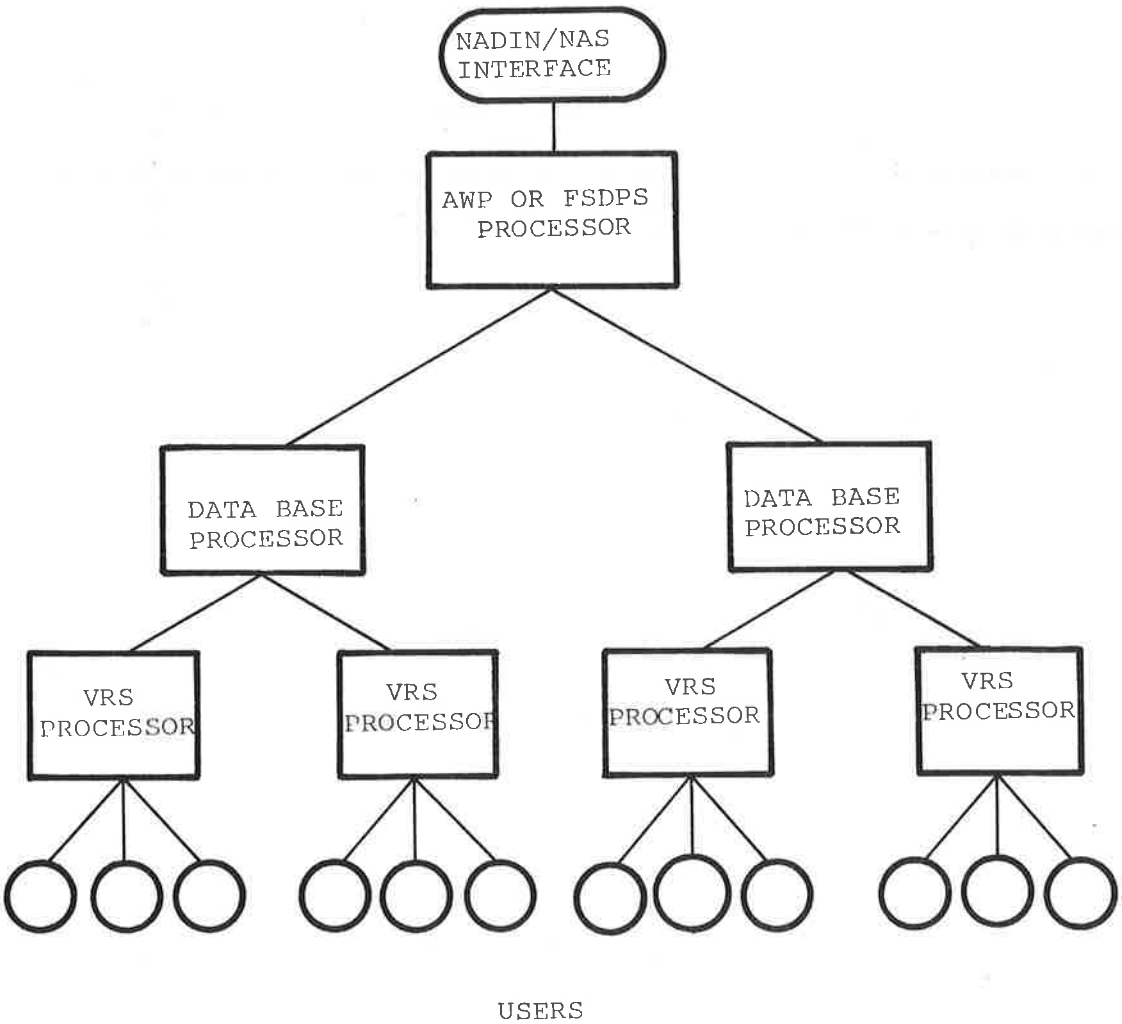


FIGURE 5.1-2 - VRS HIERARCHICAL NETWORK

The lowest level of the regional pilot briefing demand is computed at the flight service station level. Demands at the flight service station level can be summed up to determine the demands at the VRS and the Data Base Processor sites. Finally, the demands at the various sites can be summed to obtain the total national demand. Recognizing the distributed nature of this demand and the variety of VRS computer communications networks which are possible, it is necessary to consider the alternatives from centralization to decentralization. Our study attempts to provide a parametric analysis of these networks and to provide cost estimates of some candidate network configurations.

5.3 Communication Modeling Assumptions and Guidelines

Pilot Briefing Demands

The official FAA 1986 forecast figures are used for this study. The demand data includes the regional annual demand and the peak hour demand. The latter is important for proper system sizing. When the estimated 1986 PATWAS demand is added to the estimated 1986 VRS briefing forecasts, the total demand increases to 2.5 times the original FAA pilot briefing 1986 forecast. The communications analysis is based upon these forecasts and the 1995 forecasts.

Average Pilot Briefing Time

Statistics collected from the Washington DC VRS demonstration model showed that for three weather products, the average pilot briefing time was 3.75 minutes. As discussed in the Demand section, there will be more weather products and services in the national VRS in the future which results in a longer briefing time. For this study, we will focus upon 6 minutes as the average pilot connect time and also evaluate the impact of 4 and 8 minute average times.

Mathematical Model

The Erlang Multiserver Loss System model was chosen to calculate the number of voice lines required to satisfy a specific regional pilot briefing demand at a predetermined service level. The use of this loss model is applied such that callers who received busy signals, if they try again, will re-enter the system as part of the forecasted demand for the next interval.

Service Level

A 90% service level is a requirement for the national VRS. This means that the VRS will respond to 10% of the peak-hour pilot demand with a busy signal.

Computer Capacities

Based on our prototype VRS demonstration system and projected hardware advances (Section 4), this model assumes that a VRS computer is capable of handling 32 voice channels (or callers) simultaneously. It is also assumed that each Data Base Processor can service and interact with 8 VRS computers simultaneously. These capacity relationships enable the model to compute the minimum number of VRS and Data Base Processors needed to satisfy the network requirements.

5.4 Preliminary Communication Network Analysis

Early in this alternatives study, the need to narrow the scope of effort to the most important aspects of the network designs, prompted a simplified manual analysis approach. Initial estimates of demand and cost values of network configurations were made based upon preliminary data and rough approximations. The primary purpose of this first analysis was to estimate the sensitivity of network parameters and develop a quantitative estimation of communication needs.

To start this manual analysis, a number of simplifying assumptions had to be made. In the area of demand data, 100% of the 1986 forecasted pilot briefing estimates would be used as the projected VRS demand. This data was developed for each Flight Service Station in the conterminous U.S. In the area of equipment and telephone service costs, the approach was selected to assess an effective line cost per month for a given configuration, which then could be compared for relative costs. For a base line comparison, a Foreign Exchange (FX)/TELPAK average monthly cost per mile of $.59 can be considered as the most economical service for dedicated telephone line configurations. Comparisons with WATS (Wide Area Telecommunications Service) costs is more difficult since zones and inter/intra state tariffs are used. However, monthly full-time WATS costs can be considered averaging $600/month for intrastate and over $1,000/month for interstate (zone one, 240 hour measured service).

Next, considering the average length of pilot briefings, the current VRS briefing of 3.75 minutes was assumed adequate for this first analysis. Lastly, in the area of hardware, it was decided that the current VRS demonstration system equipment could be projected in capacity to handle 32 channels (telephone lines) per VRS unit and that each Data Base Processor unit could support 8 VRS units. The projected costs for each were roughly estimated at $100K for a VRS unit and $150K for a Data Base Processor system. Using these values it would thus be possible to study the cost trade-offs between centralized versus decentralized VRS networks. The equipment costs will be considered amortized over a ten-year period.

The scope of this manual analysis does not include consideration of PATWAS, Flight Plan Filing, nor adjustments approximating increased VRS briefings compared to the 1986 projected pilot briefings. The result of this analysis relative to a sample FSS is shown in Table 5.4-1.

Examination of the table leads to several interesting observations. First, it is apparent that a fully decentralized configuration, with equipment located at each Flight Service Station, is prohibitively expensive compared to the other alternatives, even ignoring facilities, maintenance and operational costs. Secondly, the centralized configuration (or 2 site Nadin) was more expensive than decentralizing to the ARTCC's for FX/TELPAK telephone rates. Although the difference is not significant for this Louisville example, the centralized configuration costs will show a greater difference for most other FSS locations since they average 50% greater mileage to Kansas City, MO, or Nadin sites. Thirdly, the WATS configurations are 2.4 to 2.9 times more expensive than the FX/TELPAK configurations. Although the FX costs do not consider the components of pilot costs in calling the FSS nor the costs of special FX and WATS lines which Louisville may need to serve its area, it is likely that these supplemental costs will not approach the magnitude of WATS costs when factored into the FX comparisons. Lastly, it is appears that the equipment costs of decentralizing the VRS computers to each individual FSS is significantly more expensive than locating the VRS units at a site where several FSS's can be serviced. The final observation of our preliminary manual analysis is that ARTCC configuration should serve as a focal point for our computerized network analysis since it possesses both practical and economical potential. Further increases in demand, e.g., for increased message lengths, PATWAS and Flight Plan Filing services, will require additional VRS computers and Data Base Processors and this will tend to favor shorter telephone lines, leading to somewhat more decentralization of VRS units than the ARTCC sites. It was therefore concluded that analysis with the

Table 5.4-1: LOUISVILLE'S SHARE OF COSTS FOR VARIOUS CONFIGURATIONS

(1986 Demand, 100% Pilot Briefings, 3.75 minute average message length, 7 lines)

	Monthly Shared Cost of Equipment Per Line	Total FX Telephone Line/Miles	WATS, FX, or Local Telephone Cost Estimates Per Line (1)	Effective Total Cost Per Line (2)
1. a. Centralized at KCW (or ATL NADIN site)	$ 224	3,164 miles	$ 354	$ 578/mo.
b. For Interstate WATS (240 hr.)	$ 224	Zone 1	$1,150	$1,374/mo.
2. a. Data Processor and VRS at ARTCC (Indianapolis)	$ 365	769 miles	$ 152	$ 517/mo.
b. For Interstate WATS (240 hr.)	$ 365	Zone 1	$1,150	$1,515/mo.
3. Data Base Processors at ARTCC (Indianapolis) and VRS at Louisville	$1,012	110 miles	$ 40	$1,052/mo.
4. Data Base Processor and VRS at Louisville (Decentralized)	$2,083	Local	18 per line	$2,101/mo.

(1) Estimates computed as follows:
1. Distance 452 mile avg. - $87 + 452 x $0.59 = $354/line/mo.
2. Distance 110 mile avg. - $87 + 110 x $0.59 = $152/line/mo.
3. Distance 110 mile avg. - 18 + 1/7 ($87 + 110 x $0.59) = $40/line/mo.
4. Local lines only = $18/line/mo.

(2) These costs do not consider redundant equipment configurations, facilities, maintenance and operational expenses.

computerized model would focus on configurations with decentralization ranging from 5[illegible] VFS sites up to as high as 2[illegible] VFS sites.

5.5 Computerized Communication Network Analysis

The need for computerizing at least a part of network alternatives analysis became obvious at the outset of the preliminary analysis. In fact, the computational load for that simplified case made it obvious that any reasonable, multiple case study would require automatic computation. The design which finally evolved emphasizes simplicity of program structure and versatility. The ability to generate graphics as well as tabular output was designed into the system from the beginning. An option to permit the computerized model to run in an interactive graphics environment allows it to be used as a design tool as well. The additional complexity and computation involved in automatic network optimization procedures was considered to be too great for the scope of this study effort. Accordingly, the communication network alternatives to be analyzed by the model were manually selected and specified. The computer then performs a detailed analysis of each network, and the outputs are compared manually. The actual networks, demand data, costing data, etc., used were dictated by the type of analysis to be performed. These analyses are detailed in Section 6. A summary of all model runs made is contained in Table 4.1.5-1.

The procedure for analysis appears to be quite adequate, since the computer performs all lengthy, tedious calculations while analysts observe results and draw conclusions. Thus, a relatively detailed analysis is quite accessible.

In practice, an iterative approach developed. In this mode, the analyst selects a set of runs changing those variables expected to be important. The model runs are made, and the analyst inspects the quantitative output of the various runs. The analyst then specifies further runs with changed inputs. The output from these runs is used to refine the analytical results. This iterative procedure never required more than three cycles for any of the interative analyses.

It should be kept in mind that model results are based on estimated data. The accuracy of these computed results depend upon the accuracy of the assumptions used in preparing the model inputs. The real usefulness of such results is the comparative analysis made possible by observing variation in output data relative to controlled alteration of input data. Of course, incorporation of accurate input values and refinement of the costing calculations would result in model outputs which would produce quite accurate predictions of actual system cost. One must not assume such accuracy, however, without fully verifying the accuracy of the input data. A detailed description of the Communications Network Model is presented in Appendix F.

6. SYSTEM TRADE-OFF ANALYSIS

Before examining the individual trade-off parameters, the role of voice recognition capability must be placed into perspective to permit proper understanding of the following sections. The functional requirements call for the VRS alternatives to provide a voice recognition capability. This capability enables the pilot to vocally select services offered, in place of tone input operations. The vocal feature has merit for broadening the available service to pilots not having access to tone devices or push-button telephones. However, in examining the cost projections for the voice recognition equipment required to provide this capability, it was found that its costs were one and one-half times the basic VRS unit cost. The projected VRS unit cost with tone input capabilities is $40,000, while the VRS unit with voice recognition capability added is estimated at $100,000. This significant difference has a profound effect on the VRS alternative trade-offs. Therefore, a decision has been made to analyze the alternatives with two VRS unit designs, one with voice recognition ($100,000 per unit) and the other without voice recognition ($40,000 per unit). This parallel analysis is done for several of the major trade-offs. However, it was not possible to do this analysis for every trade-off factor. As a result, the lower cost VRS unit design was selected as the most conservative approach for several of the trade-off comparisons since the economy considerations might have a negative influence on a decision to include voice recognition.

Lastly, these alternative results have been based upon a fail-soft national configuration. This means that no site will have less than two units, even if only one is needed to serve the total demand. Extra units will not be added to sites which normally have two or more units to meet the demand. The fail-soft level was selected to provide a continuing level of service although it assumes that the specific recovery specifications can be relaxed to permit the resulting fail-soft service levels.

The following trade-off discussions are based primarily upon computerized analysis. The majority of the computer data used is presented in Appendix G. This appendix contains summary reports from the individual model runs and is included in this study report for possible further analysis.

6.1 Centralization versus Decentralization

As indicated in the manual analysis of various network configurations, the computerized analysis clearly showed that communication costs predominate in centralized configurations. Both of the VRS unit designs, with and without voice recognition, showed minimal system cost alternatives favoring decentralization at least to the FSDPS level (20 ARTCC sites) but less than the full FSS decentralization (293 sites). In fact, the minimum cost configuration for the non-voice recognition design was just one step down from fully distributed VRS units at all FSS's, this optimum being the 134 VRS site/20 Data Base Processor site configuration. Figure 6.1-1 summarizes this result. This figure examines the configurations from a centralized site to all FSS's having VRS equipment. In a similar way, Figure 6.1-2 summarizes the alternatives and shows the system costs for the VRS unit design including voice recognition. These summaries are based upon a number of factors listed on the figures. These results are representative of the minimum cost for the national implemetation, assuming FX/TELPAK telephone costs for all long distance communication links. This FX/TELPAK service is in the process of being discontinued. The replacement communications cost will be much higher if link costs approximate current commercial FX rates as indicated in proposed tariff actions.

Examining Figure 6.1-1 more closely it can be seen that equipment costs exceed communication costs only in the full FSS decentralized (293/20) VRS configuration. With the added expense of maintenance, 85% of the cost is associated with the equipment for the 293/20 configuration. Only 15% is telephone costs. Moving more centralized to the 134/20 configuration, communication costs rise to a 55% level. This 134/20 configuration represents approximately a 50% consolidation of VRS sites from the full FSS sites. Both of these configurations involve additional facilities costs not factored into the analysis. Air conditioning (A/C) and power conditioning, if needed to assure equipment operational reliability, will be approximately $6,000 for VRS sites and $14,000 for Data Base Processor sites. When factored into these alternatives, even the worst case 293/20 site configuration increases insignificantly (less than 2% of the monthly system cost). To simplify the alternative cost analysis, facility costs have been dropped from these results. One additional reason for dropping these facilities costs is the uncertainties associated with specific sites. Since some future FSS and FSDPS sites may have the needed environmental control equipment associated with the FSS Automation

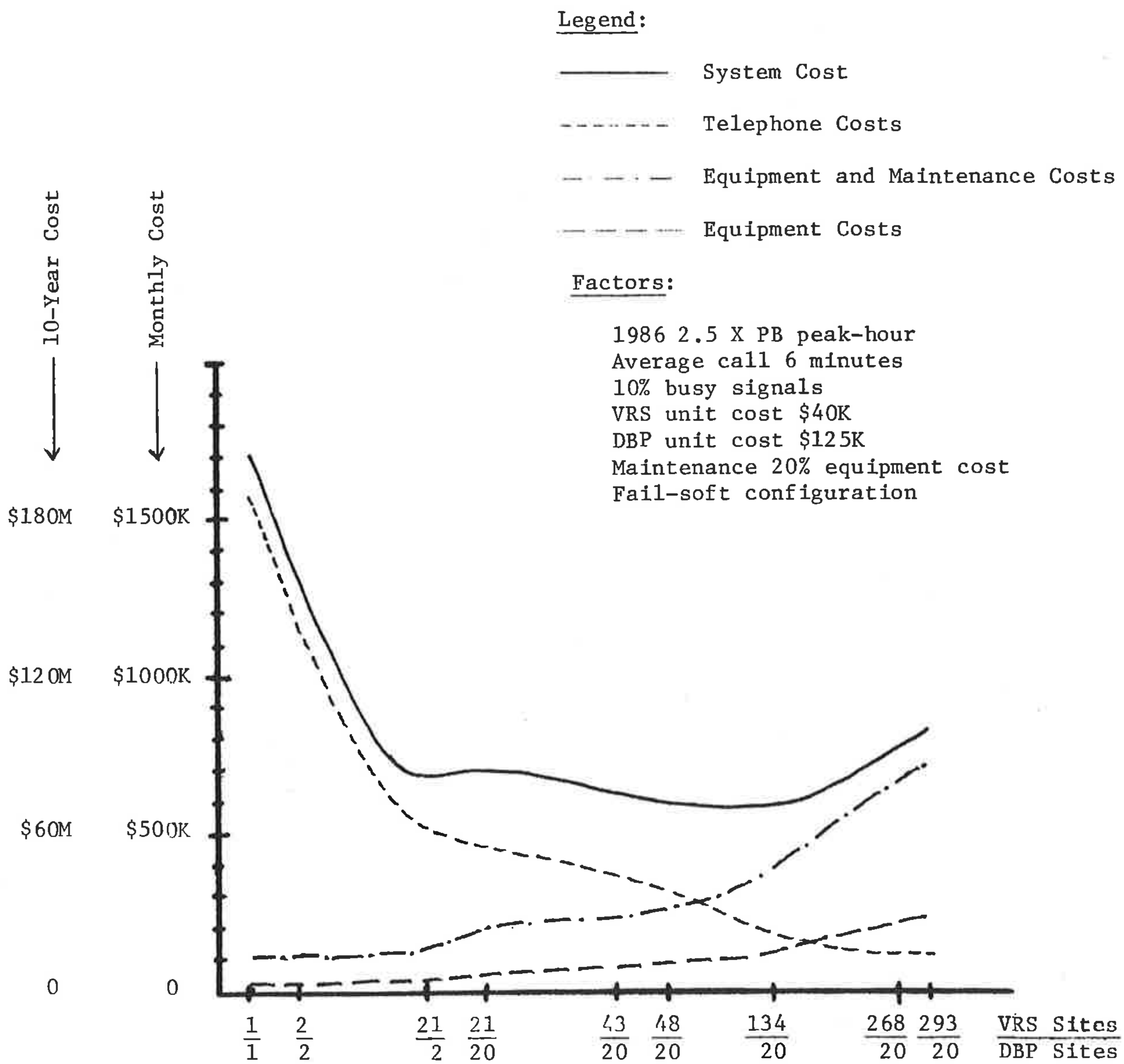


FIGURE 6.1-1 - CONFIGURATION ANALYSIS SUMMARY

(VRS units with tone input only)

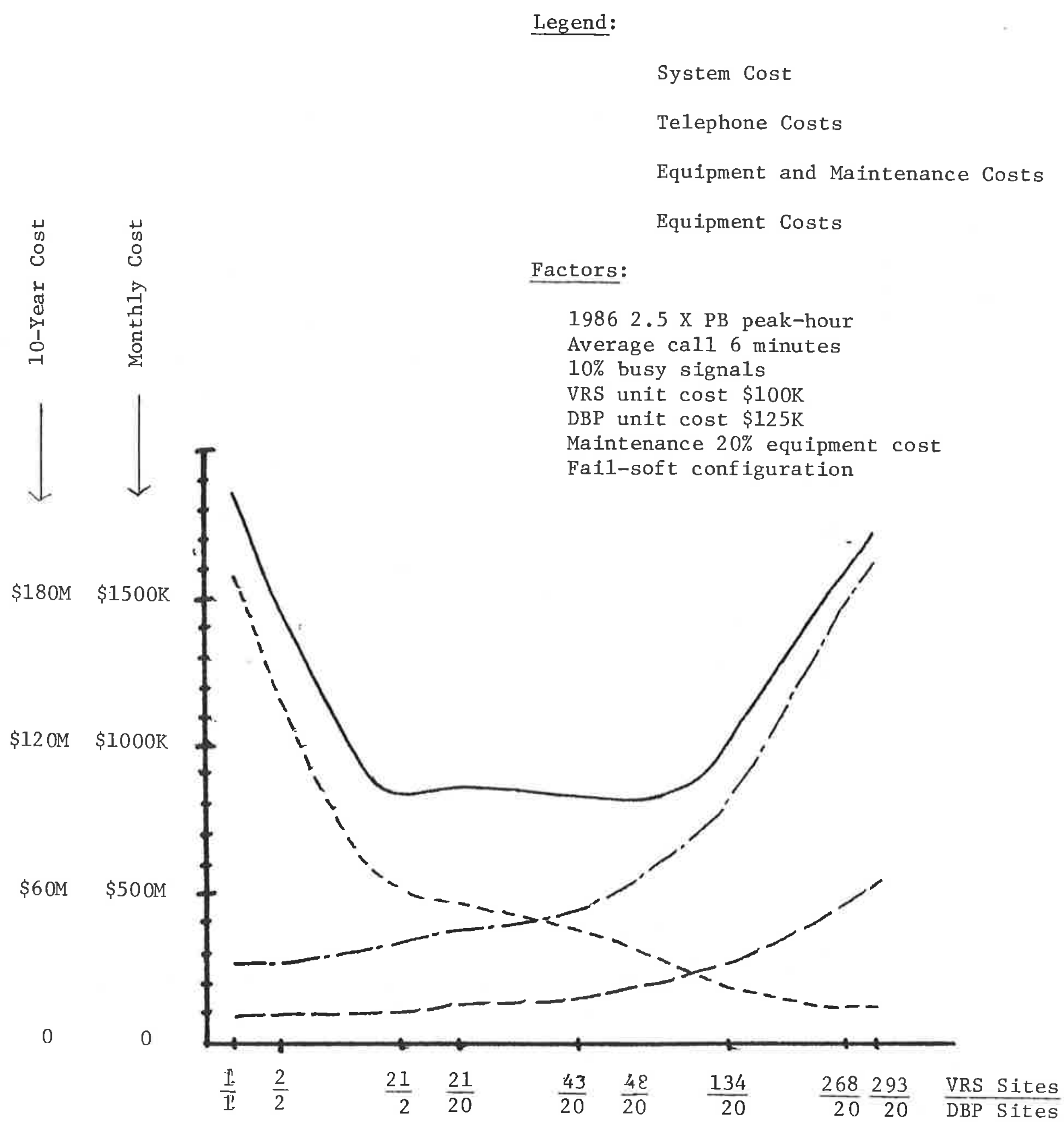


FIGURE 6.1-2 - CONFIGURATION ANALYSIS SUMMARY

(VRS units with voice recognition added)

Program, their amount of faciliites costs are even more insignificant when amortized over the same 10-year period used for the equipment.

Moving more centralized to the 43/20 configuration, the telephone cost predominates at 60% of the cost, and the total system cost increased 7% over the 134/20 configuration's minimum cost. Any further centralization results in considerably more costs as communications require more line miles of service. It should be noted that the maintenance costs will probably be less than the 20% rate used throughout this study because of the consolidation of equipment at fewer sites as more centralization is reached. But this has little effect on costs because maintenance represents about 5% of the total. A 50% maintenance reduction results in a 2.5% decrease in total cost.

If one examines Figure 6.1-2 in the same way, it can be seen that the minimum cost falls between the 43/20 and 134/20 site configurations. But this minimum is not significant. A relatively flat cost region exists from the 21/2 configuration to the 134/20 configuration. This is mainly due to the significant increase in equipment costs and the associated maintenance costs. The relationship of the telephone costs shifts the point where telephone costs predominate back to the 21/20 site configuration.

6.2 Data Base Processor Locations

Figure 6.1-1 also shows an interesting factor relating to the Data Base Processor site distribution. Examining the difference between the total costs of the 21/2 and the 21/20 configurations, it can be seen that the total costs are about the same, whether centralizing the Data Base Processors at 2 sites or at 20 sites. However, the 21/20 configuration has more than twice as many Data Base Processors as the 21/2 network (fail soft requirements result in dual equipment at sites where only single units are needed for service). This means that the 20 Data Base Processor sites will have growth potential at no extra cost. Further decentralization to more than twenty Data Base Processor sites becomes undesirable since the extra Data Base Processor equipment is very costly compared to VES units. For example, if the 43/20 configuration were changed to 43/43, the equipment and maintenance costs would increase by $75K monthly while the communications costs would drop only $10K due to the reduction in computer-to-computer lines.

There are other factors which favor a 20-site Data Base Processor configuration. The first is the co-location with the FSDPS Model I/II facilities (ARTCC sites). Since the Data Base Processor function may be accomplished by the FSDPS if sufficient capacity is available or provided, this configuration is ideal. If separate Data Base Processors are needed, then the co-location with the FSDPS provides the local tie-in to the automation system for receiving weather products and handing flight plan routine transactions automatically. It should be noted that the VRS alternative configurations with the 20-site Data Base Processors all observe ARTCC boundaries for the VRS network which each Data Base Processor site services. This preserves the normal ARTCC/FSS relationships and center jurisdiction.

6.3 Telephone Cost Analysis

This is the most important area of this study since the communication costs predominate most of the alternative configurations. As stated earlier, the computerized analysis focused around the FX/TELPAK communication rates since these are the most economical links currently available and widely used by the government today. The total system costs produced using FX/TELPAK results in the minimum cost for each configuration compared to either WATS or FX/AT&T rates. Figure 6.3-1 is presented to aid in visualizing the telephone line miles and communication costs for the various VRS configurations studied.

Examining the FX line mileage curve first, it can be seen that mileage rapidly decreases as the configurations become more decentralized. This is intuitive if the same number of lines are required to provide the same VRS service level via FX lines between the local FSS and the VRS equipment sites, providing a 10% peak-hour busy signal level of VRS service at each FSS is independent of FX line configuration. This is not true for the WATS line service approaches. WATS service is essentially independent of the exact mileage or the exact peak hour concentration of calls from a given area. Interstate WATS costs are based on zones which are crudely related to the radius distances between the caller and the WATS location. The cost implications of WATS alternatives will be discussed later in this section.

The FX/TELPAK costs are based upon mileage and a fixed cost. One can see that this FX/TELPAK cost curve closely parallels the mileage, reflecting in this overlayed graph an approximate unit cost of $1.00 per mile. The fixed cost for termination charges can be seen to have more of an effect on the decentralized configurations where line mileage costs are low. The cross-over point in this figure is at the 21 VRS site configurations.

In contrast, it can be seen that FX/AT&T costs for the same FX line mileage are considerably more expensive. Average cost per mile is 48% that of the FX/TELPAK cost for the 43/22 configuration, for example. This significant difference is very important because the telephone industry is attempting to discontinue TELPAK service in the near future. If TELPAK is discontinued, the replacement service may be closer in cost to the FX/AT&T rates than the FX/TELPAK rates. This change would undoubtedly have a profound impact on a VRS National Implementation Plan. Specifically, the imposition of higher communication rates will strongly favor greater decentralization where telephone line mileage is minimized.

Before looking at what impact FX/AT&T rates have on the various VRS alternative configurations, it is necessary to place WATS in proper perspective in this study. A WATS centralized network offers one major benefit to the alternative configurations; it permits fewer VRS units to handle the national peak hour demand and still provides only a 10% chance of a caller receiving a busy signal. This is simply due to the concentration of lines such that fuller utilization is achieved. This contrasts with the FX line approach which would dedicate a fixed number of lines to an FSS and even if these lines were not busy, they would be unavailable to service another FSS's local demand. As a result of this fuller utilization, the centralized WATS configuration could serve the nation with approximately half the number of lines compared to the FX configurations. But the problem with this national WATS approach is the cost. First of all, no full service interstate WATS is available, only measured WATS. The largest capacity service offered is 240 hours per month WATS which represents only 8 hours per day of service, 30 days per month. Any service above this limit is charged at a fixed rate per hour additional. For comparison, an interstate WATS cost has been plotted on Figure 6.3-1. This point (for the 1/1 configuration) assumed only 240 hours of service per month (a very low utilization assumption), zone 3 rates and half the number of lines. Its line cost is over 17 times that of the FX/Telpak 134/20 configuration communication cost. It is obvious that it is not cost effective in any way since the savings in equipment costs have little effect in offsetting this imbalance.

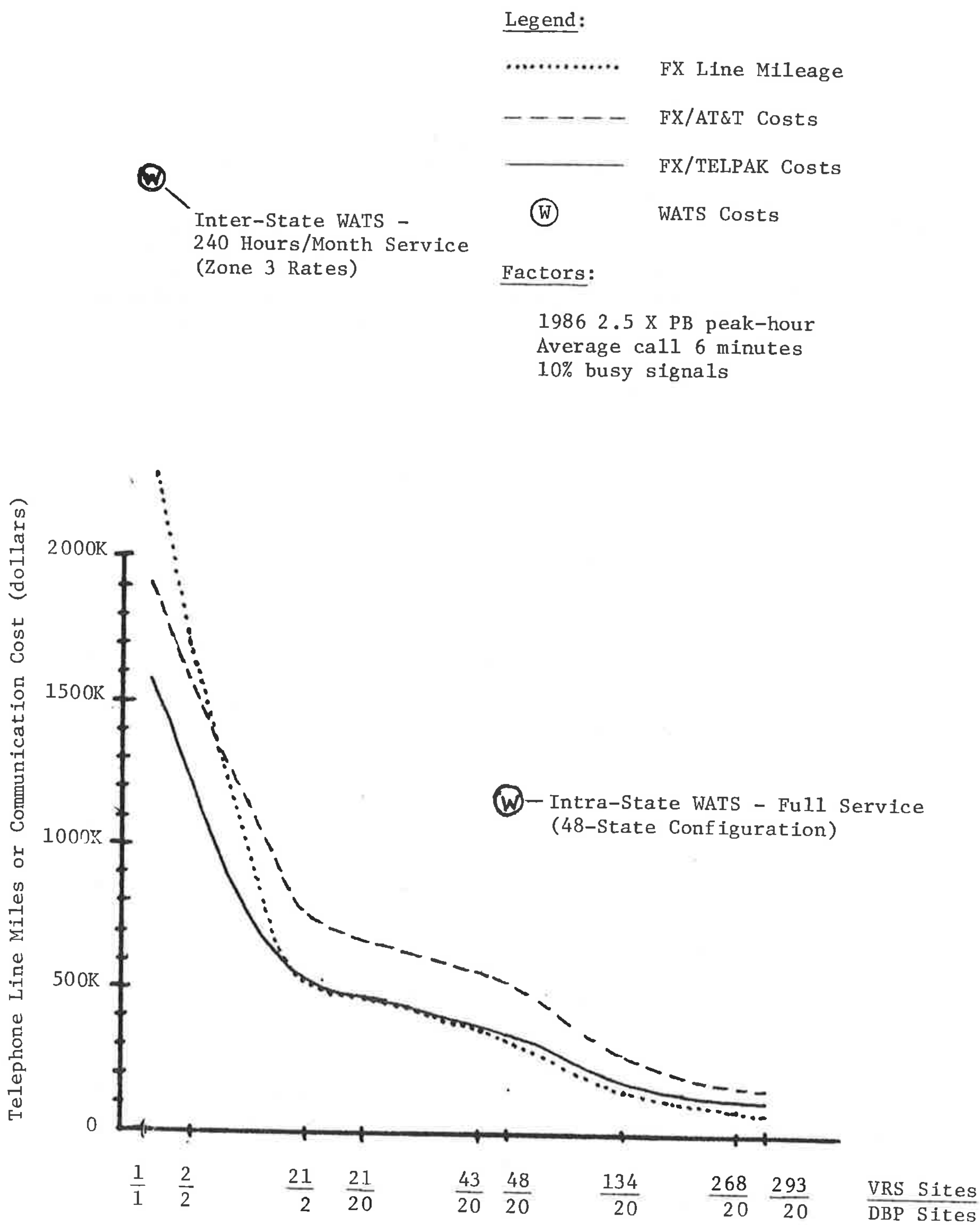


FIGURE 6.3-1 - TELEPHONE MILEAGE AND COST COMPARISONS

The other possible WATS configuration involves only intrastate WATS. This service is offered with full service rates. The utilization levels for intrastate WATS cannot match interstate WATS since only the callers in the specific state can access this intrastate service. It is estimated that 64% of the number of FX lines will provide 10% busy signal WATS peak hour service level. The point plotted on Figure 6.3-1, to the right of the 43/20 configuration data, represents the cost of such service. This point is in effect a 48/20 configuration with a group of intrastate WATS lines located in each of the 48 continental U.S. states. It can be seen that this cost exceeds the cost of the FX/AT&T approach. The reduction in equipment and maintenance costs would not change this relationship.

One major discrepancy in comparing WATS and FX service approaches must be addressed before moving on. The cost to the user, the pilot, varies depending upon whether he has local call access to an FSS. If he calls long-distance to reach the FSS, then the FX approach costs him money, while the toll-free WATS approach does not. Currently, the major FSS's across the nation provide additional FX and WATS lines beyond its local call range to supply added toll-free services. This extended coverage costs approximately $180K per month. Not all of these extended communication lines are related to the VLT, PATWAS, and TWEB uses. Assuming that 85% of these lines are related to this study's services and projecting the increased demand growth to 1986, the cost of expanding this coverage is estimated at $200K per month. This amount can be added to the FX configuration costs to compare with WATS. The result does not change the benefits favoring the decentralized configurations over WATS.

To summarize this telephone cost analysis, Figure 6.3-2 is presented showing the total system costs for the various configurations with the non-voice recognition design. The most significant point shown by these curves is that if the communication costs increase to the FX/AT&T rates, then the cost saving advantages of going to the 134/20 configuration alternative is even greater than the FX/TELPAK approach. This indicates that there is less risk in terms of impact from future telephone operational cost increases with the optimum 134/20 alternative than the more centralized configurations. In the same manner, Figure 6.3-3 presents the voice recognition system costs results. Again, the increased communications costs favors greater decentralization. In this case, however, the differences are less significant.

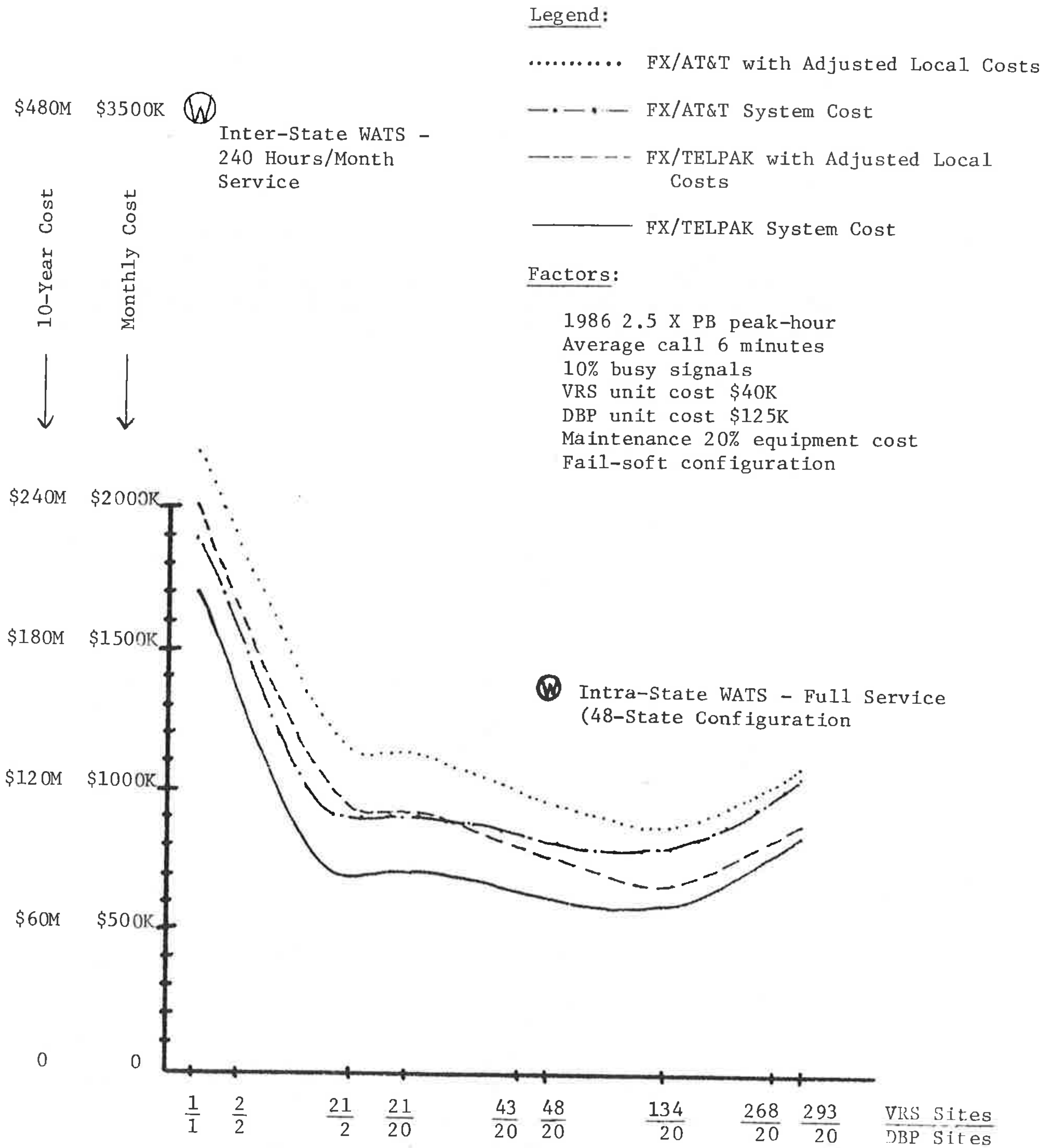


FIGURE 6.3-2 - COMMUNICATION COST ANALYSIS SUMMARY

(VRS unit with tone input only)

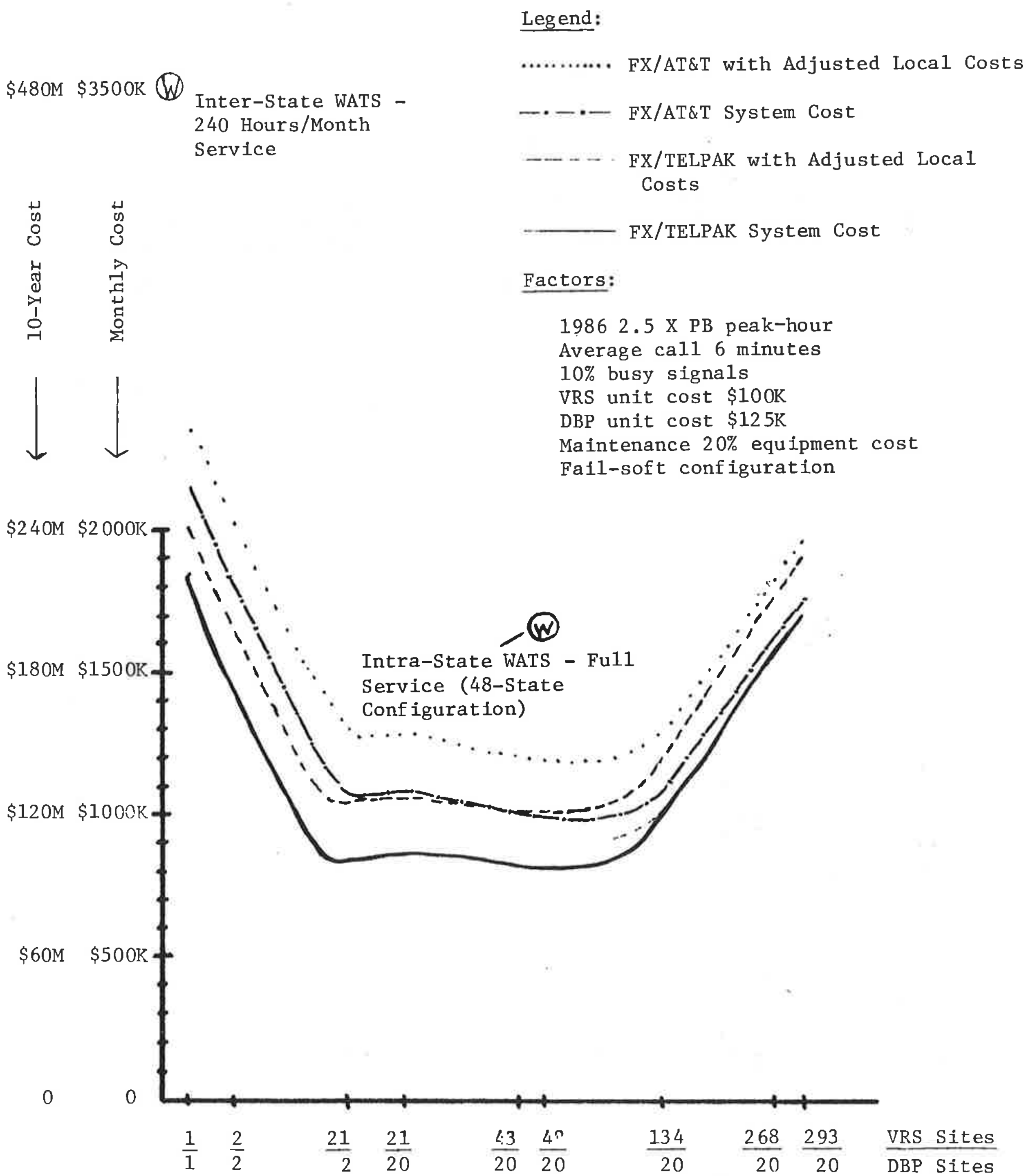


FIGURE 6.3-3 - COMMUNICATION COST ANALYSIS SUMMARY

(VRS unit with voice recognition added)

6.4 Equipment Fail-Soft Analysis

The requirement to provide reliable VRS operation in a fail-soft mode results in additional equipment for the various decentralized network configurations. One can examine the impact of this additional equipment on total system cost in Figure 6.4-1. In general, the minimum cost system remains the 134/20 configuration, with or without dual equipment at sites not requiring such for demand servicing. One can clearly see that the requirements for fail-soft (i.e., multiple equipment at every site) has more impact upon the decentralized configurations where each VRS site's demand can be readily serviced by a single 32-channel VRS unit. However, it should be pointed out that at these decentralized sites the extra VRS unit has a capacity which, in effect, makes these sites fully redundant. This means that instead of fail-soft operation at a lesser capacity, these sites have full capacity when operated on the backup system. To complete the picture for providing a fail-safe capability by adding one extra unit at every site, Figure 6.4-1 has a curve showing this. It can be seen in the decentralized region that fail-safe is only a small increment more expensive than fail-soft and that it may be worthy of consideration if no system degradation can be tolerated when one unit fails. Figure 6.4-2 has been prepared to aid in visualizing these fail-soft, fail-safe implications. In this figure, one can see the average number of VRS units at each site for different configurations, with or without fail-soft or fail-safe requirements. Since some sites require multiple VRS units to meet its service loads these sites have an inherent fail-soft capability and no additional units are required. As noted on these curves, the percentage of sites which are inherently fail-soft decreases with decentralization to a low of 5% for the 2?3/20 configuration. This leads to an important question as to whether the 32 channel VRS capacity makes sense for these decentralized configurations. The next section addresses this question.

6.5 VRS Channel Capacity and Utilization Analysis

As discussed in the hardware section, the 32-channel VRS capacity was derived from the prototype VRS experience and the technology projections for 1983. The nature of the VRS hardware offers little flexibility in reduced cost due to reduced channel capacity since even the smallest number of channels require a complete vocabulary storage capacity. This storage device represents half the cost of the VRS system. Therefore, reductions in the number of

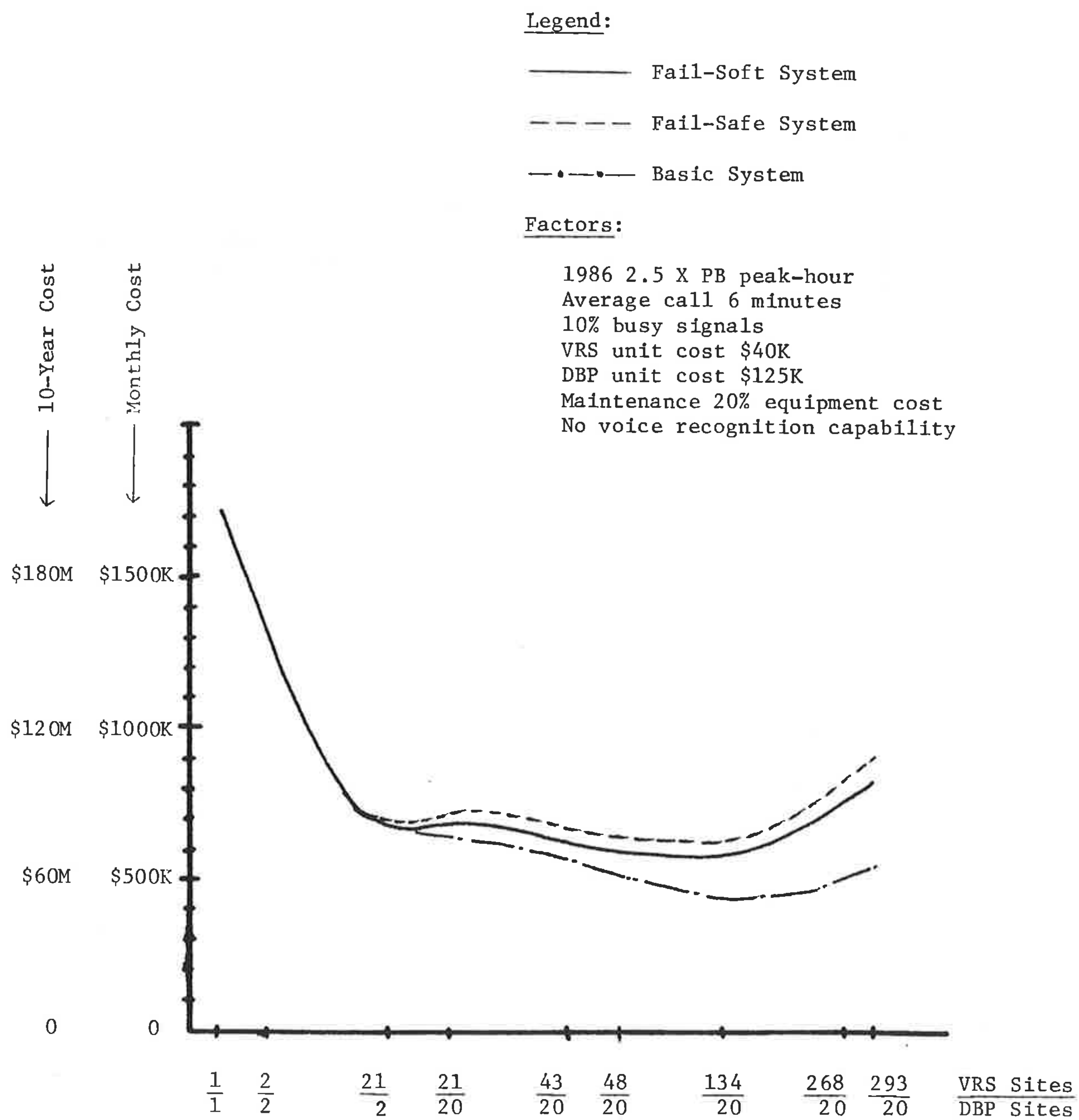


FIGURE 6.4-1 - FAIL-SOFT & FAIL-SAFE COST SUMMARY

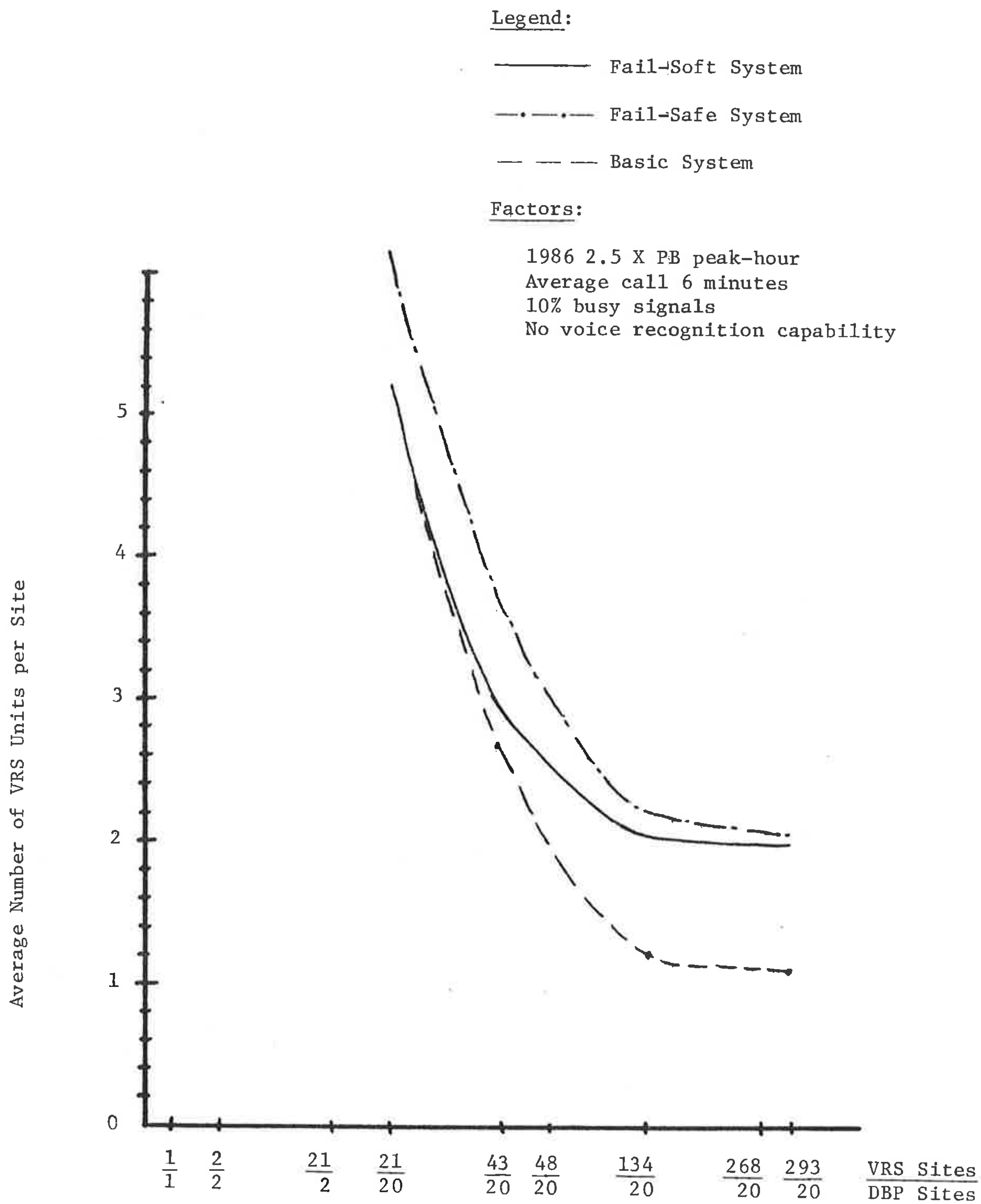


FIGURE 6.4-2 - VRS EQUIPMENT MULTIPLICITY ANALYSIS

channels can only affect half the cost. Even here, the basic logic and communication functions are the same, independent of the number of channels. Therefore, processor requirements are not reduced except in terms of buffer requirements and processor loading. The basic software instruction requirements remain unchanged. It is therefore concluded that insignificant savings result from a smaller channel system to warrant its consideration unless large volume production factors become involved by going to the smaller units and buying more of them. To see if smaller VRS units make sense, let us examine the 1995 peak-hour demand estimates (2.5 times projected Pilot Briefings). Figure 6.5-1 presents the grouping by number of lines required to meet each Flight Service Station's 1995 service level. This figure indicates that 77% of the FSS's need only 16-channel capacity for VRS units at every FSS (i.e., 293/20 configuration). If one preserves the dual equipment requirement for fail-soft considerations, one concludes that an 8-channel VRS size is needed for this 77% portion of the 293/20 configuration. This represents 452 VRS 8-channel units. Production volume decreases are not likely for this small quantity. Even so, it is possible due to the fewer parts and this level of production that a 33% unit cost reduction is possible. If one assumes the remaining sites have at least dual 32- channel units, then a total system cost of $568K per month is computed. If this cost is compared to Figure 6.1-1, it can be seen that it is comparable to the 134/20 configuration costs. The comparison is not accurate, however, since facilities costs will be higher for the 293/20 configurations, but is close enough to be considered seriously. The main advantage offered by this split 32/8-channel approach for the 293/20 system is its reduced sensitivity to telephone rate increases because it has the least long-distance telephone mileage of all systems. The one disadvantage is that it has little growth capability compared to the 134/20 system since the smaller VRS units are fully utilized in the 1995 service environment. To help visualize this, Figure 6.5-2 is presented. Note that additional channel capacity is needed to service the 1995 demand level if the initial implementation is sized on the 1986 demand estimates. The 43/20 configuration is the crossover point and the more distributed configurations have more than adequate growth capability. Although the mixed 8 and 32-channel VRS unit sizes show a considerable excess of capacity, this capacity actually exists at the 23% of the VRS sites where the 32-channel units were required. Most of the other sites were closely sized for the 1995 demand. One minor point can be seen in Figure 6.5-2. The number of lines required actually includes the computer-to-computer links along with the demand lines.

Factors:

1995 2.5 X PB peak-hour
Average call 6 minutes
10% busy signals
No voice recognition capability

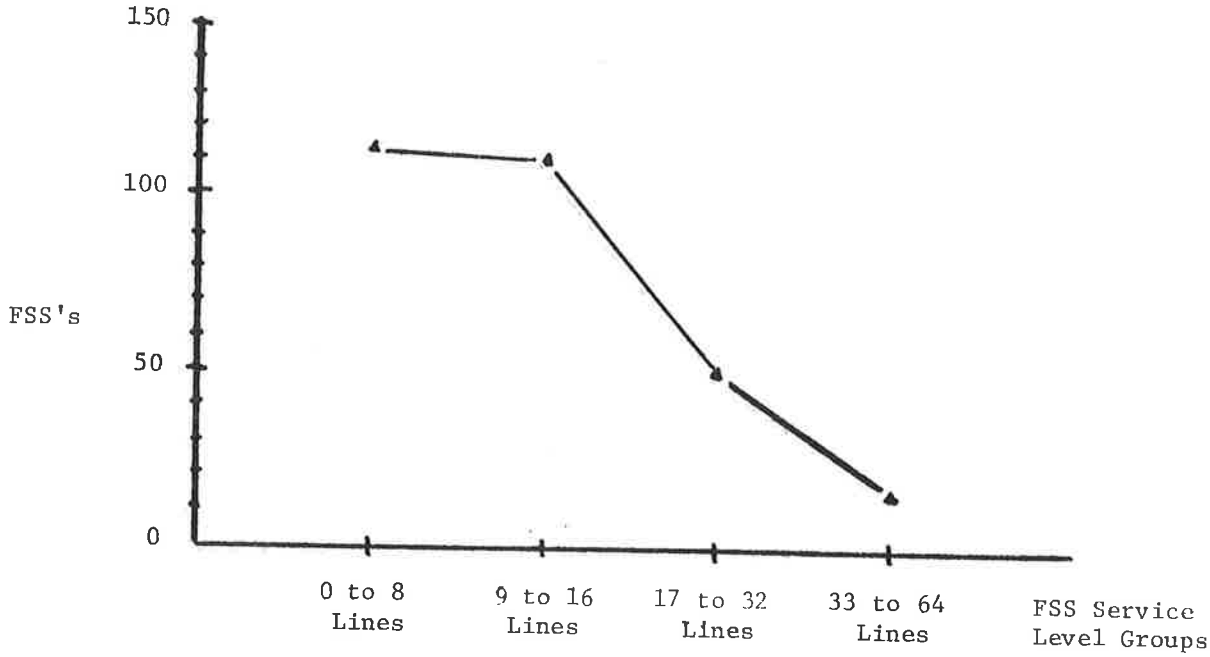


FIGURE 6.5-1 - INDIVIDUAL FSS 1995 SERVICE LEVEL GROUPING

Legend:

1986 Available VRS Channels (32 channels per VRS unit)

1986 Number of telephone lines needed to serve demand

1995 Number of telephone lines needed to serve demand

Available VRS channels (Mix of 8 and 32 channel VRS units)

Factors:

1986 2.5 X PB peak-hour
Average call 6 minutes
10% busy signals
Fail-soft configuration

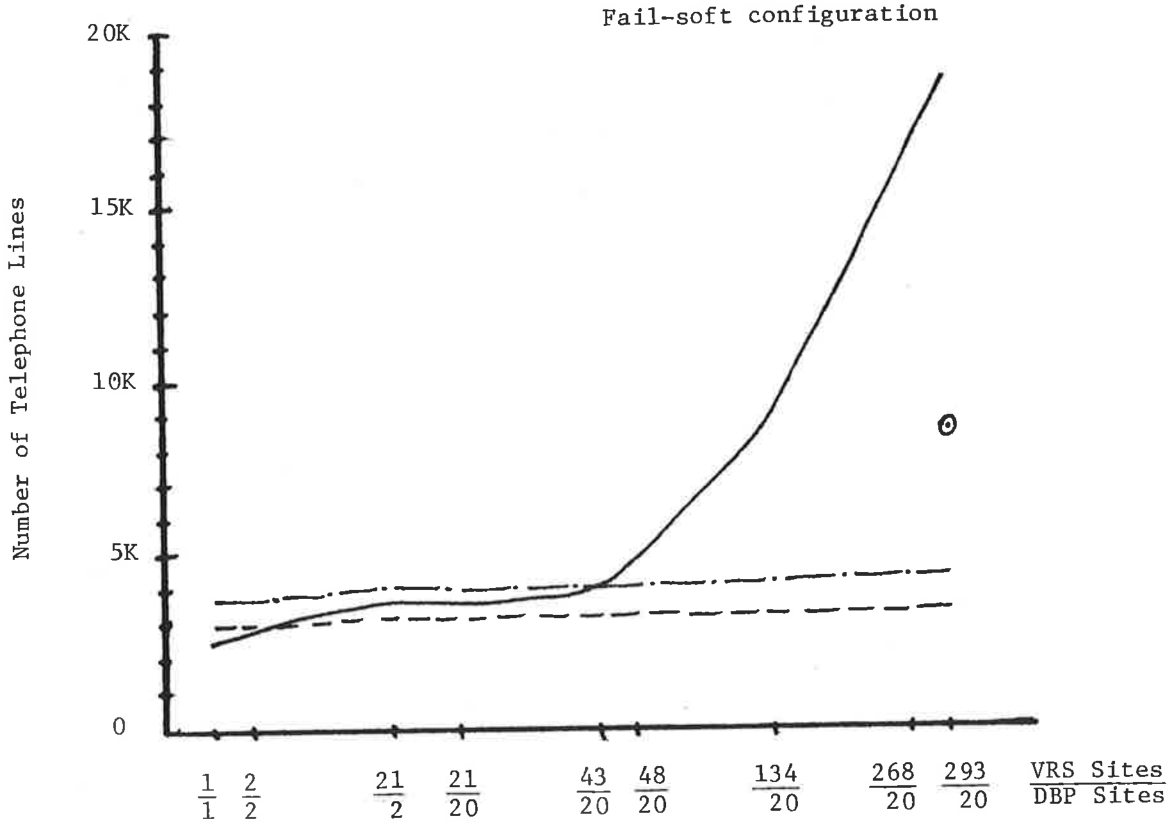


FIGURE 6.5 -2 - AVAILABLE CHANNEL CAPACITY VERSUS REQUIREMENTS

Thus the curves slope slightly downward toward the centralized configuration.

6.6 PATWAS/TWEB Analysis

The most important questions concerning the combination of VFS pilot briefings with a VFS/PATWAS/TWEB service is the impact on system cost and the sensitivity to different levels of PATWAS service. As discussed in the demand analysis section of this study, the full PATWAS/ TWEB service is greater than the VFS pilot briefing demand. Will adding it to VFS double the system cost? How about implementing only the current PATWAS and TWEB locations (72 locations)? Figure 6.6-1 shows the telephone and the system costs for 1986 demand for various levels of PATWAS/TWEB. The curves on this figure show an increase of only 30% in system cost for adding full PATWAS/TWEB service over no PATWAS service. This is less than the doubling of cost expected because the basic VFS system requires fail soft hardware configurations yielding some excess capacity to handle a portion of the PATWAS/TWEB service. These curves show that the increased system costs can be attributed mostly to communication increases needed to provide the 90% available service level. This data was computed for the 43/20 configuration. The increased costs going from no PATWAS to full PATWAS service for the more decentralized configurations will show even less an increase than 30% because less communication line mileage is involved in the added service.

One additional benefit derives from combined VFS/PATWAS/TWEB service. This benefit is the sharing of communication lines. The caller will call one number whether he requires VFS or PATWAS service and will indicate what service he requests, using either tone inputs, dial clicks, or if available, voice recognition inputs. This shared use of lines has a profound impact on the number of lines. If VFS and PATWAS are separate systems, the number of lines required would total more than twice the VFS line requirement. Sharing these lines results in only a 56% increase in lines over the VFS alone requirement.

If only the current PATWAS/TWEB locations are combined with VFS and no other areas receive the service, the system cost increases only 10% above the VFS alone system costs. The number of lines added would increase by 28%. This limited PATWAS/TWEB covers only 72 FSS areas out of 293 FSS's or only 24% of the stations. This percentage is somewhat misleading in that several FSS's may be served by one PATWAS area service. In summary, the cost of adding full PATWAS/TWEB service

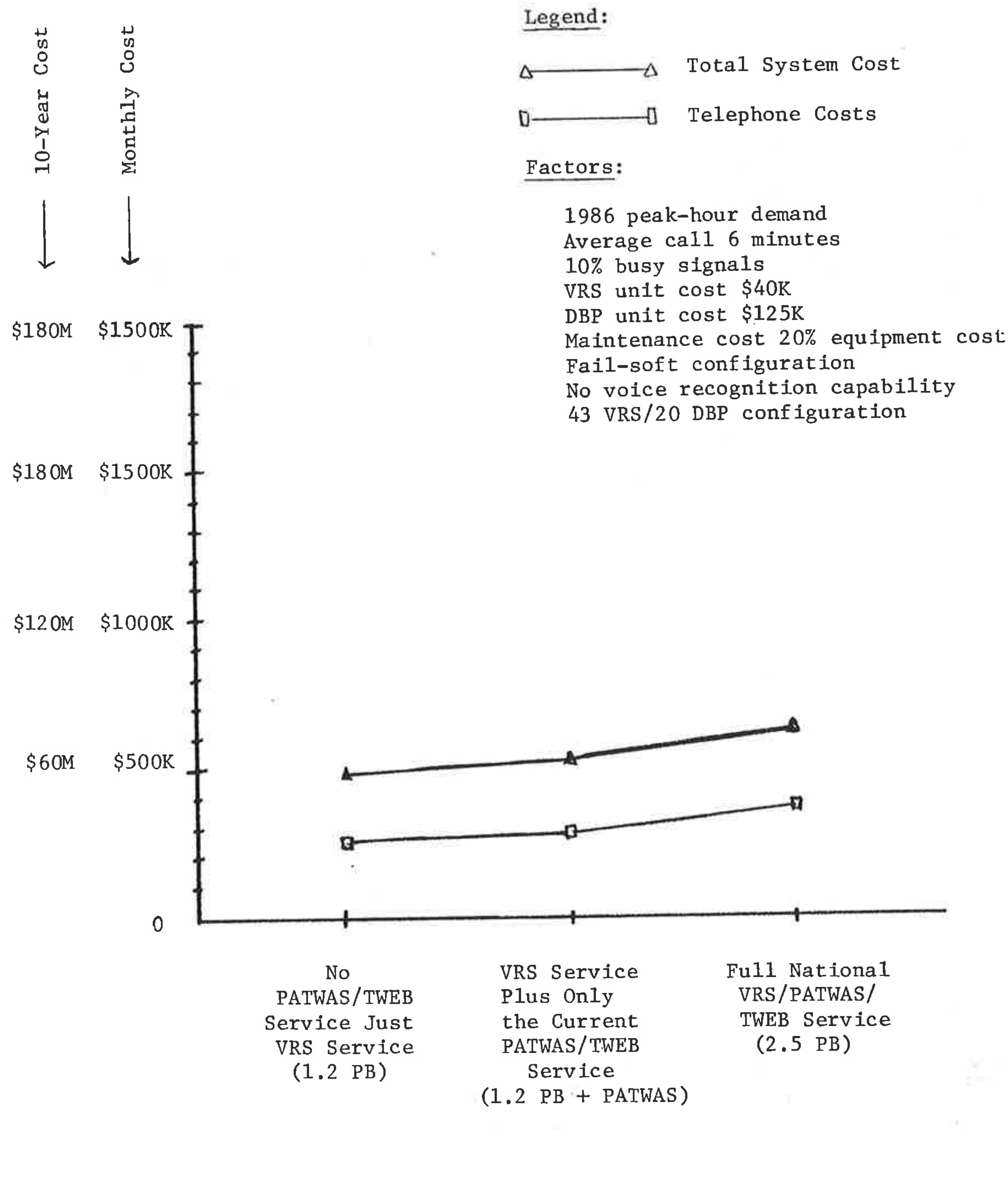


FIGURE 6.6-1 - PATWAS/TWEB SERVICE LEVEL ANALYSIS

nationwide seems cost beneficial at the 30% cost increase while providing more than double the user servicing over the VFS alone. However, if the costs are constrained, the economic advantages from receiving 24% of the FAAWAS national demand at a cost increase of only 10% are even more beneficial.

6.7 Average Message Length Analysis

There are two major factors which have a direct affect upon the system loading. The first obvious factor is the number of callers or the frequency of the calls. That factor was discussed in the demand section. The second factor is the length of each call. As discussed in the same demand section, a six minute average call length was selected for peak-hour demand calls. How sensitive is this average call length in affecting the total system cost and the associated communications requirements? This analysis exercised the 43/20 configuration to determine these effects. Figure 6.7-1 presents the results. Inspection of this figure shows that the changes are linear. The change in system costs increase by 17% and 36% for the increase from 4 to 6 and 4 to 8 minute average lengths. The 4 to 8 minute change represents a 100% increase in call length, yet the communications costs increase only 50% and the total system cost only 36%. The 50% communication costs increase is directly related to the 50% increase in number of telephone lines required. Here, as in the previous Section 6.6, the effects of available capacity of the basic VFS sites accommodate much of the changes in demand. Only the telephone lines seem to be involved in these costs. This is truly advantageous for a national VFS implementation since the telephone lines can be added when the demand growth and the increased user average call lengths require them. This advantage exists for the decentralized configurations where there is excess VFS channel capacity. The centralized configurations would require proportional increases in equipment costs and communications costs as demand load increases.

6.8 Future Year Service Analysis

Some of the growth aspects of the various VFS alternative configurations have already been discussed in the previous trade-off discussions. Figure 6.8-1 is presented to illustrate one of the major factors discussed, the growth cost factors of a decentralized configuration (134/20), a medium decentralized configuration (43/20), and an FSDFS configuration (21/20). The curves show that the major cost increase to meet the 1995 demand level are the communications

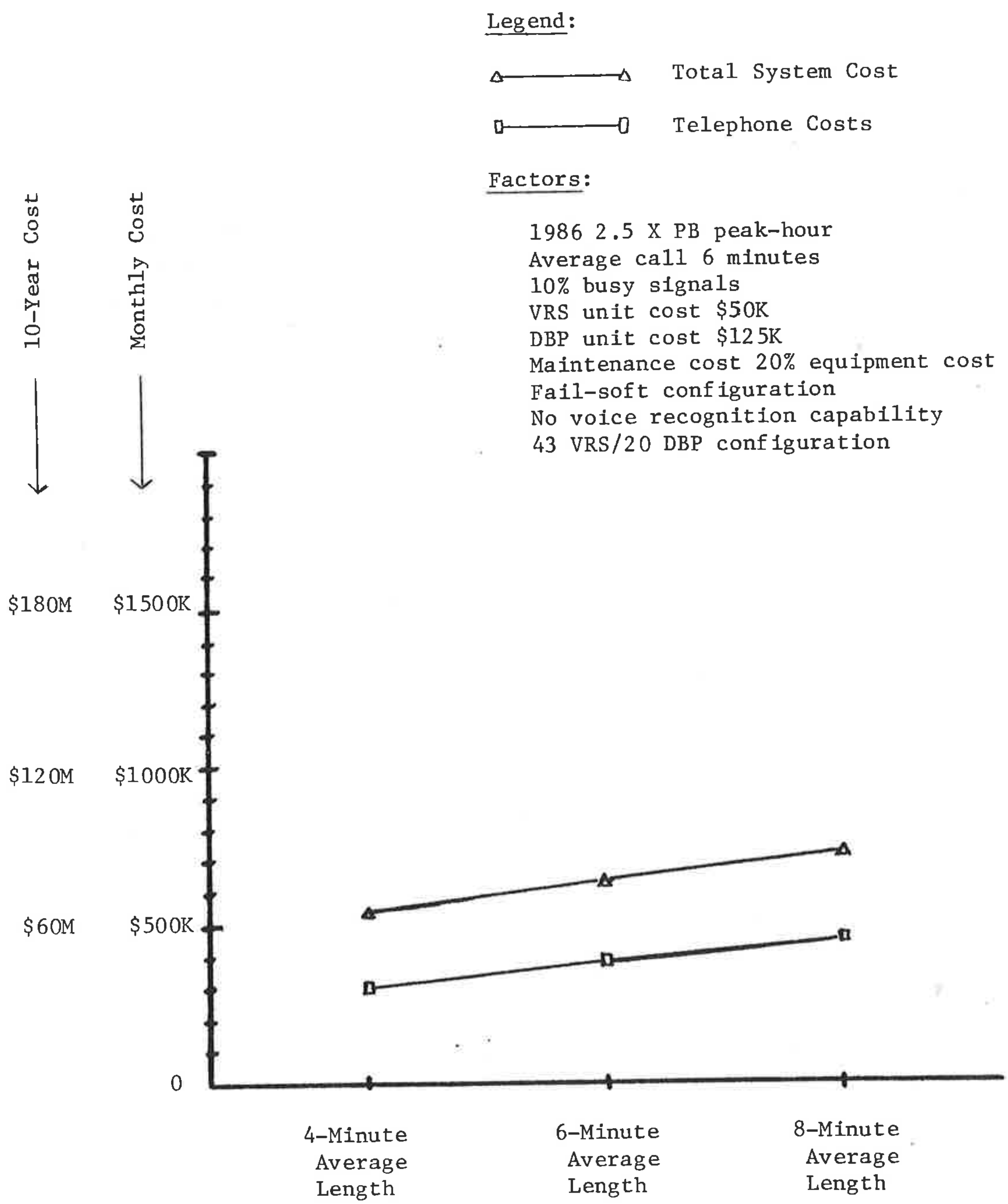


FIGURE 6.7-1 - AVERAGE MESSAGE LENGTH SENSITIVITY ANALYSIS

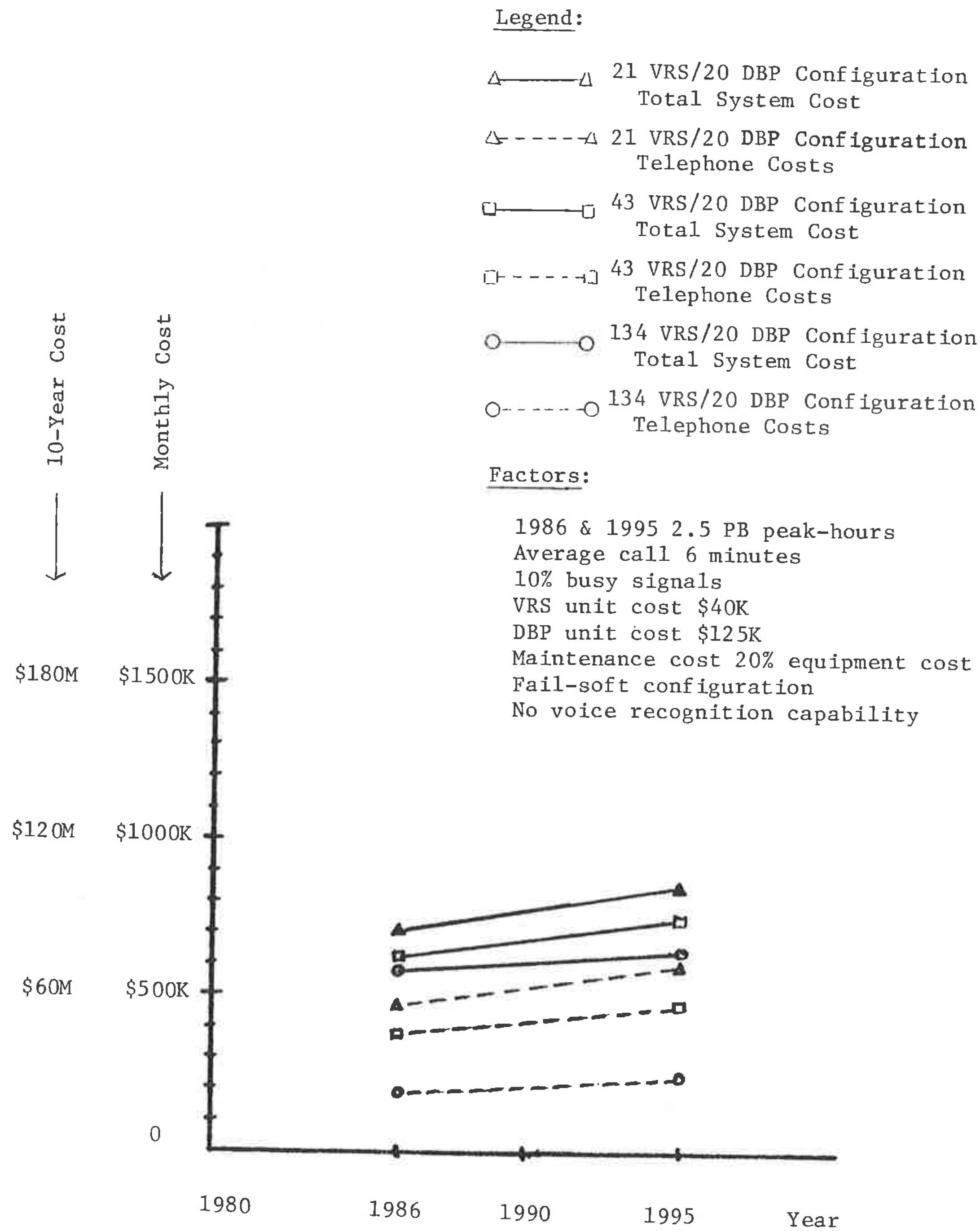


FIGURE 6.8-1 - PROJECTED SYSTEM GROWTH

costs. Even the 21/20 configuration has adequate hardware capacity at fail-soft status to handle the increased demand over the 1986 implementation level.

6.9 Phased Implementation Analysis

The next major factor of this trade off analysis concerns phased or partial implementation. Figure 6.9-1 displays the results of phasing the implementation of the 43/20 configuration by selected portions of nation. The first partial implementation considered is based on the 3 ARTCC regions representing the busiest centers in terms of pilot briefing forecasts (i.e., Washington DC, Fort Worth, and Atlanta). The second phase selected is the 14 ARTCC's scheduled to receive the Model I and II FSDPS's. These two levels are plotted against the full conterminous U.S. implementation. Examining the curves, it can be seen that equipment and maintenance costs flatten out slightly as one approaches full implementation. This is not surprising since the least busiest centers are implemented last and require less capacity. These last ARTCC's tend to be in the least populated regions of the nation and therefore one can see that more telephone mileage is involved in reading the demand areas. Therefore, the communications cost slope increases more rapidly as full implementation is approached. In terms of demand served by these partial implementations, the three center implementation computes to 18% of the national demand serviced. Three centers represent 17% of the 20 ARTCC's. The 14 center implementation services 84% of the national demand and represents 68% of the centers. These percentages indicate that the demand levels may be fairly uniform in terms of VRS system costs throughout the ARTCC's.

Plotted on Figure 6.9-1 are the system costs for partial implementations of a full PATWAS/TWEB demand level service (i.e., 2.5 times Pilot Briefings) as well as the 1.2 X PB + current PATWAS demand level service. It can be seen that the increased level of service does not change the linearity, just increases the cost uniformly as expected in adding VRS capacity and telephone lines.

6.10 Equipment Maintenance Analysis

A significant effect on the alternative system costs can be seen in varying the cost of maintenance from 20% of equipment cost to 10% of equipment cost. Figures 6.10-1 and 6.10-2 illustrate this effect for the non-voice recognition VRS design and the voice recognition VRS design, respectively. If maintenance

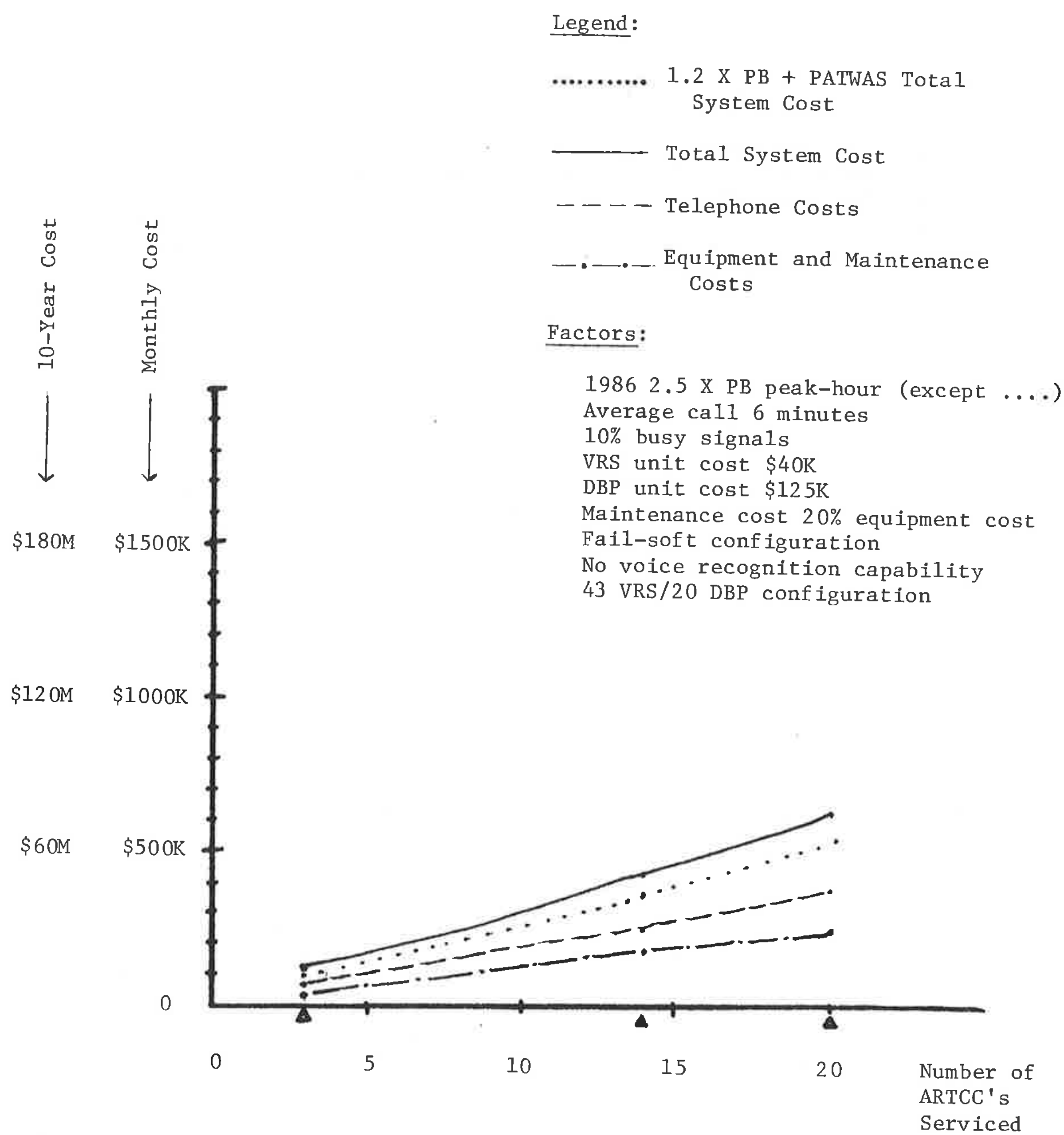


FIGURE 6.9-1 - PHASED SYSTEM IMPLEMENTATION

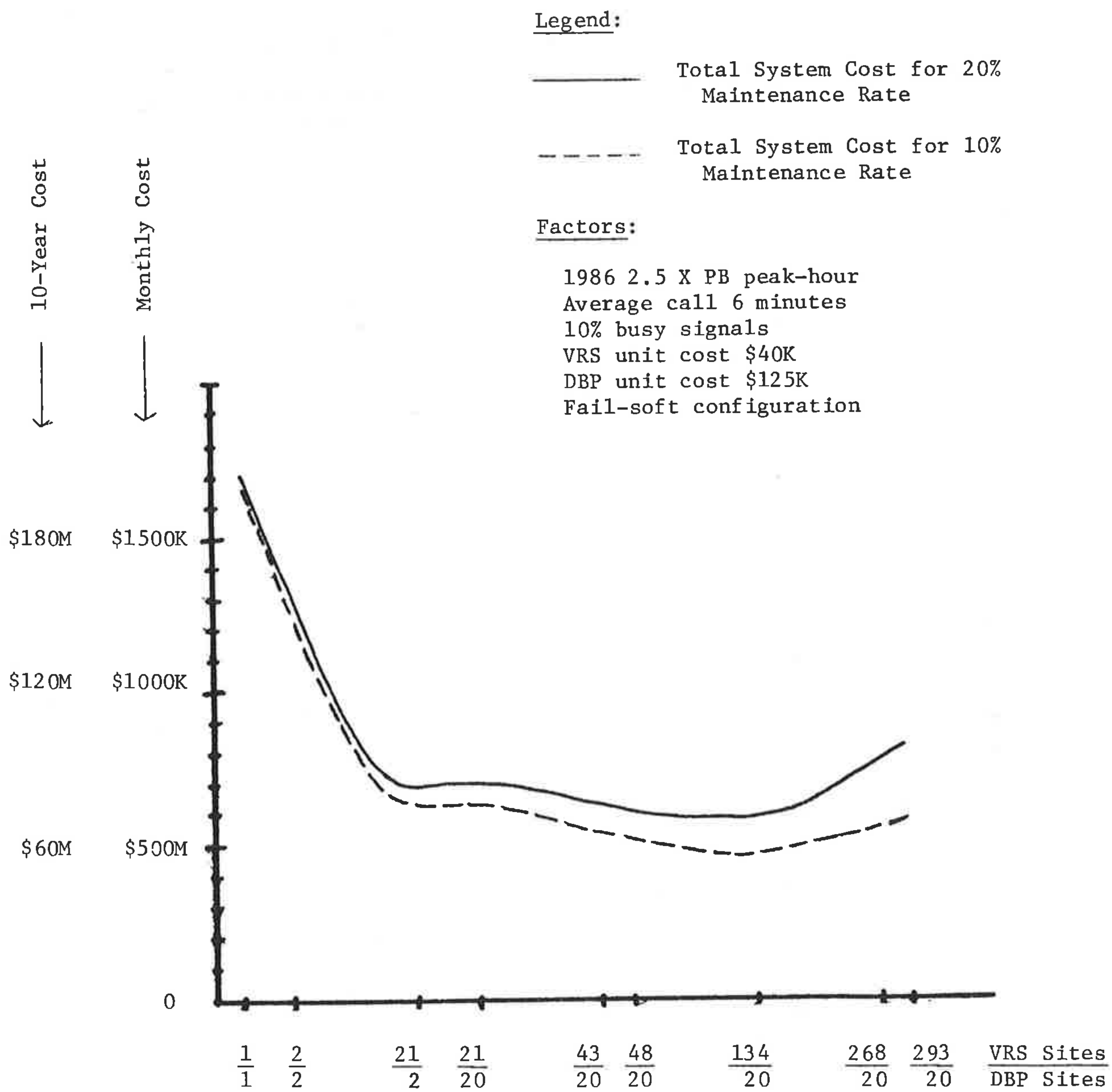


FIGURE 6.10-1 - EQUIPMENT MAINTENANCE ANALYSIS

(VRS units with tone input only)

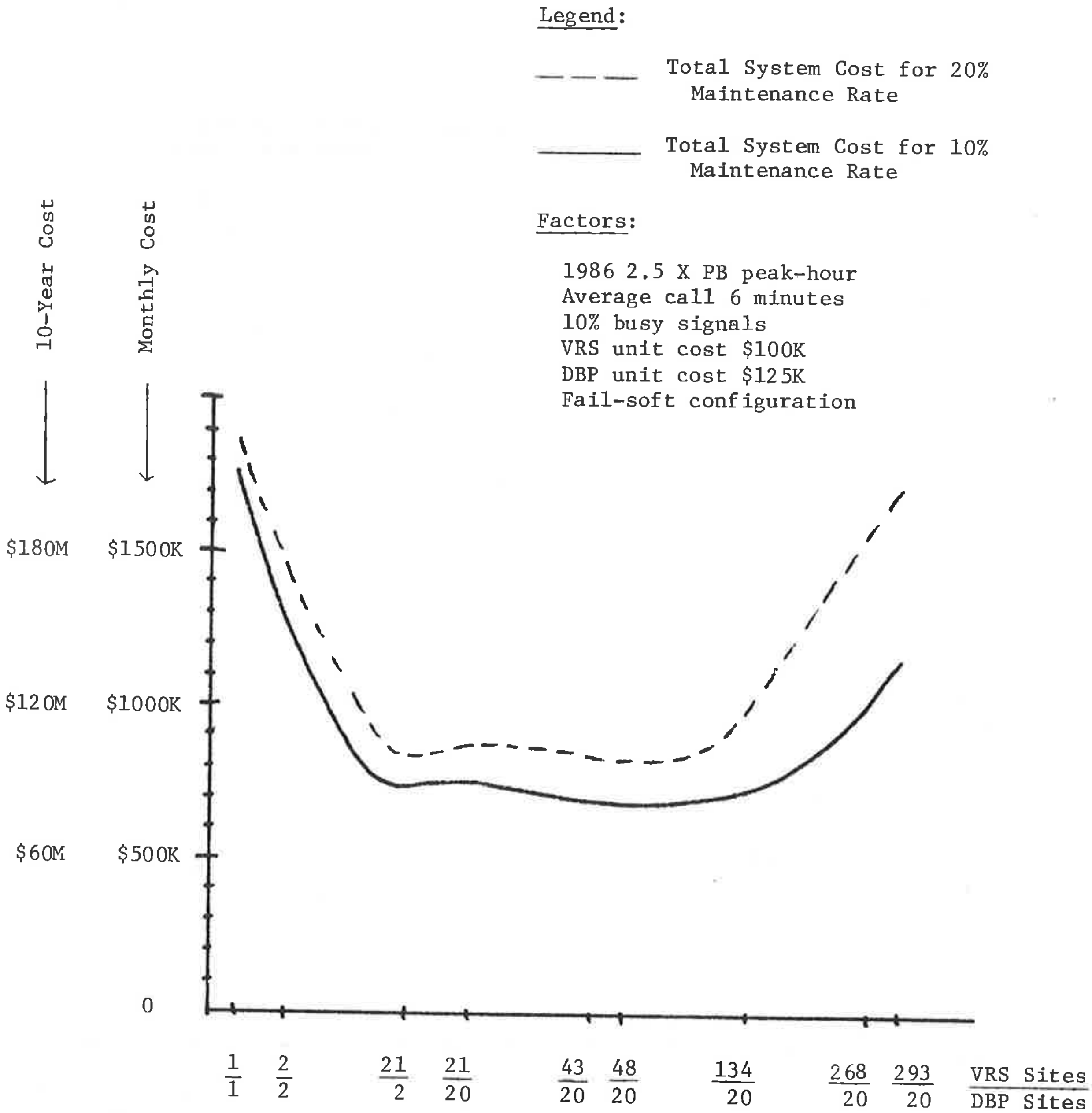


FIGURE 6.10-2 - EQUIPMENT MAINTENANCE ANALYSIS

(VRS units with voice recognition added) costs can be lowered to the 10% level, the minimum cost alternative moves toward the decentralized configurations. This effect is related to the communication cost predominance when equipment and maintenance costs are smaller. The effect is more significant for the voice recognition design as would be expected due to the higher VRS equipment cost.

6.11 LPC Special Digital Communication Network Alternative

One of the hardware configurations presented in Chapter 4 considered a digital data communication concept with decentralized LPC equipment connected to a VRS/DBP composite equipment site via digital telephone service. Currently, only 53 cities have Dataphone Digital Service offered by AT&T and 43 more cities are planned to be added to this service. Since not all FSS cities will be served in this manner, hybrid networks must be developed. The two likely hybrid configurations examined are: (293 FX) (134 LPC) (20 DBP & VRS) configuration; and (293 FX) (43 LPC) (20 DBP & VRS) configuration. Normal FX/TELPAK service is assumed for reaching all remote FSS's from the FSS containing the LPC voice generation equipment. In turn, these LPC sites are served by 20 FS/DPS locations which contain a support system combining the VRS and DBS functions. Equipment costs used were estimated as follows: LPC unit costs $9K for 32 channels with tone input only (no voice recognition capability) and DBP & VRS unit costs about $200K to service about 250 channels. The analysis assumed that 1200 bits per second LPC data rates will be adequate for voice quality. A more conservative estimate would be abut 4000 bits per second, but this would drive the digital communications to a prohibitive level. The results of these two LPC configurations are presented in Figure 6.11-1 along with the system costs for the non-digital configurations. It can be seen that the digital concept does not offer any major benefits for this national implementation.

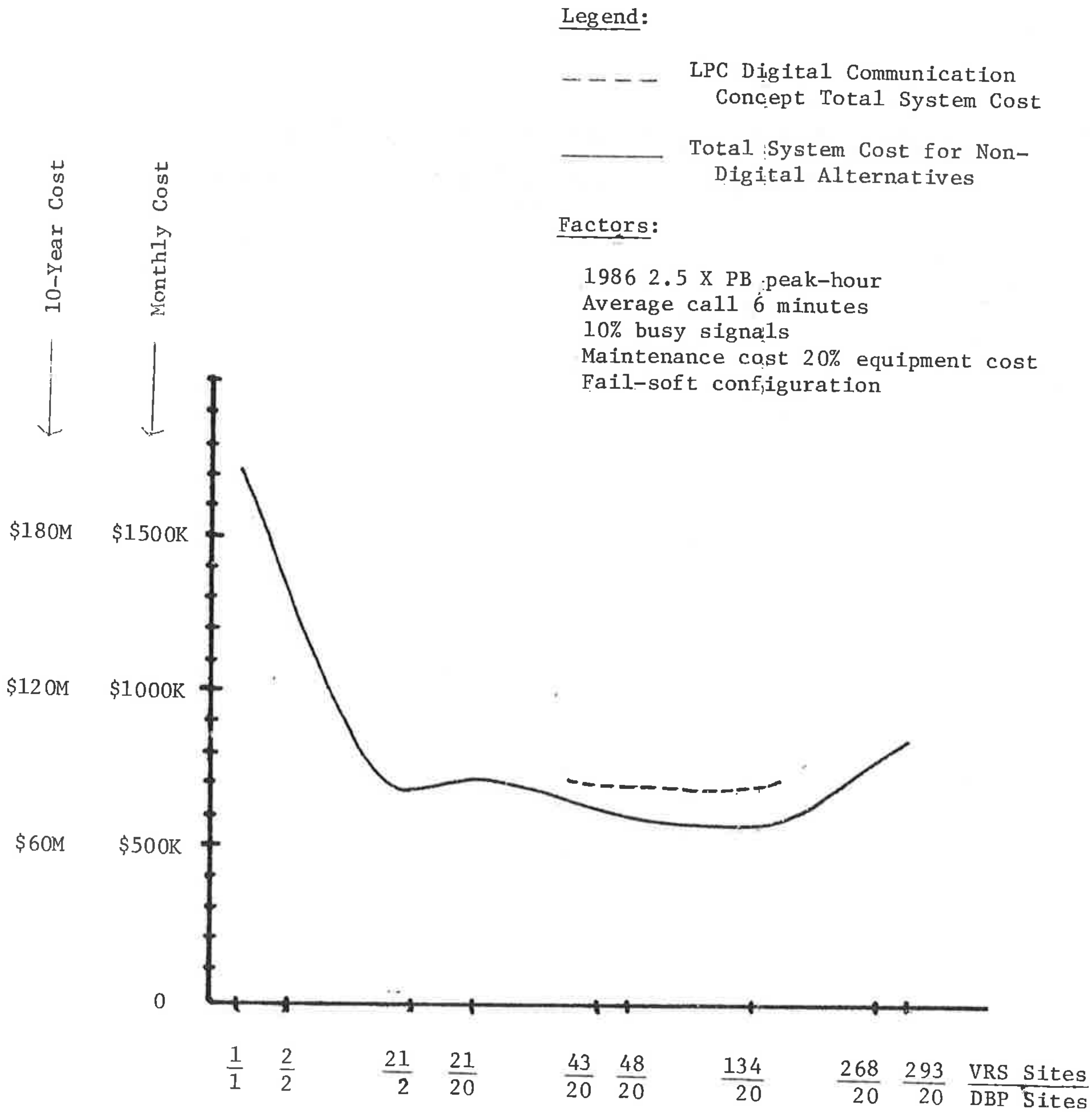


FIGURE 6.11-1 - COMMUNICATIONS ANALYSIS

7. CONCLUSIONS AND RECOMMENDATIONS

The high cost of providing voice recognition capability in addition to tone input does not appear to offer enough benefit to warrant consideration for an initial national VRS implementation. It is recommended that only tone input service be implemented first and that voice recognition be examined for implementation as an enhancement when its technology and costs become beneficial for this application. The following recommendations are therefore based on a tone input capability VRS design.

The results of the trade-offs discussed in the previous chapter showed that a relatively flat region of system costs exist for decentralized configurations ranging from the 43 to 150 VRS site alternatives. It is recognized that there are additional considerations and benefits which must be considered in narrowing the selection within this range of alternatives. This narrowing was not scoped for this study but is planned to be addressed in the National VRS Implementation Plan. In lieu of factoring in benefits as well as transition considerations involving facilities, staff, and operational constraints, the following technical recommendations are presented based upon the criteria examined in this study.

Because of reduced sensitivity to telephone rate increases as well as minimum cost, it is recommended that the 134/20 configuration be considered for the national VRS implementation plan. This configuration offers the minimum total system cost of all the configurations studied. Approximately 164 VRS units are required to provide full service to the nation at a 1986 demand level with the 134/20 configuration in a non fail-soft mode. The equipment should be modular to permit simple replacement repair at the operational site. The failed hardware problems can then be repaired at the maintenance depot. The Data Base Processor sites should be equipped with a high data rate line (9600 baud) and a multiplexor connected to the nearest Data Base Processor site for backup purposes. Maybe a data transmission service can be utilized for this purpose with charges primarily based on utilization. If a Data Base Processor site suffers a failure, the connecting VRS units will be switched to the backup Data Base Processor site via the multiplexed line. The backup Data Base Processor site would suffer some service delays if peak-loads occurred simultaneously, but this should not degrade user service to unacceptable levels.

The VRS hardware configuration recommended is the total solid state system having a 4,000-vocabulary ROM (or PROM) vocabulary storage unit and no voice recognition subsystem. Voice recognition equipment will be more than 1.5 times the cost of the rest of the VRS units of 1983 vintage. The convenience of voice input to users of the system is not deemed advantageous enough to justify the cost. The user can input VRS requests using increasingly available tone telephones and tone devices while the PATWAS caller can use either the tone inputs or the "click" input of a rotary dial telephone to key the desired PATWAS route. If at some time in the future (e.g., in five years) voice recognition devices become equivalent in price to the voice response subsystem, they can be incorporated into the system.

The channel sizing of 32 lines per VRS unit is recommended. This is based upon projected hardware technology, site demand level projections, growth capacity, the 134 site configuration and a limited 15% cost reduction estimated for a 50% reduced size unit.

All hardware purchases should take advantage of commonality with Model I, II, and III sytem components and processors. Such commonality will reduce maintenance costs, training and inventory requirements for national VRS operations.

The last recommendation concerns software development. All new software development should make maximum use of existing prototype logic designs. This approach can expedite early implementation and save software development cost. These savings are possible because the bulk of the software of the VRS computers and Data Base Processors deals with the same products and translations now existing or soon to be implemented on the prototype system. It is unlikely that major changes to the raw weather products will obsolete the data processing program logic. The one exception is a major new weather product employing grid data and forecasts. If this materializes before initial implementation, its processing software should be relatively simple (compared to free-text products) and inexpensive since this new product is specifically designed for easy automated processing.

REFERENCES

1. U.S. Department of Transportation, Federal Aviation Administration Flight Services Handbook, 7110.10D, January 1, 1977.

2. Fowler, T.B., The MITRE Corporation, Data Sources for Flight Service Station Information System Performance Requirements, Appendixes A-E, MTR 7847, December 1978.

3. Barboza, G., "Pilot Briefing Activity Forecasts for Flight Service Stations - 1984," MTR-6441, July 28, 1973.

4. U.S. Department of Transportation, Federal Aviation Administration, FAA Aviation Forecasts, Fiscal Years 1978-1989, FAA-AWP-77-32, September 1977.

5. Booth, T., "Indianapolis Flight Service Station Automation Evaluation Study," Federal Aviation Administration, AAT-12, June 1978.

6. The MITRE Corporation, FSS Configuration Analysis Study, MTR-6607, Volumes I-VII, February 1974 - November 1975.

7. Staiano, F., Shochet, E., "New York City Pilots Automatic Telephone Answering Service (PATWAS) Test," FAA-RD-77-80, October 1977.

8. Sluka, A.L., et al., "A Preliminary Test and Evaluation of the Use of Touch-Tone® Entry of Flight Plans into an Automatic FSS Voice Response System," NA-78-30-LR, May 1978.

9. Aron, J.D., "Estimating Resources for Large Programming Systems," Second NATO Conference on Software Engineering Techniques, Rome, October 1969.

10. U.S. Department of Commerce, National Bureau of Standards, Federal Information Processing Standards Publication 38 (FIPS PUB 38), February 15, 1976.

SUPPLEMENTAL READINGS

American Telephone & Telegraph Co., Inc., WATS Service Area Atlas, January 1978.

Barboza, G., "A Parametric Cost Analysis of an FSS Voice Response System," MTR-6639, March 1974.

Blake, F.M., "Technical Feasibility and Cost Analysis of an FSS Automated Voice Response System (VRS)," MTR-6759, September 1974.

Input Output Computer Services, Inc., Single-Channel Voice Response System, FAA-RD-77-177, I-III, December 1977.

Input Output Computer Services, Inc., Ten-Channel Voice Response System, DOT-TSC-1161, June 1977, on file at DOT-TSC.

Input Output Computer Services, Inc., Ten-Channel VRS Processor Design Report, DOT-TSC-1107, November 1977, on file at DOT-TSC.

Metzger, B.H., Williams, J.M., "Description of Experimental FSS Pilot Self-Briefing System," MTR-6604, February 1974.

MITRE Corporation, Cost Analysis of the 8, 8/12, and 20 Hub Flight Service Station Configuration, MTR-7166, March 1976.

MITRE Corporation, Flight Service Station National Configuration and Cost Analysis Summary, MTR-6937, July 1975.

U.S. Department of Transportation, Federal Aviation Administration, Specification for the Flight Service Information System, Volume 1-3, FAA-E-2683-2685, February 22, 1978.

APPENDIX A - FY86 PEAK-HOUR DEMANDS FOR 138 FACILITIES

FSS NAME	PB	FP	AC	SERVICES
WASHINGTON	395.1	171.4	103.5	1682.9
MIAMI	188.5	115.5	98.7	998.9
LOS ANGELES	279.0	73.0	53.5	939.0
CHICAGO	212.3	56.2	44.4	759.1
HOUSTON	194.3	69.2	57.0	740.3
BOSTON	149.5	83.7	43.5	715.0
MEMPHIS	128.3	41.3	49.3	668.4
FORT WORTH	149.4	50.0	43.5	640.2
DETROIT	155.7	67.5	20.5	630.9
CLEVELAND	137.0	72.5	14.4	610.7
MINNEAPOLIS	158.4	47.1	69.4	592.2
SAN DIEGO	112.5	56.4	55.0	588.7
OAKLAND	151.2	51.6	49.0	576.3
INDIANAPOLIS	155.2	50.0	34.8	566.6
WILKES BARRE	154.2	51.4	24.5	563.7
KANSAS CITY	119.9	48.5	35.4	489.3
PHOENIX	96.8	52.7	53.3	485.0
PITTSBURGH	116.0	46.8	35.8	474.3
DENVER	101.1	47.3	52.1	463.9
POUGHKEEPSIE	130.9	38.1	33.7	462.1
DAYTON	120.5	45.8	19.2	462.0
PHILADELPHIA	110.8	46.2	12.5	438.4
ATLANTA	110.4	44.5	19.2	437.4
SEATTLE	82.8	51.6	40.5	436.3
UTICA	93.8	47.8	48.1	428.6
LAS VEGAS	70.0	53.1	47.7	425.3
OMAHA	96.5	40.8	38.2	411.5
ST LOUIS	97.3	43.7	21.0	409.0
SACRAMENTO	100.4	36.7	38.1	400.5
RALEIGH	93.5	41.7	28.2	399.9
BIRMINGHAM	109.9	30.5	35.0	387.9
COLUMBUS	93.4	38.9	27.3	385.0
FLORENCE	73.7	42.0	39.0	373.2
CHARLESTON	94.1	34.7	30.6	371.7
ISLIP	92.5	33.3	13.1	367.2
WINDSOR LOCKS	86.9	39.0	17.8	364.4
SOUTH BEND	95.1	33.3	22.0	358.6
ST PETERSBURG	91.7	39.4	19.4	357.7
DECATUR	84.2	29.8	35.0	335.8
TETERBORO	92.2	31.2	12.1	333.6
LOUISVILLE	86.0	30.5	21.9	328.4
OKLAHOMA CITY	68.3	37.8	18.4	323.2
SAN ANTONIO	67.9	37.1	21.0	321.8
SAVANNAH	75.4	30.0	36.5	319.9
JACKSONVILLE	73.3	31.5	33.4	319.7
WICHITA	82.6	31.1	16.8	319.1
NEW ORLEANS	77.7	33.1	15.1	317.0
BUFFALO	65.4	37.9	8.0	307.5
NASHVILLE	82.7	29.2	12.4	306.1
CEDAR RAPIDS	71.7	28.5	34.9	305.6
DES MOINES	78.3	21.6	53.9	304.8
PORTLAND	77.0	25.8	35.0	302.3
TULSA	83.6	24.6	26.3	301.4
LITTLE ROCK	68.9	29.9	30.9	301.1
PENSACOLA	54.6	35.3	25.6	292.3

FSS NAME	PB	FP	AC	SERVICES
ORLANDO	72.9	27.7	21.6	259.4
HICKORY	74.0	20.8	12.6	247.4
MILWAUKEE	78.5	25.4	13.7	236.9
VERO BEACH	55.1	28.3	35.3	273.7
LANCASTER	60.2	21.4	45.9	260.5
DUBOIS	59.6	24.5	32.5	260.2
SALINA	55.0	23.6	43.3	256.3
AMARILLO	58.7	22.4	36.7	253.0
BANGOR	44.5	29.2	25.4	245.6
SHREVEPORT	51.4	27.7	16.9	244.5
EL PASO	44.2	27.6	27.8	239.4
LAKE CHARLES	34.5	23.6	21.3	233.4
GREER	64.4	13.9	20.4	230.5
SPRINGFIELD	56.0	19.7	30.5	229.4
TUCSON	34.4	30.2	22.7	225.5
MIDLAND	52.4	21.3	26.0	225.0
BILLINGS	51.7	18.1	40.5	223.6
ROANOKE	56.8	17.5	27.8	218.2
SANTA BARBARA	50.4	17.3	38.9	215.8
ALBUQUERQUE	47.5	21.0	27.5	215.5
AUSTIN	50.3	22.3	14.4	213.9
SAGINAW	50.9	21.7	8.9	206.6
RENO	34.9	23.3	29.5	203.5
SALT LAKE	45.5	20.2	20.3	200.8
GREEN BAY	48.1	17.8	24.3	199.0
JACKSON	40.1	20.0	14.9	184.0
KNOXVILLE	47.5	17.7	9.9	183.0
MACON	44.3	16.7	19.1	181.5
FRESNO	40.6	18.4	16.9	179.5
NEW BERN	29.0	22.7	18.8	178.5
GARDEN CITY	34.0	15.6	33.3	170.2
HURON	39.6	11.6	39.9	169.8
FINDLAY	38.9	15.8	21.6	169.1
GRAND FORKS	35.9	16.3	21.7	165.7
GREAT FALLS	30.6	15.8	25.1	155.5
GAINESVILLE	36.6	13.0	24.9	155.2
WALLA WALLA	33.6	12.2	32.8	153.9
TRAVERSE CITY	32.3	12.7	28.7	149.3
DOTHAN	21.2	21.1	8.4	145.5
CROSSVILLE	39.6	11.5	14.3	143.8
COLUMBIA	34.0	12.2	19.2	141.1
CAPE GIRARDEAU	28.0	15.0	15.3	137.8
GREENWOOD	42.8	9.1	12.2	136.9
NORTH PLATTE	32.6	8.8	30.1	133.6
UKIAH	31.4	9.0	30.5	132.8
MONTGOMERY	23.9	16.7	10.2	132.3
CHARLESTON	24.9	16.0	9.2	130.6
WENATCHEE	23.7	11.1	33.3	130.2
BOISE	22.7	15.8	12.3	128.1
GRAND JUNCTION	25.8	11.5	20.3	122.8
LUBBOCK	27.7	11.6	15.4	122.1
WICHITA FALLS	27.2	12.1	13.3	121.9
MUSCLE SHOALS	27.5	9.9	17.9	116.7
MINOT	22.5	10.0	25.3	115.8
PRESCOTT	18.1	10.1	33.2	114.5

APPENDIX A (continued)

FSS NAME	PB	FP	AC	SERVICES
TALLAHASSEE	24.4	11.4	11.9	111.4
BOWLING GREEN	18.0	12.7	15.5	108.3
LA CROSSE	20.1	11.9	13.5	107.0
FAYETTEVILLE	23.1	10.1	15.5	106.6
MCALLEN	18.8	12.9	9.5	104.7
HIBBING	20.3	10.4	16.4	103.4
ABILENE	20.4	11.9	9.0	103.0
MARQUETTE	21.3	7.7	21.6	98.1
SPOKANE	22.3	10.1	8.5	97.8
ROCK SPRINGS	18.8	6.7	28.4	95.5
RED BLUFF	19.7	6.6	26.4	94.9
SCOTTSBLUFF	19.5	6.9	24.9	94.2
MONTPELIER	10.0	12.9	13.0	91.2
GALLUP	16.8	8.6	17.0	89.0
BELLINGHAM	12.7	7.3	22.7	80.6
MCALESTER	19.2	5.3	13.3	79.6
BURLEY	16.5	6.1	17.1	77.0
RAPID CITY	17.0	7.5	8.6	75.7
BOZEMAN	14.	5.0	22.8	73.5
MCCOMB	17.7	5.5	12.0	71.7
REDMOND	17.6	4.1	16.1	68.8
IDAHO FALLS	17.6	5.0	10.6	67.8
ROSWELL	14.2	5.4	12.3	65.0
CASPER	15.2	5.3	10.5	64.1
PIERRE	13.5	4.1	17.0	62.0
CEDAR CITY	11.6	4.3	15.3	57.3
NORTH BEND	9.0	3.6	16.4	50.4

APPENDIX B - FY95 PEAK-HOUR DEMAND ESTIMATES FOR 138 FACILITIES

FACILITY NAME	PB	FP	AC	SERVICES
WASHINGTON	542.2	231.7	130.0	2230.4
MIAMI	265.4	156.3	123.5	1350.5
LOS ANGELES	392.9	98.7	79.6	1293.7
CHICAGO	299.0	89.4	56.0	1045.0
HOUSTON	259.5	93.5	43.8	1014.4
BOSTON	210.5	113.2	54.4	978.7
MEMPHIS	180.7	109.9	61.7	912.8
FORT WORTH	266.7	67.7	54.6	881.9
DETROIT	219.2	91.3	26.0	857.4
CLEVELAND	192.9	98.1	18.0	839.3
MINNEAPOLIS	223.0	63.7	45.8	811.0
SAN DIEGO	158.5	89.7	85.1	801.4
OAKLAND	212.9	69.8	61.3	793.4
INDIANAPOLIS	220.0	67.7	43.6	779.6
WILKES BARRE	217.1	59.5	36.9	775.0
KANSAS CITY	158.8	65.5	44.3	671.0
PHOENIX	136.3	71.2	72.9	661.9
PITTSBURGH	163.3	63.2	44.9	650.4
DAYTON	169.7	61.9	24.1	635.9
POUGHKEEPSIE	194.3	51.6	42.2	635.7
DENVER	142.3	63.9	65.2	633.0
PHILADELPHIA	156.0	62.5	15.6	603.5
ATLANTA	155.5	60.1	24.0	600.2
SEATTLE	116.6	69.8	50.7	594.8
UTICA	118.0	64.7	60.2	583.8
LAS VEGAS	98.6	71.8	59.7	577.9
OMAHA	135.9	55.1	47.9	563.0
ST LOUIS	137.0	59.0	26.3	561.5
SACRAMENTO	141.4	49.6	47.6	548.7
RALEIGH	131.7	56.4	35.2	548.1
BIRMINGHAM	154.8	41.3	43.9	532.9
COLUMBUS	131.5	52.6	34.2	529.3
CHARLESTON	132.4	47.0	38.3	509.8
FLORENCE	103.9	56.7	48.8	508.6
ISLIP	130.2	51.8	16.4	505.3
WINDSOR LOCKS	122.4	52.7	22.1	500.4
SOUTH BEND	134.0	45.0	27.5	493.0
ST PETERSBURG	115.1	53.3	24.3	490.5
TETERBORO	129.9	42.2	15.1	460.0
DECATUR	118.5	40.4	45.1	459.6
LOUISVILLE	121.1	41.3	27.4	451.2
OKLAHOMA CITY	96.2	51.1	23.0	442.6
SAN ANTONIO	95.6	50.1	26.3	440.4
WICHITA	116.3	42.1	21.0	438.8
SAVANNAH	106.2	40.6	45.7	437.1
JACKSONVILLE	103.3	42.7	41.8	437.0
NEW ORLEANS	109.5	44.8	13.9	435.6
BUFFALO	92.1	51.2	10.0	422.2
NASHVILLE	116.5	39.4	15.6	421.6
CEDAR RAPIDS	101.0	38.9	43.7	417.5
DES MOINES	110.3	29.2	67.4	415.2
TULSA	117.7	33.2	33.5	413.9
PORTLAND	108.4	34.9	43.8	413.6
LITTLE ROCK	97.0	40.4	13.7	411.5
PENSACOLA	76.9	47.7	32.0	398.6

APPENDIX B (Continued)

FACILITY NAME	PB	FP	AC	SERVICES
ORLANDO	102.7	37.4	27.1	397.1
HICKORY	104.2	33.9	15.3	395.4
MILWAUKEE	110.7	35.7	17.2	395.2
VERO BEACH	79.0	38.3	44.8	372.6
DUBOIS	83.9	33.2	40.7	355.0
LANCASTER	84.8	29.0	57.3	354.1
SALINA	77.4	32.0	54.8	350.8
AMARILLO	92.6	30.3	46.0	344.8
SHREVEPORT	72.3	37.4	23.7	334.5
BANGOR	62.7	39.4	33.1	334.3
LAKE CHARLES	90.9	27.0	27.4	327.2
EL PASO	62.3	37.3	34.8	325.7
GREER	90.7	26.9	26.0	324.8
SPRINGFIELD	78.9	26.7	38.2	313.2
TUCSON	48.4	40.8	28.4	307.9
MIDLAND	73.8	28.8	32.5	307.3
BILLINGS	72.7	24.5	50.8	303.9
ROANOKE	80.0	23.7	34.8	298.4
ALBUQUERQUE	66.9	28.4	34.5	293.8
SANTA BARBARA	71.0	23.4	48.7	293.3
AUSTIN	70.8	30.2	18.0	293.2
SAGINAW	71.6	29.4	11.0	284.0
RENO	49.0	31.6	37.1	276.0
SALT LAKE	64.1	27.3	25.4	274.5
GREEN BAY	67.7	24.1	30.4	271.9
JACKSON	56.5	27.1	18.6	251.7
KNOXVILLE	66.9	24.0	12.4	251.6
MACON	62.4	22.6	23.9	248.3
FRESNO	57.2	24.8	21.2	245.5
NEW BERN	40.8	30.7	23.5	242.7
FINDLAY	54.7	21.4	27.0	230.7
GARDEN CITY	47.8	21.0	41.7	230.4
HURON	55.8	15.7	50.9	229.9
GRAND FORKS	50.6	22.1	27.1	225.8
GREAT FALLS	43.2	21.4	31.4	212.6
GAINESVILLE	51.5	17.6	31.1	211.4
WALLA WALLA	47.3	16.6	41.0	208.5
TRAVERSE CITY	45.5	17.2	35.9	202.5
DOTHAN	29.9	28.5	10.5	198.2
CROSSVILLE	55.7	15.6	17.9	197.3
COLUMBIA	47.8	16.6	24.1	192.5
GREENWOOD	60.3	12.3	15.2	188.5
CAPE GIRARDEAU	39.5	20.2	19.1	187.9
NORTH PLATTE	46.0	11.9	37.6	181.2
MONTGOMERY	33.6	22.5	12.7	180.5
UKIAH	44.3	12.2	38.1	179.9
CHARLESTON	35.1	21.6	11.6	178.3
WENATCHEE	33.4	15.1	41.7	175.3
BOISE	32.0	21.3	15.4	174.5
GRAND JUNCTION	36.3	15.5	25.4	166.8
LUBBOCK	39.0	15.7	19.3	166.5
WICHITA FALLS	38.3	16.4	17.2	166.4
MUSCLE SHOALS	38.7	13.4	22.4	159.0
MINOT	31.7	13.6	33.0	156.3
PRESCOTT	25.5	13.7	41.6	153.5

APPENDIX B (concluded)

FACILITY NAME	PB	FP	AC	SERVICES
TALLAHASSEE	34.4	15.5	14.8	152.1
BOWLING GREEN	25.3	17.2	19.5	146.8
LA CROSSE	28.3	16.1	17.1	145.5
FAYETTEVILLE	32.5	13.7	19.5	145.0
MCALLEN	26.4	17.4	11.9	142.7
ABILENE	28.8	16.1	11.2	140.6
HIBBING	28.6	14.1	20.6	140.4
SPOKANE	31.3	13.6	10.7	133.7
MARQUETTE	30.1	10.4	27.1	132.8
ROCK SPRINGS	26.5	9.0	35.6	128.3
RED BLUFF	27.7	9.0	33.0	127.8
SCOTTSBLUFF	27.5	9.3	31.2	127.0
MONTPELIER	14.1	17.4	16.3	123.0
GALLUP	23.7	11.7	21.3	120.5
BELLINGHAM	17.9	9.8	28.4	108.0
MCALESTER	27.0	7.1	22.9	107.9
BURLEY	23.2	8.3	21.3	104.2
RAPID CITY	23.9	10.1	10.7	103.4
BOZEMAN	20.2	6.8	28.5	98.7
MCCOMB	25.0	7.5	15.0	97.7
REDMOND	24.8	5.5	20.2	93.4
IDAHO FALLS	24.9	6.8	13.3	92.5
ROSWELL	19.9	7.3	16.0	88.2
CASPER	21.5	7.1	13.1	87.3
PIERRE	19.0	5.6	21.3	83.5
CEDAR CITY	16.4	5.8	19.1	77.3
NORTH BEND	12.7	4.9	20.6	67.5

APPENDIX C - FY86 PEAK-HOUR DEMAND ESTIMATES FOR 20 FSDPS's

HUB NAME	PB	FP	AC	SERVICES	RANK*
Alburquerque	330.7	178.0	236.1	1689.2	16
Atlanta	514.0	186.3	141.1	1988.9	11
Boston	374.7	212.6	148.9	1844.8	15
Chicago	505.9	172.5	139.7	1909.3	13
Cleveland	623.3	286.8	141.8	2659.3	1
Denver	211.3	87.2	146.4	954.2	20
Fort Worth	539.5	202.4	190.1	2160.9	7
Houston	481.3	200.1	160.9	2007.9	10
Indianapolis	550.1	200.0	133.9	2114.7	8
Jacksonville	384.3	200.4	188.9	1847.8	14
Kansas City	562.8	224.3	236.2	2352.1	4
Los Angeles	583.8	235.4	279.2	2486.6	2
Memphis	459.4	217.2	184.1	2065.8	9
Miami	399.2	211.0	175.5	1911.7	12
Minneapolis	538.7	194.3	346.8	2279.6	5
New York	580.5	205.3	100.9	2165.0	6
Oakland	378.2	145.7	190.5	1589.5	17
Salt Lake City	217.8	92.8	177.2	1023.0	19
Seattle	278.7	125.8	205.5	1320.3	18
Washington, D.C.	564.4	253.4	178.6	2429.6	3
TOTAL	9078.8	3831.4	3702.1	38800.1	

*Rank is based on total services for each FSDPS

APPENDIX D - FY95 PEAK-HOUR DEMAND ESTIMATES FOR 20 FSDPS's

HUB NAME	PB	FP	AC	SERVICES	RANK*
Alburquerque	465.6	240.7	295.5	2296.2	16
Atlanta	723.8	251.8	176.5	2731.1	11
Boston	527.7	287.4	186.3	2520.3	15
Chicago	712.5	233.2	174.9	2622.7	13
Cleveland	877.8	387.7	177.5	3649.4	1
Denver	297.5	117.9	183.2	1298.5	20
Fort Worth	759.7	273.6	237.9	2961.5	7
Houston	677.7	270.5	201.3	2751.2	10
Indianapolis	774.7	270.4	167.6	2905.8	8
Jacksonville	541.1	270.9	236.4	2521.3	14
Kansas City	792.6	303.2	295.6	3217.9	4
Los Angeles	822.2	318.3	349.4	3397.7	2
Memphis	646.9	293.6	230.4	2824.8	9
Miami	562.2	285.2	219.6	2610.7	12
Minneapolis	758.6	262.7	434.0	3106.1	5
New York	817.4	277.6	126.2	2980.5	6
Oakland	532.6	197.0	238.4	2171.3	17
Salt Lake City	306.7	125.4	221.8	1389.1	19
Seattle	392.5	170.1	257.1	1794.9	18
Washington, D.C.	794.8	342.5	223.5	3328.6	3
TOTAL	12784.5	5179.8	4633.1	53079.4	

*Based on total flight services for each FSDPS

APPENDIX E – FSS SUMMARY DATA

TABLE E-1

FSDPS – FSS SUMMARY DATA FOR ALBUQUERQUE

NAME	FSS NAME	STATE CODE	DISTANCE (MILES)	ANNUAL 1986 DEMAND (THOUSANDS) PB	FP	AC
ALBUQUERQUE	ALBUQUERQUE	30	8.6	151.3	70.5	78.3
ALBUQUERQUE	LAS VEGAS	30	8.6	15.0	2.8	18.2
ALBUQUERQUE	2		8.6	166.2	73.4	96.4
AMARILLO	AMARILLO	42	274.5	108.2	35.6	38.1
AMARILLO	TUCUMCARI	30	274.5	43.1	32.3	33.8
AMARILLO	DALHART	42	274.5	27.1	6.0	33.5
AMARILLO	GAGE	35	274.5	26.7	4.6	23.1
AMARILLO	4		274.5	205.1	78.4	128.5
EL PASO	EL PASO	42	233.1	132.3	87.6	50.7
EL PASO	DEMING	30	233.1	18.0	7.0	32.1
EL PASO	TRUTH OR CONSEQ	30	233.1	4.4	1.9	14.4
EL PASO	3		233.1	154.7	96.5	97.2
GALLUP	GALLUP	30	127.1	58.9	30.2	59.5
GALLUP	1		127.1	58.9	30.2	59.5
PHOENIX	PHOENIX	2	333.1	249.2	139.0	123.7
PHOENIX	BLYTHE	4	333.1	89.2	45.1	80.0
PHOENIX	2		333.1	338.4	184.1	203.7
PRESCOTT	PRESCOTT	2	297.5	63.3	35.4	116.2
PRESCOTT	1		297.5	63.3	35.4	116.2
ROSWELL	ROSWELL	30	173.7	37.1	14.4	21.2
ROSWELL	CARLSBAD	30	173.7	12.4	4.6	23.5
ROSWELL	2		173.7	49.5	19.0	44.8
TUCSON	TUCSON	2	328.5	83.0	70.0	48.1
TUCSON	DOUGLAS	2	328.5	37.1	35.4	31.2
TUCSON	2		328.5	120.1	105.5	79.3
ALBUQUERQUE	17			1156.2	622.5	825.5

TABLE E-2

FSDPS - FSS SUMMARY DATA FOR ATLANTA

NAME	FSS NAME	STATE CODE	DISTANCE (MILES)	ANNUAL 1986 DEMAND (THOUSANDS) PB	FP	AC
ATLANTA	ATLANTA	10	30.5	386.1	155.5	67.1
ATLANTA	1		30.5	386.1	155.5	67.1
BIRMINGHAM	BIRMINGHAM	1	141.7	197.2	58.4	36.4
BIRMINGHAM	ANNISTON	1	141.7	116.1	25.1	54.3
BIRMINGHAM	TUSCALOOSA	1	141.7	71.0	23.2	31.6
BIRMINGHAM	3		141.7	384.3	106.7	122.3
CROSSVILLE	CROSSVILLE	41	182.9	138.3	40.4	50.0
CROSSVILLE	1		182.9	138.3	40.4	50.0
GREER	GREER	39	158.7	181.8	57.4	37.7
GREER	ANDERSON	39	158.7	43.3	12.1	35.1
GREER	2		158.7	225.1	69.5	72.8
HICKORY	HICKORY	32	232.1	258.6	100.6	44.2
HICKORY	1		232.1	258.6	100.6	44.2
MACON	MACON	10	62.0	85.8	38.1	37.4
MACON	ALBANY	10	62.0	69.2	20.4	29.5
MACON	2		62.0	155.1	58.4	66.8
MONTGOMERY	MONTGOMERY	1	142.0	83.4	58.3	35.5
MONTGOMERY	1		142.0	83.4	58.3	35.5
KNOXVILLE	KNOXVILLE	41	169.0	125.7	44.2	34.5
KNOXVILLE	BRISTOL-TRI CIT	41	169.0	40.5	17.7	0.0
KNOXVILLE	2		169.0	166.2	61.9	34.5
ATLANTA	13			1797.2	651.3	493.2

TABLE E-3

FSDPS- FSS SUMMARY DATA FOR BOSTON

NAME	FSS NAME	STATE CODE	DISTANCE (MILES)	ANNUAL 1986 DEMAND (THOUSANDS) PB	FP	AC
WINDSOR LOCKS	WINDSOR LOCKS	6	82.7	303.9	136.4	62.4
WINDSOR LOCKS	1		82.7	303.9	136.4	62.4
BANGOR	BANGOR	18	195.0	75.0	57.6	19.5
BANGOR	AUGUSTA	18	195.0	61.5	32.1	60.6
BANGOR	HOULTON	18	195.0	19.2	12.3	12.3
BANGOR	3		195.0	155.7	102.0	92.4
BOSTON	BOSTON	20	36.2	381.5	229.0	46.1
BOSTON	CONCORD	28	36.2	75.4	43.0	65.0
BOSTON	LEBANON	28	36.2	65.7	20.7	41.0
BOSTON	3		36.2	522.6	292.7	152.0
MONTPELIER	MONTPELIER	44	115.8	35.1	45.1	45.5
MONTPELIER	1		115.8	35.1	45.1	45.5
UTICA	UTICA	31	199.2	78.4	52.5	19.2
UTICA	GLENS FALLS	31	199.2	31.7	11.9	46.6
UTICA	MASSENA	31	199.2	29.5	43.5	29.2
UTICA	WATERTOWN	31	199.2	42.9	11.4	33.9
UTICA	ELMIRA	31	199.2	110.4	47.9	39.3
UTICA	5		199.2	292.9	167.2	168.2
BOSTON	13			1310.3	743.4	520.5

TABLE E-4

FSDPS- FSS SUMMARY DATA FOR CHICAGO

NAME	FSS NAME	STATE CODE	DISTANCE (MILES)	ANNUAL 1986 DEMAND (THOUSANDS) PB	FP	AC
CHICAGO	CHICAGO	12	10.2	614.0	191.5	117.2
CHICAGO	ROCKFORD	12	10.2	128.3	39.8	39.3
CHICAGO	2		10.2	742.3	231.3	156.5
CEDAR RAPIDS	CEDAR RAPIDS	14	173.4	191.2	70.4	57.0
CEDAR RAPIDS	BURLINGTON	14	173.4	59.7	30.4	65.1
CEDAR RAPIDS	2		173.4	250.8	100.7	122.1
GREEN BAY	GREEN BAY	48	186.8	100.0	39.0	31.2
GREEN BAY	WAUSAU	48	186.8	68.2	23.3	53.9
GREEN BAY	2		186.8	168.2	62.3	85.0
MILWAUKEE	MILWAUKEE	48	83.6	275.0	92.3	47.9
MILWAUKEE	1		83.6	275.0	92.3	47.9
SOUTH BEND	SOUTH BEND	13	103.7	207.1	70.4	47.9
SOUTH BEND	FORT WAYNE	13	103.7	125.5	46.0	29.0
SOUTH BEND	2		103.7	332.7	116.4	77.0
CHICAGO	9			1769.0	603.0	488.6

TABLE E-5

FSDPS- FSS SUMMARY DATA FOR CLEVELAND

NAME	FSS NAME	STATE CODE	DISTANCE (MILES)	ANNUAL 1986 DEMAND (THOUSANDS) PB	FP	AC
PITTSBURGH	PITTSBURGH	37	132.4	292.1	119.0	31.3
PITTSBURGH	ALTOONA	37	132.4	65.5	26.9	45.6
PITTSBURGH	JOHNSTOWN	37	132.4	47.9	17.7	48.2
PITTSBURGH	3		132.4	405.5	163.6	125.2
BUFFALO	BUFFALO	31	210.7	228.7	132.5	27.9
BUFFALO	1		210.7	228.7	132.5	27.9
CLEVELAND	CLEVELAND	34	20.2	332.3	203.4	34.8
CLEVELAND	YOUNGSTOWN	34	20.2	146.7	50.2	15.4
CLEVELAND	2		20.2	478.9	253.6	50.2
DETROIT	DETROIT	21	87.9	389.9	190.6	40.4
DETROIT	JACKSON	21	87.9	77.0	25.1	18.0
DETROIT	LANSING	21	87.9	77.4	20.4	14.1
DETROIT	3		87.9	544.4	236.0	72.6
DUBOIS	DUBOIS	37	171.7	63.1	27.0	37.1
DUBOIS	BRADFORD	37	171.7	58.9	17.9	33.9
DUBOIS	ERIE	37	171.7	44.3	14.0	3.8
DUBOIS	PHILIPSBURG	37	171.7	42.1	26.9	39.0
DUBOIS	4		171.7	208.3	85.8	113.8
FINDLAY	FINDLAY	34	78.4	135.9	55.3	75.4
FINDLAY	1		78.4	135.9	55.3	75.4
SAGINAW	SAGINAW	21	181.7	177.8	76.0	30.8
SAGINAW	1		181.7	177.8	76.0	30.8
CLEVELAND	15			2179.5	1002.8	495.8

TABLE E-6

FSDPS- FSS SUMMARY DATA FOR DENVER

NAME	FSS NAME	STATE CODE	DISTANCE (MILES)	ANNUAL 1986 DEMAND (THOUSANDS) PR	FP	AC
SCOTTSBLUFF	SCOTTSBLUFF	26	141.1	47.9	17.2	53.9
SCOTTSBLUFF	CHADRON	25	141.1	12.0	4.0	15.4
SCOTTSBLUFF	SIDNEY	26	141.1	8.4	2.8	17.8
SCOTTSBLUFF	3		141.1	68.2	24.0	87.1
CASPER	CASPER	49	199.2	53.3	18.4	36.7
CASPER	1		199.2	53.3	18.4	36.7
DENVER	DENVER	5	32.2	289.0	146.4	105.7
DENVER	AKRON	5	32.2	19.2	5.3	24.8
DENVER	LA JUNTA	5	32.2	24.3	7.0	28.4
DENVER	TRINIDAD	5	32.2	21.0	6.7	23.2
DENVER	4		32.2	353.4	165.3	182.2
GRAND JUNCTION	GRAND JUNCTION	5	195.0	70.4	32.1	44.8
GRAND JUNCTION	EAGLE	5	195.0	19.8	8.1	26.1
GRAND JUNCTION	2		195.0	90.2	40.2	70.9
NORTH PLATTE	NORTH PLATTE	26	240.6	65.9	17.7	60.2
NORTH PLATTE	GOODLAND	15	240.6	41.1	11.4	38.3
NORTH PLATTE	HILL CITY	15	240.6	7.2	1.6	6.6
NORTH PLATTE	3		240.6	114.1	30.7	105.1
RAPID CITY	RAPID CITY	40	286.6	59.5	26.1	30.0
RAPID CITY	1		286.6	59.5	26.1	30.0
DENVER	14			738.7	304.8	512.0

TABLE E-7

FSDPS - FSS SUMMARY DATA FOR FORT WORTH

NAME	FSS NAME	STATE CODE	DISTANCE (MILES)	ANNUAL 1986 DEMAND (THOUSANDS) PB	FP	AC
ABILENE	ABILENE	42	154.8	71.4	41.8	31.3
ABILENE	1		154.8	71.4	41.8	31.3
FORT WORTH	FORT WORTH	42	16.5	260.9	62.5	68.4
FORT WORTH	DALLAS	42	16.5	379.7	106.3	57.8
FORT WORTH	MINERAL WELLS	42	16.5	21.8	6.1	26.3
FORT WORTH	3		16.5	662.3	175.0	152.5
LUBBOCK	LUBBOCK	42	280.2	83.4	37.7	26.6
LUBBOCK	CHILDRESS	42	280.2	13.4	2.8	27.4
LUBBOCK	2		280.2	96.8	40.5	54.0
MIDLAND	MIDLAND	42	305.6	92.8	31.6	26.7
MIDLAND	WINK	42	305.6	15.8	5.8	23.5
MIDLAND	ALICE	42	305.6	74.6	37.2	40.6
MIDLAND	3		305.6	183.2	74.6	90.8
MCALESTER	MCALESTER	35	159.6	67.0	18.4	64.0
MCALESTER	1		159.6	67.0	18.4	64.0
OKLAHOMA CITY	OKLAHOMA CITY	35	180.3	238.9	132.1	64.2
OKLAHOMA CITY	1		180.3	238.9	132.1	64.2
SHREVEPORT	SHREVEPORT	17	194.7	0.0	0.0	0.0
SHREVEPORT	EL DORADO	3	194.7	39.7	31.6	44.0
SHREVEPORT	MONROE	17	194.7	139.9	65.1	22.1
SHREVEPORT	3		194.7	179.6	96.7	66.1
WICHITA FALLS	WICHITA FALLS	42	114.7	64.9	30.7	27.1
WICHITA FALLS	HOBART	35	114.7	30.1	11.8	20.9
WICHITA FALLS	2		114.7	95.0	42.5	48.1
TULSA	TULSA	35	242.1	267.8	79.3	47.8
TULSA	PONCA CITY	35	242.1	24.3	6.7	45.9
TULSA	2		242.1	292.1	86.0	93.7
FORT WORTH	18			1886.4	707.6	664.7

TABLE E-8

FSDPS - FSS SUMMARY DATA FOR HOUSTON

NAME	FSS NAME	STATE CODE	DISTANCE (MILES)	ANNUAL 1986 DEMAND (THOUSANDS) PB	FP	AC
AUSTIN	AUSTIN	42	143.4	175.8	78.1	50.4
AUSTIN	1		143.4	175.8	78.1	50.4
HOUSTON	HOUSTON	42	21.8	447.6	190.2	51.1
HOUSTON	COLLEGE STATION	42	21.8	46.5	12.1	30.6
HOUSTON	GALVESTON	42	21.8	43.1	10.7	64.1
HOUSTON	LUFKIN	42	21.8	55.3	17.0	40.4
HOUSTON	PALACIOS	42	21.8	51.9	11.8	47.9
HOUSTON	5		21.8	644.4	241.8	234.2
LAKE CHARLES	LAKE CHARLES	17	126.9	69.4	20.2	27.7
LAKE CHARLES	ALEXANDRIA	17	126.9	58.3	25.8	24.5
LAKE CHARLES	LAFAYETTE	17	126.9	98.0	23.9	24.3
LAKE CHARLES	3		126.9	225.7	69.8	76.5
MCCOMB	MCCOMB	23	301.2	62.1	19.3	42.0
MCCOMB	1		301.2	62.1	19.3	42.0
MCALLEN	MCALLEN	42	316.0	65.7	45.1	33.4
MCALLEN	1		316.0	65.7	45.1	33.4
NEW ORLEANS	NEW ORLEANS	17	316.7	271.8	115.8	52.7
NEW ORLEANS	1		316.7	271.8	115.8	52.7
SAN ANTONIO	SAN ANTONIO	42	190.3	177.6	109.2	44.9
SAN ANTONIO	COTULLA	42	190.3	59.9	20.5	28.4
SAN ANTONIO	2		190.3	237.5	129.7	73.3
HOUSTON	14			1682.8	699.7	562.5

TABLE E-9

FSDPS - FSS SUMMARY DATA FOR INDIANAPOLIS

NAME	FSS NAME	STATE CODE	DISTANCE (MILES)	ANNUAL 1986 DEMAND (THOUSANDS) PB	FP	AC
COLUMBUS	COLUMBUS	34	180.8	275.6	121.8	44.8
COLUMBUS	ZANESVILLE	34	180.8	50.9	14.2	50.7
COLUMBUS	2		180.8	326.5	136.0	95.4
CHARLESTON	MORGANTOWN	47	268.2	50.7	46.9	20.1
CHARLESTON	CHARLESTON	47	268.2	69.0	29.7	30.6
CHARLESTON	HUNTINGTON	47	268.2	71.6	22.6	14.7
CHARLESTON	PARKERSBURG	47	268.2	94.6	16.1	21.1
CHARLESTON	ELKINS	47	268.2	42.9	6.1	20.6
CHARLESTON	5		268.2	328.9	121.4	107.1
DAYTON	DAYTON	34	110.0	263.4	90.6	39.4
DAYTON	CINCINNATI	34	110.0	157.9	69.5	27.9
DAYTON	2		110.0	421.3	160.0	67.3
INDIANAPOLIS	INDIANAPOLIS	13	0.3	328.1	112.1	56.7
INDIANAPOLIS	LAFAYETTE	13	0.3	99.6	17.5	28.2
INDIANAPOLIS	TERRE HAUTE	13	0.3	118.5	45.3	36.8
INDIANAPOLIS	3		0.3	546.2	175.0	121.7
LOUISVILLE	LOUISVILLE	16	108.9	209.9	72.1	37.1
LOUISVILLE	LONDON	16	108.9	90.8	34.7	39.6
LOUISVILLE	2		108.9	300.7	106.9	76.7
INDIANAPOLIS	14			1923.5	699.3	468.2

TABLE E-10

FSDPS - FSS SUMMARY DATA FOR JACKSONVILLE

NAME	FSS NAME	STATE CODE	DISTANCE (MILES)	ANNUAL 1986 DEMAND (THOUSANDS) PB	FP	AC
CHARLESTON	CHARLESTON	39	187.4	87.2	56.0	32.3
CHARLESTON	1		187.4	87.2	56.0	32.3
DOTHAN	DOTHAN	1	213.7	74.2	73.7	29.5
DOTHAN	1		213.7	74.2	73.7	29.5
FLORENCE	FLORENCE	39	272.1	203.1	130.9	101.8
FLORENCE	MYRTLE BEACH	39	272.1	54.5	15.8	34.5
FLORENCE	2		272.1	257.6	146.7	136.3
GAINESVILLE	GAINESVILLE	9	73.5	127.9	45.5	86.9
GAINESVILLE	1		73.5	127.9	45.5	86.9
JACKSONVILLE	JACKSONVILLE	9	34.6	180.0	93.0	106.5
JACKSONVILLE	VALDOSTA	10	34.6	76.4	17.4	10.3
JACKSONVILLE	2		34.6	256.4	110.4	116.8
PENSACOLA	MOBILE	1	313.9	116.7	73.2	41.0
PENSACOLA	PENSACOLA	9	313.9	30.3	17.7	14.9
PENSACOLA	CRESTVIEW	9	313.9	43.9	32.5	33.6
PENSACOLA	3		313.9	191.0	123.4	89.5
SAVANNAH	SAVANNAH	10	107.2	137.5	71.8	50.1
SAVANNAH	ALMA	10	107.2	60.3	11.9	38.1
SAVANNAH	BRUNSWICK	10	107.2	66.1	21.2	39.4
SAVANNAH	3		107.2	263.8	104.9	127.6
TALLAHASSEE	TALLAHASSEE	9	146.6	85.4	40.0	41.4
TALLAHASSEE	1		146.6	85.4	40.0	41.4
JACKSONVILLE	14			1343.6	700.6	660.4

TABLE E-11

FSDPS- FSS SUMMARY DATA FOR KANSAS CITY

NAME	FSS NAME	STATE CODE	DISTANCE (MILES)	ANNUAL 1986 DEMAND (THOUSANDS) PB	FP	AC
COLUMBIA	COLUMBIA	24	138.4	118.7	42.8	67.3
COLUMBIA	1		138.4	118.7	42.8	67.3
DECATUR	DECATUR	12	322.9	189.9	72.8	59.0
DECATUR	QUINCY	12	322.9	104.6	31.6	67.0
DECATUR	2		322.9	294.3	104.4	126.0
GARDEN CITY	GARDEN CITY	15	328.0	69.0	20.2	65.3
GARDEN CITY	DODGE CITY	15	328.0	49.7	34.2	51.3
GARDEN CITY	2		328.0	118.7	54.4	116.5
WICHITA	WICHITA	15	166.5	288.8	108.8	58.8
WICHITA	1		166.5	288.8	108.8	58.8
KANSAS CITY	KANSAS CITY	24	19.3	351.2	155.3	88.4
KANSAS CITY	CHANUTE	15	19.3	67.8	14.2	35.5
KANSAS CITY	2		19.3	419.1	169.5	123.9
SPRINGFIELD	SPRINGFIELD	24	136.0	92.0	26.3	35.4
SPRINGFIELD	JOPLIN	24	136.0	62.7	14.7	27.1
SPRINGFIELD	VICHY	24	136.0	41.3	27.9	44.2
SPRINGFIELD	3		136.0	196.0	69.0	106.7
SALINA	SALINA	15	153.9	45.3	37.6	27.4
SALINA	EMPORIA	15	153.9	28.5	6.1	30.3
SALINA	MANHATTAN	15	153.9	47.9	22.6	56.7
SALINA	RUSSELL	15	153.9	70.4	16.3	38.7
SALINA	4		153.9	192.2	82.7	153.2
ST LOUIS	ST LOUIS	24	238.1	340.2	152.7	73.5
ST LOUIS	1		238.1	340.2	152.7	73.5
KANSAS CITY	16			1968.0	784.3	825.8

TABLE E-12

FSDPS - FSS SUMMARY DATA FOR LOS ANGELES

NAME	FSS NAME	STATE CODE	DISTANCE (MILES)	ANNUAL 1986 DEMAND (THOUSANDS) PB	FP	AC
CEDAR CITY	CEDAR CITY	43	350.5	36.7	13.5	46.9
CEDAR CITY	BRYCE CANYON	43	350.5	4.0	1.4	6.5
CEDAR CITY	2		350.5	40.7	14.9	53.4
LAS VEGAS	LAS VEGAS	27	194.3	193.9	160.4	82.7
LAS VEGAS	NEEDLES	4	194.3	30.1	11.1	37.0
LAS VEGAS	ELY	27	194.3	8.6	5.3	15.7
LAS VEGAS	TONOPAH	27	194.3	12.4	9.0	31.3
LAS VEGAS	4		194.3	244.9	185.7	166.8
LOS ANGELES	LOS ANGELES	4	48.5	644.6	153.4	159.2
LOS ANGELES	FULLERTON	4	48.5	28.7	4.4	0.0
LOS ANGELES	ONTARIO	4	48.5	263.4	88.5	63.1
LOS ANGELES	SANTA ANA	4	48.5	38.9	8.8	0.0
LOS ANGELES	4		48.5	975.6	255.2	222.3
SAN DIEGO	SAN DIEGO	4	139.1	231.9	129.3	83.0
SAN DIEGO	YUMA	2	139.1	29.7	42.8	27.3
SAN DIEGO	IMPERIAL	4	139.1	76.8	40.0	57.5
SAN DIEGO	THERMAL	4	139.1	55.1	19.8	69.9
SAN DIEGO	4		139.1	393.5	232.0	237.6
SANTA BARBARA	SANTA BARBARA	4	100.1	114.5	47.2	56.5
SANTA BARBARA	PASO ROBLES	4	100.1	61.7	13.3	79.6
SANTA BARBARA	2		100.1	176.2	60.5	136.0
LANCASTER	LANCASTER	4	11.7	62.7	38.6	43.9
LANCASTER	BAKERSFIELD	4	11.7	99.2	24.7	65.5
LANCASTER	DAGGETT	4	11.7	48.7	11.6	50.5
LANCASTER	3		11.7	210.5	74.9	160.0
LOS ANGELES	19			2041.4	823.2	976.1

TABLE E-13

FSDPS - FSS SUMMARY DATA FOR MEMPHIS

NAME	FSS NAME	STATE CODE	DISTANCE (MILES)	ANNUAL 1986 DEMAND (THOUSANDS) PB	FP	AC
NASHVILLE	NASHVILLE	41	198.0	289.2	102.0	43.5
NASHVILLE	1		198.0	289.2	102.0	43.5
BOWLING GREEN	BOWLING GREEN	16	237.3	62.9	44.4	54.6
BOWLING GREEN	1		237.3	62.9	44.4	54.6
CAPE GIRARDEAU	CAPE GIRARDEAU	24	151.2	98.0	52.3	53.4
CAPE GIRARDEAU	1		151.2	98.0	52.3	53.4
FAYETTEVILLE	FAYETTEVILLE	3	245.0	56.1	24.0	21.7
FAYETTEVILLE	HARRISON	3	245.0	24.5	11.4	32.8
FAYETTEVILLE	2		245.0	80.6	35.4	54.4
GREENWOOD	GREENWOOD	23	108.4	149.7	31.8	42.6
GREENWOOD	1		108.4	149.7	31.8	42.6
JACKSON	JACKSON	23	190.0	96.4	38.1	26.9
JACKSON	MERIDIAN	23	190.0	43.9	31.9	25.1
JACKSON	2		190.0	140.3	70.0	52.0
LITTLE ROCK	LITTLE ROCK	3	130.8	164.2	81.4	53.7
LITTLE ROCK	JONESBORO	3	130.8	47.5	18.6	49.8
LITTLE ROCK	PINE BLUFF	3	130.8	29.1	4.6	4.6
LITTLE ROCK	3		130.8	240.9	104.6	108.1
MEMPHIS	MEMPHIS	41	1.6	258.6	227.4	41.0
MEMPHIS	PADUCAH	16	1.6	77.4	19.5	33.9
MEMPHIS	DYERSBURG	41	1.6	61.7	22.6	42.2
MEMPHIS	JACKSON	41	1.6	50.9	14.6	55.3
MEMPHIS	4		1.6	448.6	284.1	172.4
MUSCLE SHOALS	MUSCLE SHOALS	1	134.4	96.2	34.7	62.7
MUSCLE SHOALS	1		134.4	96.2	34.7	62.7
MEMPHIS	16			1606.2	759.4	643.6

TABLE E-14

FSDPS - FSS SUMMARY DATA FOR MIAMI

NAME	FSS NAME	STATE CODE	DISTANCE (MILES)	ANNUAL 1986 DEMAND (THOUSANDS) PB	FP	AC
MIAMI	MIAMI	9	14.1	498.3	295.5	269.5
MIAMI	FORT MYERS	9	14.1	105.8	57.0	52.3
MIAMI	KEY WEST	9	14.1	54.9	51.6	23.2
MIAMI	3		14.1	658.9	404.2	345.1
ORLANDO	ORLANDO	9	201.2	255.0	96.7	75.7
ORLANDO	1		201.2	255.0	96.7	75.7
ST PETERSBURG	ST PETERSBURG	9	208.7	285.8	137.8	67.9
ST PETERSBURG	1		208.7	285.8	137.8	67.9
VERO BEACH	VERO BEACH	9	128.5	130.1	55.6	78.3
VERO BEACH	MELBOURNE	9	128.5	66.1	43.3	46.8
VERO BEACH	2		128.5	196.2	99.0	125.0
MIAMI	7			1395.9	737.6	613.6

TABLE E-15

FBDBS- FSS SUMMARY DATA FOR MINNEAPOLIS

NAME	FSS NAME	STATE CODE	DISTANCE (MILES)	ANNUAL 1986 DEMAND (THOUSANDS) PR	FP	AC
DES MOINES	OTTUMWA	14	232.8	50.9	16.7	46.2
DES MOINES	DES MOINES	14	232.8	157.0	42.5	37.1
DES MOINES	MASON CITY	14	232.8	65.9	16.5	105.1
DES MOINES	3		232.8	273.8	75.6	188.4
GRAND FORKS	GRAND FORKS	33	283.1	62.1	35.4	35.5
GRAND FORKS	JAMESTOWN	33	283.1	63.5	21.6	40.3
GRAND FORKS	2		283.1	125.5	57.0	75.8
HIBBING	HIBBING	22	173.2	71.0	36.5	57.5
HIBBING	1		173.2	71.0	36.5	57.5
HURON	HURON	40	252.1	102.0	28.6	71.0
HURON	ABERDEEN	40	252.1	13.4	6.0	35.1
HURON	WATERTOWN	40	252.1	23.1	6.0	33.5
HURON	3		252.1	138.5	40.5	139.6
LA CROSSE	LONE ROCK	48	119.5	15.6	2.6	17.8
LA CROSSE	LA CROSSE	48	119.5	54.7	39.1	29.9
LA CROSSE	2		119.5	70.2	41.8	47.6
MINOT	MINOT	33	447.6	58.9	29.8	76.8
MINOT	DICKINSON	33	447.6	19.8	5.3	15.3
MINOT	2		447.6	78.6	35.1	92.1
MARQUETTE	MARQUETTE	21	295.2	52.5	19.7	57.6
MARQUETTE	HANCOCK	21	295.2	22.2	7.2	18.0
MARQUETTE	2		295.2	74.6	26.9	75.7
MINNEAPOLIS	MINNEAPOLIS	22	0.4	341.0	100.6	68.7
MINNEAPOLIS	ALEXANDRIA	22	0.4	50.9	17.2	53.7
MINNEAPOLIS	REDWOOD FALLS	22	0.4	63.9	18.6	39.0
MINNEAPOLIS	ROCHESTER	22	0.4	64.5	16.5	21.5
MINNEAPOLIS	EAU CLAIRE	48	0.4	33.5	11.9	59.6
MINNEAPOLIS	5		0.4	553.8	164.8	242.6
OMAHA	OMAHA	26	282.1	189.0	94.8	41.1
OMAHA	GRAND ISLAND	26	282.1	67.8	19.5	59.3
OMAHA	LINCOLN	26	282.1	80.6	28.3	33.2
OMAHA	3		282.1	337.4	142.5	133.7
PIERRE	PIERRE	40	348.5	47.1	14.4	59.5
PIERRE	1		348.5	47.1	14.4	59.5
TRAVERSE CITY	TRAVERSE CITY	21	374.1	61.3	21.9	47.4
TRAVERSE CITY	PELLSTON	21	374.1	47.5	18.6	38.7
TRAVERSE CITY	SAULT STE MARIE	21	374.1	4.2	3.9	14.1
TRAVERSE CITY	3		374.1	112.9	44.4	100.2
MINNEAPOLIS	27			1883.6	679.5	1212.6

TABLE E-16

FSDPS - FSS SUMMARY DATA FOR NEW YORK

NAME	FSS NAME	STATE CODE	DISTANCE (MILES)	ANNUAL 1986 DEMAND (THOUSANDS) PR	FP	AC
WILKES BARRE	WILKES BARRE	37	141.5	105.6	59.1	31.2
WILKES BARRE	HARRISBURG	37	141.5	344.4	96.0	51.5
WILKES BARRE	WILLIAMSPORT	37	141.5	89.0	24.7	20.5
WILKES BARRE	3		141.5	539.0	179.9	103.2
ISLIP	ISLIP	31	1.1	323.3	133.9	45.8
ISLIP	1		1.1	323.3	133.9	45.8
PHILADELPHIA	PHILADELPHIA	37	111.8	387.3	161.6	43.6
PHILADELPHIA	1		111.8	387.3	161.6	43.6
POUGHKEEPSIE	ALBANY	31	71.4	223.1	59.5	34.9
POUGHKEEPSIE	POUGHKEEPSIE	31	71.4	234.5	73.9	83.0
POUGHKEEPSIE	2		71.4	457.6	133.4	118.0
TETERBORO	TETERBORO	29	50.8	322.5	109.2	42.2
TETERBORO	1		50.8	322.5	109.2	42.2
NEW YORK	8			2029.7	717.9	352.7

TABLE E-17

FSDPS - FSS SUMMARY DATA FOR OAKLAND

NAME	FSS NAME	STATE CODE	DISTANCE (MILES)	ANNUAL 1986 DEMAND (THOUSANDS) PB	FP	AC	
FRESNO	FRESNO	Ø4	137.3	142.1	64.2	59.2	435
FRESNO	1		137.3	142.1	64.2	59.2	132
OAKLAND	OAKLAND	Ø4	17.2	429.4	140.7	131.4	436
OAKLAND	SALINAS	Ø4	17.2	99.2	39.8	39.8	437
OAKLAND	2		17.2	528.6	180.6	171.2	134
RED BLUFF	RED BLUFF	Ø4	180.4	56.1	20.0	75.1	435
RED BLUFF	MONTAGUE	Ø4	180.4	12.8	3.2	17.2	439
RED BLUFF	2		180.4	68.8	23.2	92.3	135
RENO	RENO	27	181.6	82.4	54.8	37.5	440
RENO	LOVELOCK	27	181.6	10.4	13.7	21.1	441
RENO	ELKO	27	181.6	28.9	13.2	45.0	442
RENO	3		181.6	121.7	81.6	103.7	136
SACRAMENTO	SACRAMENTO	Ø4	72.8	233.1	85.6	60.3	443
SACRAMENTO	MARYSVILLE	Ø4	72.8	46.9	20.0	27.7	444
SACRAMENTO	STOCKTON	Ø4	72.8	71.2	22.6	45.0	445
SACRAMENTO	3		72.8	351.2	128.3	133.1	137
UKIAH	UKIAH	Ø4	127.2	72.2	15.8	55.7	446
UKIAH	ARCATA	Ø4	127.2	27.7	12.8	36.2	447
UKIAH	CRESCENT CITY	Ø4	127.2	10.0	3.0	14.6	448
UKIAH	3		127.2	110.0	31.6	106.5	138
OAKLAND	14	Ø6		1322.4	509.5	666.0	Ø17

TABLE E-18

FSDPS - FSS SUMMARY DATA FOR SALT LAKE CITY

NAME	FSS NAME	STATE CODE	DISTANCE (MILES)	ANNUAL 1986 DEMAND (THOUSANDS) PB	FP	AC	
BILLINGS	BILLINGS	25	386.4	68.6	20.9	32.5	447
BILLINGS	MILES CITY	25	386.4	43.9	14.4	39.6	450
BILLINGS	SHERIDAN	49	386.4	37.3	14.2	37.1	451
BILLINGS	WORLAND	49	386.4	30.7	13.9	32.8	452
BILLINGS	4		386.4	180.6	63.4	141.9	139
BOISE	BOISE	11	291.2	79.4	55.1	43.0	453
BOISE	1		291.2	79.4	55.1	43.0	141
BURLEY	BURLEY	11	152.6	57.7	21.4	59.6	454
BURLEY	1		152.6	57.7	21.4	59.6	141
BOZEMAN	BOZEMAN	25	347.3	20.0	7.5	36.7	455
BOZEMAN	BUTTE	25	347.3	12.8	5.3	30.0	456
BOZEMAN	LIVINGSTON	25	347.3	17.4	4.7	13.0	457
BOZEMAN	3		347.3	50.1	17.5	79.7	142
GREAT FALLS	GREAT FALLS	25	463.3	53.9	32.3	30.0	455
GREAT FALLS	CUT BANK	25	463.3	6.8	3.7	11.0	459
GREAT FALLS	LEWISTOWN	25	463.3	8.8	3.3	19.9	460
GREAT FALLS	MISSOULA	25	463.3	37.7	16.0	26.9	461
GREAT FALLS	4		463.3	107.2	55.3	87.8	143
IDAHO FALLS	IDAHO FALLS	11	188.6	61.7	17.5	37.1	462
IDAHO FALLS	1		188.6	61.7	17.5	37.1	144
ROCK SPRINGS	LARAMIE	49	160.1	23.5	6.1	33.5	463
ROCK SPRINGS	ROCK SPRINGS	49	160.1	29.3	11.8	45.3	464
ROCK SPRINGS	RAWLINS	49	160.1	13.0	5.4	20.6	465
ROCK SPRINGS	3		160.1	65.9	23.3	99.5	145
SALT LAKE	SALT LAKE	43	0.2	159.0	70.7	71.0	466
SALT LAKE	1		0.2	159.0	70.7	71.0	146
SALT LAKE CITY	18	Ø8		761.5	324.3	619.7	013

TABLE E-19

FSDPS- FSS SUMMARY DATA FOR SEATTLE

NAME	FSS NAME	STATE CODE	DISTANCE (MILES)	ANNUAL 1986 DEMAND (THOUSANDS) PB	FP	AC	
WALLA WALLA	BAKER	36	202.3	29.1	14.4	30.8	467
WALLA WALLA	WALLA WALLA	46	202.3	88.4	28.4	83.9	468
WALLA WALLA	2		202.3	117.5	42.8	114.6	147
BELLINGHAM	BELLINGHAM	46	105.6	44.5	25.4	79.4	469
BELLINGHAM	1		105.6	44.5	25.4	79.4	148
WENATCHEE	WENATCHEE	46	92.6	53.3	25.6	78.8	470
WENATCHEE	EPHRATA	46	92.6	29.7	13.3	37.7	471
WENATCHEE	2		92.6	83.0	39.0	116.5	149
NORTH BEND	NORTH BEND	36	285.3	31.5	12.6	57.5	472
NORTH BEND	1		285.3	31.5	12.6	57.5	150
PORTLAND	PORTLAND	36	119.3	247.0	86.0	92.1	473
PORTLAND	DALLESPORT	46	119.3	22.2	4.2	30.3	474
PORTLAND	2		119.3	269.2	90.2	122.4	151
REDMOND	REDMOND	36	215.6	61.5	14.2	56.3	465
REDMOND	1		215.6	61.5	14.2	56.3	152
SEATTLE	SEATTLE	46	17.7	265.2	169.7	79.8	476
SEATTLE	HOQUIAM	46	17.7	15.0	7.2	46.3	477
SEATTLE	TOLEDO	46	17.7	9.4	3.5	15.6	479
SEATTLE	3		17.7	289.6	180.4	141.8	153
SEATTLE							
SPOKANE	SPOKANE	46	228.9	77.8	35.3	29.9	479
SPOKANE	1		228.9	77.8	35.3	29.9	154
SEATTLE	13	∅8		974.6	440.0	718.4	019

TABLE E-20

FSDPS FSS SUMMARY DATA FOR WASHINGTON, D.C.

NAME	FSS NAME	STATE CODE	DISTANCE (MILES)	ANNUAL 1986 DEMAND (THOUSANDS) PB	FP	AC	
WASHINGTON	SALISBURY	19	32.4	64.3	23.0	74.6	480
WASHINGTON	MILLVILLE	29	32.4	412.1	105.8	32.1	481
WASHINGTON	WASHINGTON	Ø8	32.4	359.6	192.9	64.1	482
WASHINGTON	CHARLOTTESVILLE	45	32.4	60.3	21.1	23.8	483
WASHINGTON	NEWPORT NEWS	45	32.4	186.2	152.3	37.4	484
WASHINGTON	MARTINSBURG	47	32.4	76.4	46.3	43.5	485
WASHINGTON	RICHMOND	45	32.4	187.6	57.9	37.5	486
WASHINGTON	7		32.4	1346.4	599.3	363.1	155
NEW BERN	NEW BERN	32	279.8	81.6	59.1	51.4	487
NEW BERN	ELIZABETH CITY	32	279.8	19.8	20.4	14.3	488
NEW BERN	2		279.8	101.4	79.5	65.7	156
RALEIGH	RALEIGH	32	233.4	279.0	131.8	62.4	487
RALEIGH	ROCKY MOUNT	32	233.4	48.1	14.0	36.1	480
RALEIGH	2		233.4	327.1	145.8	98.5	157
ROANOKE	BLUEFIELD	47	180.8	76.0	16.1	40.9	491
ROANOKE	ROANOKE	45	180.8	100.2	34.7	18.3	492
ROANOKE	DANVILLE	45	180.8	22.5	10.4	38.1	158
WASHINGTON, D.C.	14	Ø4		1973.6	885.9	624.6	120

APPENDIX F - COMMUNICATIONS NETWORK MODEL

F.1 Computer Model

The computer model itself was designed and developed at TSC. The model is written in FORTRAN IV, and runs on either TSC's Prime or Decsystem-10 computer systems. The Basic operation of the system is diagrammed in Figure F.1-1. The basic structure is outlined in Figure F.1-2.

The model calculations use a heuristic tree-following approach. The network is assumed to have been ordered in reverse hierarchy. Any network not adhering to a strict hierarchical structure will have been rejected by the preprocessor, as described in Section F.2. Thus, the network is processed starting at the most distributed tips and working towards the "main" or "central" node of the network. This concept is shown in Figure F.1-3.

Due to the ordering imposed by the preprocessor, every node will have been accounted for by one pass through the network file. It should be noted that a node defined in the node file, having demand in the demand file, will be ignored if it doesn't appear in the network file.

Communication costs used by the model were developed from real current costs, but those rates were not duplicated in the program due to their complexity. Communication lines in the system fall into three categories. First is the line or connection between the computer in the system handling the weather data base and the systems source of weather data. For purposes of the model, it was assumed that this cost is equal to the cost of a single business telephone or $18.00/month on the average. The second type of line is that interconnecting a VRS computer and its associated weather Data Base Processor. This line has been assumed to be 2400 baud data line purchased via TELPAK. This rate is $0.58/mile plus service terminals at each end at $43.30 each. The third type of line is a voice line by which a user may access the VRS. This line will either be local or long distance. If it is long distance, it will be one of FX using TELPAK, FX using commercial AT&T rates, intrastate WATS or interstate WATS. Costs used by the model for each of these services are given in Table F.1-1.

Since the calculation for TELPAK is relatively simple, the equation is duplicated in the model. Wherever a local line is called for, the charge of $18.00/month has been used. This is an average figure for the

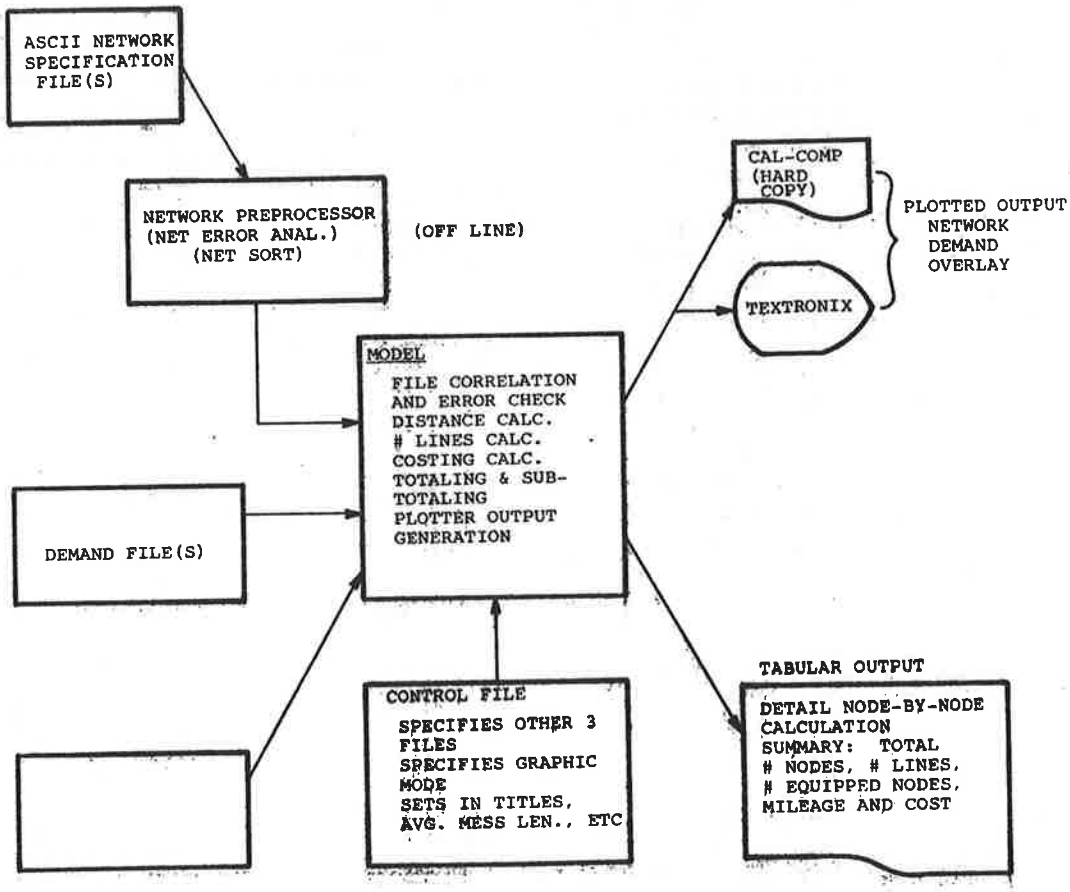


FIGURE F.1-1 - COMPUTER MODEL OPERATION

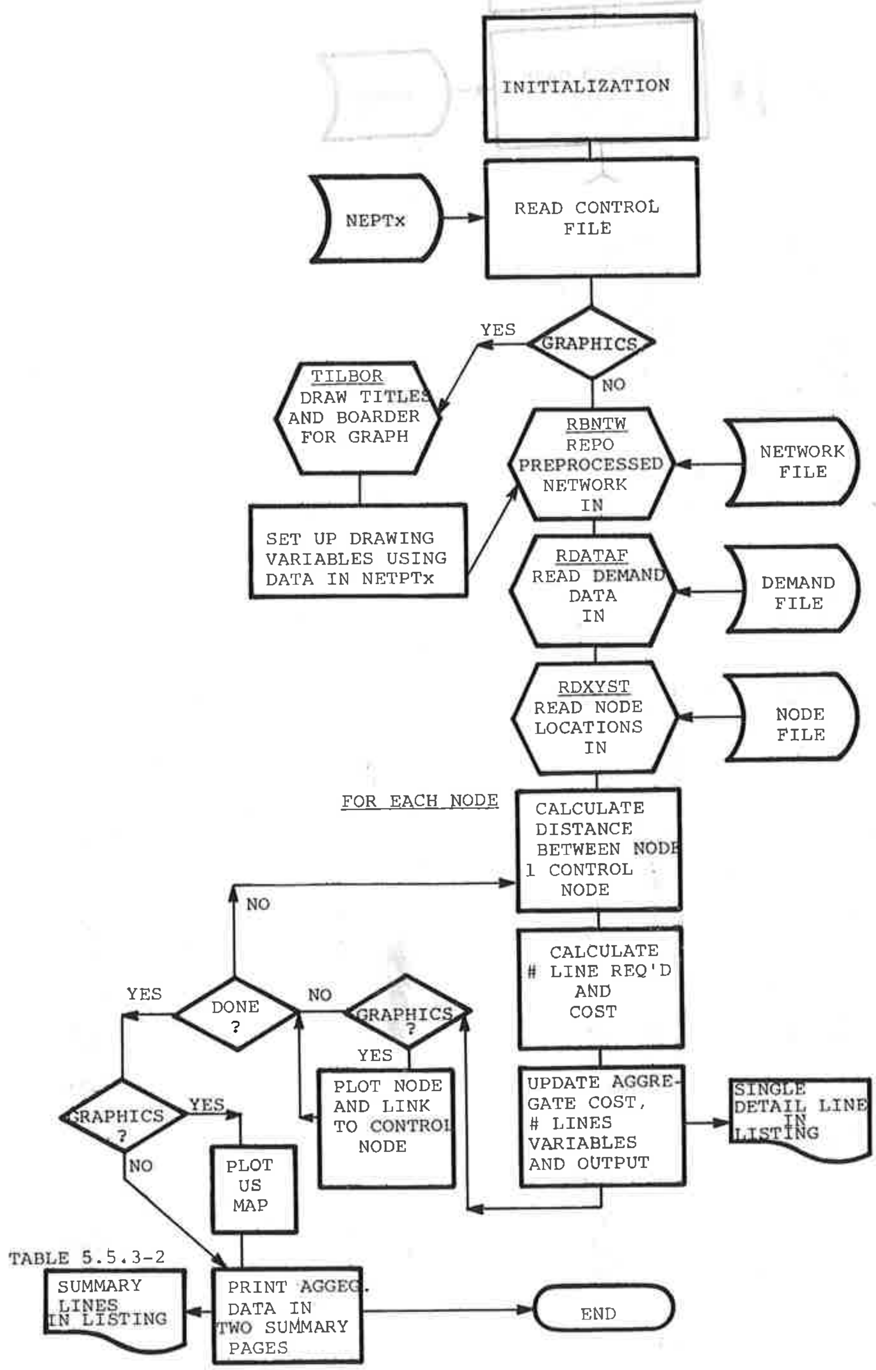
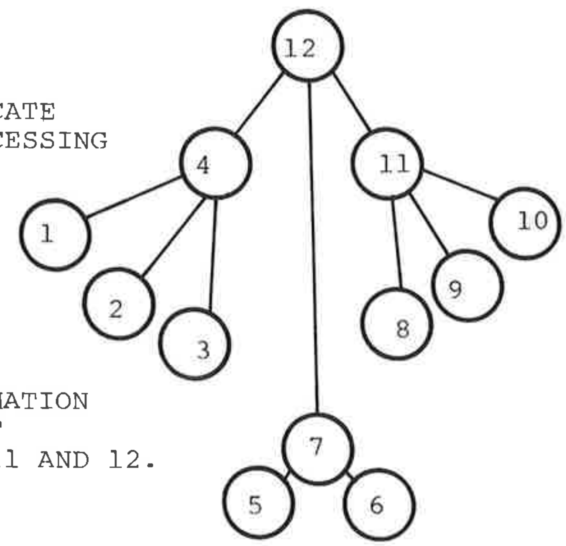


FIGURE F.1-2. – BASIC MODEL STRUCTURE

NUMBERS INDICATE
ORDER OF PROCESSING

DIRECTION OF
PROCESSING



NOTE: INFORMATION
AGGREGATED AT
NODES 4, 7, 11 AND 12.

FIGURE F.1.3 - MODEL PROGRESS THROUGH NETWORK TREE

TABLE F.1-1

COMMUNICATION COSTS

1. Weather Polling Line: \$18.00

2. Data Line - 2400 Baud via TELPAK:

   Cost = \$.58 X (# Miles) + \$86.60

3. Local Voice: \$18.00

4. Long Distance Voice:

   A) FX, TELPAK: Cost = \$.58 X (# Miles) + \$86.60

   B) FX, AT&T: Cost = \$3.30 X (# Miles) + \$52.00 (# Miles $<$ 15)

   = \$3.10 X (# Miles - 15) + \$98.20 (# Miles $<$ 25)

   = \$2.00 X (# Miles - 25) + \$129.20 (# Miles $<$ 40)

   = \$1.35 X (# Miles - 40) + \$159.20 (# Miles $<$ 100)

   = \$.66 X (# Miles - 100) + \$240.20 (# Miles $<$ 1000)

   = \$.40 X (# Miles - 1000) + \$834.20 (# Miles $\leq$ 1000)

   C) WATS, INTRASTATE: Cost = \$630.00

   D) WATS, INTERSTATE: Cost = \$1418.00 (Loading $\leq$ 240)

   Cost = \$3.29 X (Loading) + \$1418.00 (Loading $>$ 240)

NOTE: All costs per line and per month.

country which may vary from locale to locale. In designing costing algorithms for the model, an attempt was made to avoid calculations which were dependent on geographical position due to the additional overhead related to this type of computation. In the case of local lines, they are few enough in the system, and a small enough cost component so that a single, average figure should serve the purposes of this model.

For FX via AT&T, the real, current rate schedule is a complicated function of distance and geography. This rate was simplified by choosing the average geographic parameter--rate center A to rate Center B, and using the full distance calculation. This was done to assure that the final system cost for a network using FX via AT&T would not be incorrectly biased for, or against, distribution of the network.

In order to fairly evaluate WATS, it is necessary to redesign the network to take advantage of the particular characteristics of WATS. By analyzing intrastate WATS over the country, it was determined that a monthly rate of $630.00 per line for unlimited service is accurate. By coincidence, this value corresponds with the Massachusetts rate. For states with limited-use WATS, it was assumed that unlimited was available to avoid the necessity to incorporate line loading calculations into the rate calculation. For interstate WATS, the bulk of the voice lines fall into Zone 2 in a system designed to make good use of WATS features. The average monthly figure is $1,400 per line. A factor for line loading was used to increase accuracy for this rather large and therefore rather sensitive cost.

It should be noted that actual charges computed will not be equal to real commercial rates particularly those for the 1986 and 1995 time periods being studied. They do provide, however, a reliable basis to compare system costs. In all events, real costs will most probably represent an increase in communication costs over those shown by the model. The implications of that fact are obvious from the results in Section 6, i.e., the system is more strongly driven to decentralization.

F.2 Communication Model Inputs

The model requires four input files. Each of these is prepared in a different fashion and provides basic information for the model operation.

Node Information File

This file contains information about all possibile nodes in the network. In the case of the VRS Alternatives Communication Study, this information consists of the three-letter identifier, latitude, longitude, and internal system index for each FSS in the conterminous U.S. Table F.2-1 is a listing of part of this file.

Demand Information File

This data file contains a demand figure for each node in the network. Since the node system index is derived from the order of the entries in this file, there must be an entry for every possible node -- even if it's zero. Since separate demand predictions exist to account for varying VRS features and different future dates, separate demand files have been created. These are reflected in Table 4.1.5-1. Each record (or line) of the file contains projected demand for the node whose index matches the order of that record in the file. A partial listing appears in Table F.2-2.

Network Specification File

This file is the most complex of the model input data files and provides specific, detailed information on the structure of the particular network involved. For each node to be included in the network, the following information is supplied:

1. Node type (1-5)
2. Node I.D. (up to 300)
3. Controlling node (i.e., node next higher than this one is network hierarchy)
4. Line type to controlling node (1-5)

Node types and line types are delineated in Table F.2-3. Table F.2-4 is a partial listing of a node file and Figure F.2-1 shows the structure of each record (or line) of the file.

The raw input data for the network file is usually ordered in a manner convenient to the network author. This is not the optimum format for the model to process. It is also not guaranteed to be free of errors in the network structure. A preprocessor program therefore performs reformating, ordering, and error-checking functions and then writes out a properly

TABLE F.2-1

SECTION OF NODE INFORMATION FILE

Code	FSS Name	State Num	State Txt	Radians Lat.	Radians Lon.	ARTCC	Index
ABQ	ALBUQUERQUE	30	NM	0.61160	1.86061	ZAB	201
LVS	LAS VEGAS	30	NM	0.62228	1.83508	ZAB	202
AMA	AMARILLO	42	TX	0.61472	1.77518	ZAB	203
TCC	TUCUMCARI	30	NM	0.61401	1.80824	ZAB	204
DHT	DALHART	42	TX	0.62861	1.78983	ZAB	205
GAG	GAGE	35	OK	0.63348	1.74140	ZKC	206
ELP	EL PASO	42	TX	0.55514	1.85680	ZAB	207
DMN	DEMING	30	NM	0.56300	1.88002	ZAB	208
TCS	TRUTH OR CONSEQ	30	NM	0.58009	1.87223	ZAB	209
GUP	GALLUP	30	NM	0.61979	1.89868	ZAB	210
PHX	PHOENIX	02	AZ	0.58356	1.95498	ZAB	211
BLH	BLYTHE	04	CA	0.58679	2.00222	ZLA	212
PRC	PRESCOTT	02	AZ	0.60478	1.96211	ZAB	213
ROW	ROSWELL	30	NM	0.58119	1.82439	ZAB	214
CNM	CARLSBAD	30	NM	0.56439	1.81973	ZAB	215
TUS	TUCSON	02	AZ	0.56057	1.93632	ZAB	216
DUG	DOUGLAS	02	AZ	0.54922	1.91293	ZAB	217
ATL	ATLANTA	10	GA	0.58956	1.47518	ZTL	218
BHM	BIRMINGHAM	01	AL	0.58579	1.51417	ZTL	219
ANB	ANNISTON	01	AL	0.58626	1.49847	ZTL	220
TCL	TUSCALOOSA	01	AL	0.57981	1.52911	ZTL	221
CSV	CROSSVILLE	41	TN	0.62747	1.48501	ZTL	222
GSP	GREER	39	SC	0.60912	1.43497	ZTL	223
AND	ANDERSON	39	SC	0.60206	1.44353	ZTL	224
HKY	HICKORY	32	NC	0.62379	1.42052	ZTL	225
MCN	MACON	10	GA	0.57061	1.45993	ZTL	226
ABY	ALBANY	10	GA	0.55039	1.46947	ZTL	227
MGM	MONTGOMERY	01	AL	0.56375	1.50785	ZTL	228
TYS	KNOXVILLE	41	TN	0.62505	1.46595	ZTL	229
TRI	BRISTOL-TRI CIT	41	TN	0.63663	1.43826	ZTL	230
BDL	WINDSOR LOCKS	06	CT	0.73197	1.26857	ZBW	231
BGR	BANGOR	18	ME	0.78204	1.20128	ZBW	232
AUG	AUGUSTA	18	ME	0.77354	1.21817	ZBW	233
HUL	HOULTON	18	ME	0.80502	1.18320	ZBW	234
BOS	BOSTON	20	MA	0.73937	1.23928	ZBW	235
CON	CONCORD	28	NH	0.75406	1.24794	ZBW	236
LEB	LEBANON	28	NH	0.76145	1.26197	ZBW	237
MPV	MONTPELIER	44	VT	0.77150	1.26646	ZBW	238
UCA	UTICA	31	NY	0.75302	1.31570	ZBW	239
GFL	GLENS FALLS	31	NY	0.75646	1.28473	ZBW	240
MSS	MASSENA	31	NY	0.78426	1.30632	ZBW	241
ART	WATERTOWN	31	NY	0.76779	1.32684	ZBW	242
ELM	ELMIRA	31	NY	0.73582	1.34204	ZNY	243
CHI	CHICAGO	12	IL	0.73154	1.54019	ZAU	244
RFD	ROCKFORD	12	IL	0.73652	1.55495	ZAU	245
CID	CEDAR RAPIDS	14	IA	0.73103	1.60062	ZAU	246
BRL	BURLINGTON	14	IA	0.71180	1.59043	ZAU	247
GRB	GREEN BAY	48	WI	0.77646	1.53816	ZAU	248

TABLE F.2-2

SAMPLE DEMAND FILE

PEAK HOUR PILOT BRIEF DEMAND - 86

PEAK HOUR PILOT BRIEF DEMAND - 86

FSS NODE	PILOT BRIEF DEMAND
1	43.274994
2	4.290000
3	30.947998
4	12.327999
5	7.750999
6	7.636999
7	37.840996
8	5.148000
9	1.259000
10	16.846996
11	71.276993
12	25.512997
13	18.105000
14	10.610998
15	3.547000
16	23.739998
17	10.617998
18	110.424988
19	56.398994
20	33.264994
21	20.306000
22	39.553993
23	51.994995
24	12.333999
25	73.959991
26	24.530998
27	19.790997
28	23.851997
29	35.949997
30	11.587998
31	86.904999
32	21.446999
33	17.586998
34	5.430999
35	109.095993
36	21.551996
37	18.737998
38	10.036999
39	22.419998
40	9.064999
41	8.435999
42	12.258000
43	31.570999

TABLE F.2-3

LINE & NODE TYPES

Line Types

TYPE	DESCRIPTION
1	Central Node Drop. Represents communication required to interconnect DBP to Central Weather Facility.
2	VRS Data Line. Each thirty-two (32) channels of VRS requires one 1200 baud line back to the DBP.
3	Local Voice Line.
4	Foreign Exchange (FX) Line via TELPAK.
5	FX Line via AT&T.
6	Intrastate WATS (Wide-Area Telephone Service).
7	Interstate WATS.

Node Types

TYPE	DESCRIPTION
1	Central Node.
2	DBP Node. Includes both Weather Data Base Processor(s) and VRS Processor(s).
3	VRS Node. Includes VRS Processor(s).
4	Remote Demand. Interconnected by some form of long-distance voice line.
5	Local Demand. Interconnected by Local Voice Line.

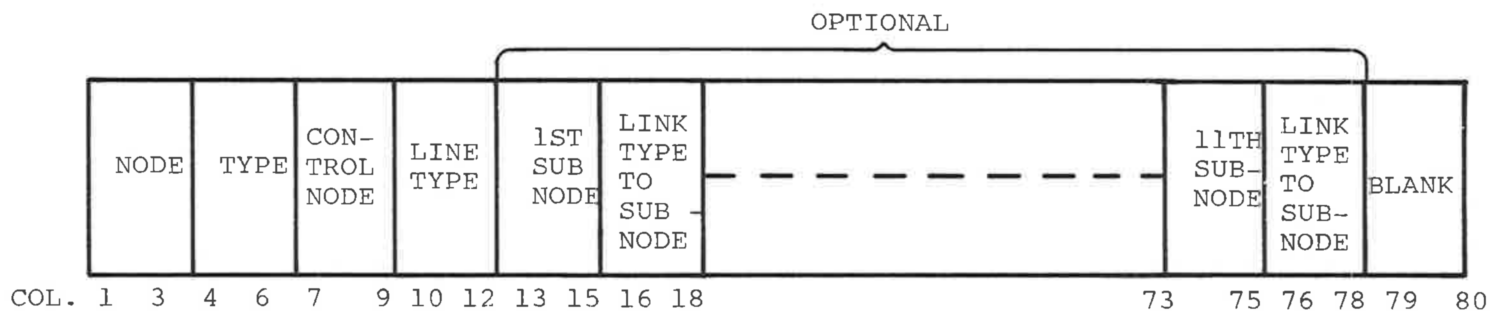
TABLE F.2-4

NETWORK NODE FILE

Col. 1 Col. 80

```
175   4174   4                                                       141
176   4174   4                                                       142
188002148001189003190003191003                                       143
177   3180   2                                                       144
178   3188   2                                                       145
179   3108   2                                                       146
180   3188   2                                                       147
181   4180   4                                                       148
182   3188   2                                                       149
183   3188   2                                                       150
184   4183   4                                                       151
185   3188   2                                                       152
186   4188   4                                                       153
187   4185   4                                                       154
192   3188   2                                                       155
193002148001194003                                                   156
195   4193005                                                        157
196   3193002                                                        158
197   3193   2                                                       159
198   3193   2                                                       160
199   4198   4                                                       161
215002148001216003217003218003219003                                 162
200   4201   4                                                       163
201   3215   2                                                       164
202   4201   4                                                       165
```

NOTE: SEE FIGURE F.2-1 FOR FILE ORGANIZATION



NOTE: IF COL. 1-12 ARE ZERO OR BLANK, COLS. 13-78 CONTINUE LIST OF SUB-NODES ON PREVIOUS LINE (CARD).

NOTE: IF SUBNODE IS TYPE 5, ENTRY OF ITS INDEX AND LINK TYPE IN THE CONTROLLING NODE SPECIFICATION LINE ARE SUFFICIENT TO FULLY SPECIFY THE SUBNODE. A SEPARATE ENTRY FOR THE SUBNODE IS OPTIONAL.

FIGURE F.2-1 - NETWORK NODE FILE STRUCTURE ordered network file. It also produces diagnostics identifying nodes not connected into the system, duplicate entries, missing entries, and the like. Once a network file has been passed by the preprocessor, there is no need to reprocess it. Thus, the preprocessor provides an efficient method to prepare networks for production runs of the model.

Model Control File

This file tells the model program the particulars of each run. The file includes detailed output and plotting specifications, information about which forms of output to include or which to suppress and which data files are to be used for the model run. One control file is Table F.2 5.

F.3 Communication Model Outputs

Model output is divided into two main categories: graphical plots and tabular data.

Graphical Plots

The plotting function has been designed to be very versatile. The Model Control File specifies all particulars of the plotting format including title, style of border, colors of various node line tapes, cross hatch and object fill modes, and demand sensitivity. Each node is represented by a circle whose size varies between an upper and lower limit according to demand at that node. The hierarchy of interconnected nodes is represented by lines which may be single lines or double lines, dotted, dashed or solid lines. Demand nodes (type 4) are vertically cross hatched, and the grid may be set to completely file the node circle. V&S nodes (type 3) are demand sized according to separate upper and lower limits. The demand circle is not cross-hatched, but a smaller, inner circle is solid filled giving V&S nodes the appearance of an anulus. Data Base Processor nodes (type 2) are represented by a horizontally crossed hatched circle. Again, separate limits for size regulate the size of the circle according to demand. The central node (type 1) is represented by a horizontally cross hatched square if it is present. During the course of the study, the model was set to skip the plotting of demand information. Plots of the various networks used appear in Chapter 4, Figures 4.4.4-1 to 4.4.4-8. Figure F.3-1 is an example of a network plot with demand circles shown. A display of the U.S. background map is optional.

TABLE F.2-5

NETWORK MODEL CONTROL FILE

```
    XYIRAB PKPB03 BNETBN 1
    06,FOR PB:X2.5  NET$2  AML=06
    1 -1.000 2 00.500 3 -1.000,3,00.000,3 00.000 3 00.000 3 00.000
    2,2,2,2,3,3,3,4,0,5
    00.750,00.050,00.000,00.750,00.050,00.000
    00.000,02.500,00.500,0.00000,0000090.0,01.00000
    BLACK .1,RED    .2,BLUE  .3,GREEN .1
    -02.000,039.000,000.000,027.750,000.250
01
    -02.000,039.000,026.000,026.750,040
URS COMMUNICATION NETWORK $1
    000.000,040.000,024.500,025.000,040
1986 PROJECTED DEMAND
01
```

1986 Projected Demand

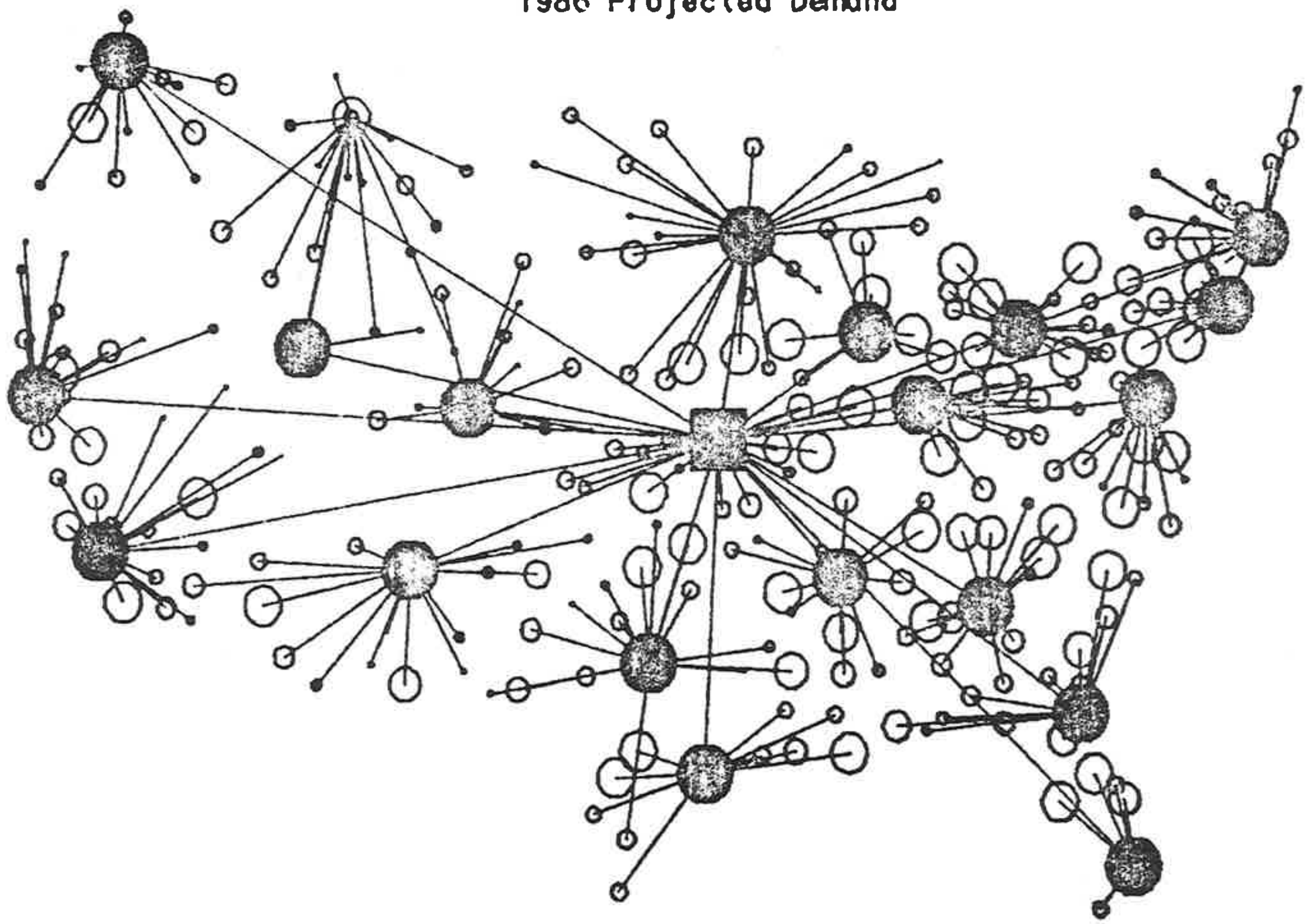


FIGURE F.3-1 — VRS COMMUNICATION NETWORK #1

A geographical output may be generated on either the Tektronix 4000 series of displays or on a CalComp Plotter. For plotter output, pen change commands allow different colors of ink to be used for different components of the plot. Because of the nature of the devices, CalComp Plotter generated output looks better -- but takes longer to produce -- than Tektronix output.

Tabular Data

Tabular output is generated in three tables. These are the node-by-node detailed listing, the node summary, and the line summary. The node-by-node detail contains one line for each node in the network. For that line, the listing shows the standard FAA 3-letter identification for the node, the internal model index for the node, node type and type of communication link to the next higher node in the system, and 3 letter ID for the next higher node (called the controlling node). Also shown are aggregate demand for the node not including demand generated by separate, subsidiary nodes, number of voice lines required at the node, number of voice lines required to communicate with the node's controlling node, mileage per line to the controlling node, cost per line, and, finally total cost for lines serving this node from the controlling node. One page of detailed output appears in Table F.3-1.

The line summary shows the network totals for number of lines, total mileage, and total costs. These totals are broken down by line type. A line summary appears in Table F.3-2.

The node summary table contains a summary of all nodes by type. Also printed in this summary is the total system demand total number of lines, number of nodes with computing equipment, and total system communication cost. An example appears in Table F.3-3.

F.4 Model Enhancements

The design of the model makes it amenable to analysis of other networks. The possibility of altering the model to be a general purpose network analysis tool is being investigated.

The model has the inherent ability to do a more complete analysis using node costing information as well as communication costing. This feature was not activated previously since no accurate cost estimates were available. This feature will be activated to

TABLE F.3-1 SAMPLE NODE DETAIL LISTING

SUMMARY STATISTICS FOR PR*2.5 NET*2 AML=06

NODE LINE(S) CONNECTED TO CONTROLLING NODE

NODE	NODE TYPE	LINK TYPE	CONTROL-LING NODE	AGGREGATE DEMAND	VOICE LINES	NO. LINES	MILEAGE PER LINE	COST PER LINE	TOTAL COST OF LINE(S)
DAN 293	4	4	DCA	16,085	5	5	197.25	200.40	1002.02
ROA 292	4	4	DCA	71,637	11	11	189.55	195.94	2155.35
BLF 291	4	4	DCA	54,335	8	8	250.10	231.06	1848.48
RWI 290	4	4	DCA	34,387	7	7	205.99	205.48	1438.34
RDU 289	4	4	DCA	199,467	22	22	221.69	214.58	4720.75
ECG 288	4	4	DCA	14,155	5	5	177.99	189.23	946.16
EWN 287	4	4	DCA	58,340	9	9	254.12	233.39	2100.50
RIC 286	4	4	DCA	134,122	16	16	87.09	136.51	2184.21
MRB 285	4	4	DCA	54,620	8	8	69.40	126.25	1010.03
PHF 284	4	4	DCA	133,120	16	16	115.27	152.85	2445.66
CHO 283	4	4	DCA	43,110	7	7	89.19	137.73	964.11
MIV 281	4	4	DCA	294,625	31	31	111.49	150.67	4670.64
SBY 280	4	4	DCA	45,970	8	8	85.31	135.48	1083.85
			DCA	257,092	27	27		18.00	486.00
DCA 282	3	2	ATL	1411,067	180	6	541.45	400.04	2400.24
SFF 279	4	4	SEA	55,620	8	8	232.06	220.60	1764.77
HQM 277	4	4	SEA	10,722	3	3	85.86	135.80	407.40
RDM 275	4	4	SEA	43,967	7	7	232.87	221.07	1547.46
DLS 274	4	4	SEA	15,870	5	5	142.57	168.69	843.45
PDX 273	4	4	SEA	176,582	20	20	140.99	167.77	3355.49
OTH 272	4	4	SEA	22,520	6	6	299.24	259.56	1557.35
EPH 271	4	4	SEA	21,232	6	6	131.29	162.15	972.87
EAT 270	4	4	SEA	38,105	7	7	98.12	142.91	1000.35
BLI 269	4	4	SEA	31,812	7	7	88.29	137.21	960.47
ALW 268	4	4	SEA	63,197	9	9	214.03	210.14	1891.23
BKF 267	4	4	SEA	20,805	6	6	284.03	250.74	1504.43
TDO 278	5	3	SEA	6,720	3	3	76.46	18.00	54.00
			SEA	189,592	21	21		18.00	378.00
SEA 276	3	2	SLC	696,747	108	4	691.37	487.00	1947.98
RWL 265	4	4	SLC	9,295	3	3	257.06	235.09	705.28
RKS 264	4	4	SLC	20,950	6	6	160.91	179.33	1075.97
LAR 263	4	4	SLC	16,802	5	5	329.84	277.31	1386.55
IDA 262	4	4	SLC	44,117	7	7	188.86	195.54	1368.76
BYI 254	4	4	SLC	41,257	7	7	153.05	174.77	1223.39
BOI 253	4	4	SLC	56,775	9	9	290.48	254.48	2290.33
WRL 252	4	4	SLC	21,952	6	6	300.50	260.29	1561.74
SHR 251	4	4	SLC	26,670	6	6	374.06	302.96	1817.73
MSO 261	4	4	GTF	26,957	6	6	133.49	163.42	980.55
LWT 260	4	4	GTF	6,292	3	3	94.04	140.54	421.62
CTB 259	4	4	GTF	4,862	2	2	90.86	138.70	277.40
LVM 257	4	4	GTF	12,442	5	5	130.66	161.78	808.92
BTM 256	4	4	GTF	9,152	3	3	118.36	154.65	463.95
BZN 255	4	4	GTF	14,300	5	5	118.12	154.51	772.56
MLS 250	4	4	GTF	31,390	7	7	268.65	241.82	1692.71
BIL 249	4	4	GTF	49,052	8	8	177.58	189.00	1511.99
			GTF	38,540	7	7		18.00	126.00
GTF 258	3	2	SLC	192,990	46	2	463.75	354.97	709.95

TABLE F.3-2

LINE SUMMARY

TYPES OF LINES

LINE TYPE	TOTAL NO. OF LINES	TOTAL MILEAGE OF LINES	TOTAL COST FOR LINE TYPE
1	1	1576.93	18.00
2	101	61866.22	44568.41
3	203	15803.53	3654.00
4	2368	442211.06	460130.41
5	7	785.10	1266.87
6	0	0.00	0.00
7	0	0.00	0.00
LOCAL	539		9702.00
TOTALS	3219	522242.85	519339.69

TABLE F.3-3

NODE SUMMARY

TYPES OF NODES

NODE TYPE	NO. OF NODES
1	1
2	1
3	19
4	248
5	24

AGGREGATE DEMAND ON SYSTEM	TOTAL NO. OF LINES	NO. OF NODES WITH EQUIPMENT	TOTAL COST OF COMMUNICATION
22696.99	3219	21	519339.69

increase the model's utility and accuracy.

By use of some established estimating factors and other information stored internally in the model, it is possible to greatly enhance the node summary table. The enhanced table would provide statistics in terms of numbers of VRS computers and Data Processors. In addition, fail-soft and fail-safe alternatives would be summarized. The costing algorithm would take into account both node and line cost to provide system ground total estimates.

An advanced interactive graphics installation is available at TSC. This installation will be used to allow a designer to make many refinements to a network and see immediately the effect of such changes. In this fashion, an optimal network design could be generated very quickly. The. interactive graphics feature will be very useful in the development of a national VRS implementation plan.

APPENDIX G - COMPUTER DATA SUMMARIES

These computer summaries were initially based upon a 10% maintenance rate. The 20% maintenance figures can be calculated by multiplying the total equipment cost estimates by 1.5 and adding communication costs.

SUMMARY STATISTICS FOR 1986,PB*2.5,AML=6,TLPK,1VRS/1DBP

VRS AND DBP SUMMARY

	MINIMAL TO SERVE DEMAND		FAIL SOFT (AT LEAST 2/SITE)		FAIL SAFE (FULLY REDUNDANT)	
NO. VRS UNITS/SITES	NO. OF SITES	NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. CF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS
	1	92	0	92	1	93
COST VRS (INCL. MAINT.)	$ 61364.00		$ 61364.00		$ 62031.00	
NO. DBP UNITS/SITES	NO. OF SITES	NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NC. CF UNITS	SITES W/XTRA UNIT	TOTAL NO. CF UNITS
	1	12	0	12	1	13
COST DBP (INCL. MAINT.)	$ 24000.00		$ 24000.00		$ 26000.00	
TOTAL EQUIP. COST EST.	$ 85364.00		$ 85364.00		$ 88031.00	
COST OF COMMUNICATION	$ 1582254.20		$ 1582254.20		$ 1582254.20	
SYSTEM CCST (MONTHLY)	$ 1667618.20		$ 1667618.20		$ 1670285.20	

NC. COMM. LINES : 2914
NO. SYSTEM MILES : 2299114.00
TOTAL SYSTEM DEMAND : 21434.81

SUMMARY STATISTICS FOR 1986,PB*2.5,AML=6,TELPAK,2VRS/2DBP

VRS AND DBP SUMMARY

	MINIMAL TO SERVE DEMAND		FAIL SOFT (AT LEAST 2/SITE)		FAIL SAFE (FULLY REDUNDANT)	
NO. VRS UNITS/SITES	NO. OF SITES	NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS
	2	92	0	92	2	94
COST VRS (INCL. MAINT.)	$ 61364.00		$ 61364.00		$ 62698.00	
NO. DBP UNITS/SITES	NO. OF SITES	NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS
	2	12	0	12	2	14
COST DBP (INCL. MAINT.)	$ 24000.00		$ 24000.00		$ 28000.00	
TOTAL EQUIP. COST EST.	$ 85364.00		$ 85364.00		$ 90698.00	
COST OF COMMUNICATION	$ 1190200.00		$ 1190200.00		$ 1190200.00	
SYSTEM COST (MONTHLY)	$ 1275564.00		$ 1275564.00		$ 1280898.00	

NO. COMM. LINES : 2915
NO. SYSTEM MILES : 1626580.30
TOTAL SYSTEM DEMAND : 21434.81

SUMMARY STATISTICS FOR 1986,PB*2.5,AML=6,TELPAK,21VRS/2DBP

VRS AND DBP SUMMARY

	MINIMAL TO SERVE DEMAND		FAIL SOFT (AT LEAST 2/SITE)		FAIL SAFE (FULLY REDUNDANT)	
NO. VRS UNITS/SITES	NO. OF SITES	NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS
	21	109	0	109	21	130
COST VRS (INCL. MAINT.)	$ 72703.00		$ 72703.00		$ 86710.00	
NO. DBP UNITS/SITES	NO. OF SITES	NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS
	2	15	0	15	2	17
COST DBP (INCL. MAINT.)	$ 30000.00		$ 30000.00		$ 34000.00	
TOTAL EQUIP. COST EST.	$ 102703.00		$ 102703.00		$ 120710.00	
COST OF COMMUNICATION	$ 519810.39		$ 519810.39		$ 519810.39	
SYSTEM COST (MONTHLY)	$ 622513.39		$ 622513.39		$ 640520.39	

NO. COMM. LINES : 3219
NO. SYSTEM MILES : 522242.85
TOTAL SYSTEM DEMAND : 22696.99

SUMMARY STATISTICS FOR 1986,PB*2.5,AML=6,TELPAK,21VRS/20DBP

VRS AND DBP SUMMARY

	MINIMAL TO SERVE DEMAND		FAIL SOFT (AT LEAST 2/SITE)		FAIL SAFE (FULLY REDUNDANT)	
NO. VRS UNITS/SITES	NO. OF SITES	NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS
	21	109	0	109	21	130
COST VRS (INCL. MAINT.)	$ 72703.00		$ 72703.00		$ 86710.00	
NO. DBP UNITS/SITES	NO. OF SITES	NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS
	20	20	20	40	20	40
COST DBP (INCL. MAINT.)	$ 40000.00		$ 80000.00		$ 80000.00	
TOTAL EQUIP. COST EST.	$ 112703.00		$ 152703.00		$ 166710.00	
COST OF COMMUNICATION	$ 475214.15		$ 475214.15		$ 475214.15	
SYSTEM COST (MONTHLY)	$ 587917.16		$ 627917.16		$ 641924.16	

NO. COMM. LINES : 3138
NO. SYSTEM MILES : 475904.32
TOTAL SYSTEM DEMAND : 22696.99

SUMMARY STATISTICS FOR 1986,PB*2.5,AML=6,TELPAK,43VRS/20DBP

VRS AND DBP SUMMARY

	MINIMAL TO SERVE DEMAND		FAIL SOFT (AT LEAST 2/SITE)		FAIL SAFE (FULLY REDUNDANT)	
NO. VRS UNITS/SITES	NO. OF SITES	NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS
	43	118	10	128	43	161
COST VRS (INCL. MAINT.)	$ 78706.00		$ 85376.00		$ 107387.00	
NO. DBP UNITS/SITES	NO. OF SITES	NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS
	20	21	19	40	20	41
COST DBP (INCL. MAINT.)	$ 42000.00		$ 80000.00		$ 82000.00	
TOTAL EQUIP. COST EST.	$ 120706.00		$ 165376.00		$ 189387.00	
COST OF COMMUNICATION	$ 379441.91		$ 379441.91		$ 379441.91	
SYSTEM COST (MONTHLY)	$ 500147.91		$ 544817.91		$ 568828.91	

NO. COMM. LINES : 3173
NO. SYSTEM MILES : 362217.70
TOTAL SYSTEM DEMAND : 22696.99

SUMMARY STATISTICS FOR 1986,PB*2.5,AML=6,TLPK,134VRS/2CDBP

VRS AND DBP SUMMARY

	MINIMAL TO SERVE DEMAND		FAIL SOFT (AT LEAST 2/SITE)		FAIL SAFE (FULLY REDUNDANT)	
NO. VRS UNITS/SITES	NO. OF SITES	NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. CF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS
	134	164	107	271	134	298
COST VRS (INCL. MAINT.)	$ 109388.00		$ 180757.00		$ 198766.00	
NO. DBP UNITS/SITES	NO. OF SITES	NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NC. CF UNITS
	20	27	13	40	20	47
COST DBP (INCL. MAINT.)	$ 54000.00		$ 80000.00		$ 94000.00	
TOTAL EQUIP. COST EST.	$ 163388.00		$ 260757.00		$ 292766.00	
COST OF COMMUNICATION	$ 196261.20		$ 196261.20		$ 196261.20	
SYSTEM COST (MONTHLY)	$ 359649.20		$ 457018.20		$ 489027.20	

NC. CCMM. LINES : 3262
NO. SYSTEM MILES : 140937.15
TOTAL SYSTEM DEMAND : 22696.99

SUMMARY STATISTICS FOR 1986,PB*2.5,AML=6,TELPAK,268VRS/20DB

VRS AND DBP SUMMARY

	MINIMAL TO SERVE DEMAND		FAIL SOFT (AT LEAST 2/SITE)		FAIL SAFE (FULLY REDUNDANT)	
NO. VRS UNITS/SITES	NO. OF SITES	NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS
	268	279	257	536	268	547
COST VRS (INCL. MAINT.)	$ 186093.00		$ 357512.00		$ 364849.00	
NO. DBP UNITS/SITES	NO. OF SITES	NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS
	20	42	3	45	20	62
COST DBP (INCL. MAINT.)	$ 84000.00		$ 90000.00		$ 124000.00	
TOTAL EQUIP. COST EST.	$ 270093.00		$ 447512.00		$ 488849.00	
COST OF COMMUNICATION	$ 106690.19		$ 106690.19		$ 106690.19	
SYSTEM COST (MONTHLY)	$ 376783.19		$ 554202.19		$ 595539.19	

NO. COMM. LINES :	3384
NO. SYSTEM MILES :	82725.43
TOTAL SYSTEM DEMAND :	22696.99

SUMMARY STATISTICS FOR 1986,PB*2.5,AML=6,AT&T,21VRS/2DBP

VRS AND DBP SUMMARY

	MINIMAL TO SERVE DEMAND		FAIL SOFT (AT LEAST 2/SITE)		FAIL SAFE (FULLY REDUNDANT)	
NO. VRS UNITS/SITES	NO. OF SITES	NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS
	21	109	0	109	21	130
COST VRS (INCL. MAINT.)	$ 72703.00		$ 72703.00		$ 86710.00	
NO. DBP UNITS/SITES	NO. OF SITES	NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS
	2	15	0	15	2	17
COST DBP (INCL. MAINT.)	$ 30000.00		$ 30000.00		$ 34000.00	
TOTAL EQUIP. COST EST.	$ 102703.00		$ 102703.00		$ 120710.00	
COST OF COMMUNICATION	$ 755464.46		$ 755464.46		$ 755464.46	
SYSTEM COST (MONTHLY)	$ 858167.46		$ 858167.46		$ 876174.46	

NO. COMM. LINES : 3219
NO. SYSTEM MILES : 522242.85
TOTAL SYSTEM DEMAND : 22696.99

SUMMARY STATISTICS FOR 1986,PB*2.5,AML=6,AT&T,21VRS/20DBP

VRS AND DBP SUMMARY

	MINIMAL TO SERVE DEMAND		FAIL SOFT (AT LEAST 2/SITE)		FAIL SAFE (FULLY REDUNDANT)	
NO. VRS UNITS/SITES	NO. OF SITES	NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS
	21	109	0	109	21	130
COST VRS (INCL. MAINT.)	$ 72703.00		$ 72703.00		$ 86710.00	
NO. DBP UNITS/SITES	NO. OF SITES	NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS
	20	20	20	40	20	40
COST DBP (INCL. MAINT.)	$ 40000.00		$ 80000.00		$ 80000.00	
TOTAL EQUIP. COST EST.	$ 112703.00		$ 152703.00		$ 166710.00	
COST OF COMMUNICATION	$ 691773.80		$ 691773.80		$ 691773.80	
SYSTEM COST (MONTHLY)	$ 804476.80		$ 844476.80		$ 858483.80	

NO. COMM. LINES :	3138
NO. SYSTEM MILES :	475904.33
TOTAL SYSTEM DEMAND :	22696.99

SUMMARY STATISTICS FOR 1986,PB*2.5,AML=6,AT&T,43VRS/20DBP

VRS AND DBP SUMMARY

	MINIMAL TO SERVE DEMAND		FAIL SOFT (AT LEAST 2/SITE)		FAIL SAFE (FULLY REDUNDANT)	
NO. VRS UNITS/SITES	NO. OF SITES	NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS
	43	118	10	128	43	161
COST VRS (INCL. MAINT.)	$ 78706.00		$ 85376.00		$ 107387.00	
NO. DBP UNITS/SITES	NO. OF SITES	NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS
	20	21	19	40	20	41
COST DBP (INCL. MAINT.)	$ 42000.00		$ 80000.00		$ 82000.00	
TOTAL EQUIP. COST EST.	$ 120706.00		$ 165376.00		$ 189387.00	
COST OF COMMUNICATION	$ 564360.48		$ 564360.48		$ 564360.48	
SYSTEM COST (MONTHLY)	$ 685066.48		$ 729736.48		$ 753747.48	

NO. COMM. LINES : 3173
NO. SYSTEM MILES : 362217.70
TOTAL SYSTEM DEMAND : 22696.99

SUMMARY STATISTICS FOR,1986 PB*2.5,AML=6,AT&T,134VRS/20DBP

VRS AND DBP SUMMARY

	MINIMAL TO SERVE DEMAND		FAIL SOFT (AT LEAST 2/SITE)		FAIL SAFE (FULLY REDUNDANT)	
NO. VRS UNITS/SITES	NO. OF SITES	NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS
	134	164	107	271	134	298
COST VRS (INCL. MAINT.)	$ 109388.00		$ 180757.00		$ 198766.00	
NO. DBP UNITS/SITES	NO. OF SITES	NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS
	20	27	13	40	20	47
COST DBP (INCL. MAINT.)	$ 54000.00		$ 80000.00		$ 94000.00	
TOTAL EQUIP. COST EST.	$ 163388.00		$ 260757.00		$ 292766.00	
COST OF COMMUNICATION	$ 272467.76		$ 272467.76		$ 272467.76	
SYSTEM COST (MONTHLY)	$ 435855.76		$ 533224.77		$ 565233.77	

NO. COMM. LINES : 3262
NO. SYSTEM MILES : 140937.15
TOTAL SYSTEM DEMAND : 22696.99

SUMMARY STATISTICS FOR 1995,PB*2.5,AML=6,TELPAK,1VRS/1DBP

VRS AND DBP SUMMARY

	MINIMAL TO SERVE DEMAND		FAIL SOFT (AT LEAST 2/SITE)		FAIL SAFE (FULLY REDUNDANT)	
NO. VRS UNITS/SITES	NO. OF SITES	NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS
	1	116	0	116	1	117
COST VRS (INCL. MAINT.)	$ 77372.00		$ 77372.00		$ 78039.00	
NO. DBP UNITS/SITES	NO. OF SITES	NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS
	1	15	0	15	1	16
COST DBP (INCL. MAINT.)	$ 30000.00		$ 30000.00		$ 32000.00	
TOTAL EQUIP. COST EST.	$ 107372.00		$ 107372.00		$ 110039.00	
COST OF COMMUNICATION	$ 2011182.20		$ 2011182.20		$ 2011182.20	
SYSTEM COST (MONTHLY)	$ 2118554.20		$ 2118554.20		$ 2121221.20	

NO. COMM. LINES : 3705
NO. SYSTEM MILES : 2922297.00
TOTAL SYSTEM DEMAND : 30008.73

SUMMARY STATISTICS FOR 1995,PB*2.5,AML=6,TELPAK,2VRS/2DBP

VRS AND DBP SUMMARY

	MINIMAL TO SERVE DEMAND		FAIL SOFT (AT LEAST 2/SITE)		FAIL SAFE (FULLY REDUNDANT)	
NO. VRS UNITS/SITES	NO. OF SITES	NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS
	2	116	0	116	2	118
COST VRS (INCL. MAINT.)	$ 77372.00		$ 77372.00		$ 78706.00	
NO. DBP UNITS/SITES	NO. OF SITES	NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS
	2	15	0	15	2	17
COST DBP (INCL. MAINT.)	$ 30000.00		$ 30000.00		$ 34000.00	
TOTAL EQUIP. COST EST.	$ 107372.00		$ 107372.00		$ 112706.00	
COST OF COMMUNICATION	$ 1514677.40		$ 1514677.40		$ 1514677.40	
SYSTEM COST (MONTHLY)	$ 1622049.40		$ 1622049.40		$ 1627383.40	

NO. COMM. LINES : 3706
NO. SYSTEM MILES : 2070261.90
TOTAL SYSTEM DEMAND : 30008.73

SUMMARY STATISTICS FOR 1995,PB*2.5,AML=6,TELPAK,21VRS/2DBP

VRS AND DBP SUMMARY

	MINIMAL TO SERVE DEMAND		FAIL SOFT (AT LEAST 2/SITE)		FAIL SAFE (FULLY REDUNDANT)	
NO. VRS UNITS/SITES	NO. OF SITES	NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS
	21	135	0	135	21	156
COST VRS (INCL. MAINT.)	$ 90045.00		$ 90045.00		$ 104052.00	
NO. DBP UNITS/SITES	NO. OF SITES	NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS
	2	18	0	18	2	20
COST DBP (INCL. MAINT.)	$ 36000.00		$ 36000.00		$ 40000.00	
TOTAL EQUIP. COST EST.	$ 126045.00		$ 126045.00		$ 144052.00	
COST OF COMMUNICATION	$ 653161.11		$ 653161.11		$ 653161.11	
SYSTEM COST (MONTHLY)	$ 779206.11		$ 779206.11		$ 797213.11	

NO. COMM. LINES :	4076
NO. SYSTEM MILES :	653573.32
TOTAL SYSTEM DEMAND :	31775.79

SUMMARY STATISTICS FOR 1995,PB*2.5,AML=6,TELPAK,21VRS/20DBP

VRS AND DBP SUMMARY

	MINIMAL TO SERVE DEMAND		FAIL SOFT (AT LEAST 2/SITE)		FAIL SAFE (FULLY REDUNDANT)	
NO. VRS UNITS/SITES	NO. OF SITES	NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS
	21	135	0	135	21	156
COST VRS (INCL. MAINT.)	$ 90045.00		$ 90045.00		$ 104052.00	
NO. DBP UNITS/SITES	NO. OF SITES	NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS
	20	21	19	40	20	41
COST DBP (INCL. MAINT.)	$ 42000.00		$ 80000.00		$ 82000.00	
TOTAL EQUIP. COST EST.	$ 132045.00		$ 170045.00		$ 186052.00	
COST OF COMMUNICATION	$ 597739.16		$ 597739.16		$ 597739.16	
SYSTEM COST (MONTHLY)	$ 729784.16		$ 767784.16		$ 783791.16	

NO. COMM. LINES : 3971
NO. SYSTEM MILES : 592357.27
TOTAL SYSTEM DEMAND : 31775.79

SUMMARY STATISTICS FOR 1995,PR*2.5,AML=6,TELPAK,43VRS/20DBP

VRS AND DBP SUMMARY

	MINIMAL TO SERVE DEMAND		FAIL SOFT (AT LEAST 2/SITE)		FAIL SAFE (FULLY REDUNDANT)	
NO. VRS UNITS/SITES	NO. OF SITES	NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS
	43	147	4	151	43	190
COST VRS (INCL. MAINT.)	$ 98049.00		$ 100717.00		$ 126730.00	
NO. DBP UNITS/SITES	NO. OF SITES	NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS
	20	26	14	40	20	46
COST DBP (INCL. MAINT.)	$ 52000.00		$ 80000.00		$ 92000.00	
TOTAL EQUIP. COST EST.	$ 150049.00		$ 180717.00		$ 218730.00	
COST OF COMMUNICATION	$ 472727.38		$ 472727.38		$ 472727.38	
SYSTEM COST (MONTHLY)	$ 622776.38		$ 653444.38		$ 691457.38	

NO. COMM. LINES : 4015
NO. SYSTEM MILES : 445095.56
TOTAL SYSTEM DEMAND : 31775.79

SUMMARY STATISTICS FOR 1995,PB*2.5,AML=6,TELPAK,134VRS/20DB

VRS AND DBP SUMMARY

	MINIMAL TO SERVE DEMAND		FAIL SOFT (AT LEAST 2/SITE)		FAIL SAFE (FULLY REDUNDANT)	
NO. VRS UNITS/SITES	NO. OF SITES	NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS
	134	187	91	278	134	321
COST VRS (INCL. MAINT.)	$ 124729.00		$ 195426.00		$ 214107.00	
NO. DBP UNITS/SITES	NO. OF SITES	NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS
	20	34	7	41	20	54
COST DBP (INCL. MAINT.)	$ 68000.00		$ 82000.00		$ 108000.00	
TOTAL EQUIP. COST EST.	$ 192729.00		$ 267426.00		$ 322107.00	
COST OF COMMUNICATION	$ 239144.81		$ 239144.81		$ 239144.81	
SYSTEM COST (MONTHLY)	$ 431873.82		$ 506570.82		$ 561251.81	

NO. COMM. LINES : 4108
NO. SYSTEM MILES : 165280.83
TOTAL SYSTEM DEMAND : 31775.79

SUMMARY STATISTICS FOR 1995,PB*2.5,AML=6,TELPAK,268VRS/20DB

VRS AND DBP SUMMARY

	MINIMAL TO SERVE DEMAND		FAIL SOFT (AT LEAST 2/SITE)		FAIL SAFE (FULLY REDUNDANT)	
NO. VRS UNITS/SITES	NO. OF SITES	NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS
	268	294	246	540	268	562
COST VRS (INCL. MAINT.)	$ 196098.00		$ 360180.00		$ 374854.00	
NO. DBP UNITS/SITES	NO. OF SITES	NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS
	20	45	2	47	20	65
COST DBP (INCL. MAINT.)	$ 90000.00		$ 94000.00		$ 130000.00	
TOTAL EQUIP. COST EST.	$ 286098.00		$ 454180.00		$ 504854.00	
COST OF COMMUNICATION	$ 122653.11		$ 122653.11		$ 122653.11	
SYSTEM COST (MONTHLY)	$ 408751.11		$ 576833.11		$ 627507.11	

NO. COMM. LINES :	4223
NO. SYSTEM MILES :	86949.22
TOTAL SYSTEM DEMAND :	31775.79

SUMMARY STATISTICS FOR 1986,PB*2.5,AML=4,TELPAK,43VRS/20DBP

VRS AND DBP SUMMARY

	MINIMAL TO SERVE DEMAND		FAIL SOFT (AT LEAST 2/SITE)		FAIL SAFE (FULLY REDUNDANT)	
NO. VRS UNITS/SITES	NO. OF SITES	NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS
	43	95	17	112	43	138
COST VRS (INCL. MAINT.)	$ 63365.00		$ 74704.00		$ 92046.00	
NO. DBP UNITS/SITES	NO. OF SITES	NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS
	20	20	20	40	20	40
COST DBP (INCL. MAINT.)	$ 40000.00		$ 80000.00		$ 80000.00	
TOTAL EQUIP. COST EST.	$ 103365.00		$ 154704.00		$ 172046.00	
COST OF COMMUNICATION	$ 301949.54		$ 301949.54		$ 301949.54	
SYSTEM COST (MONTHLY)	$ 405314.54		$ 456653.54		$ 473995.54	

NO. COMM. LINES : 2451
NO. SYSTEM MILES : 293121.25
TOTAL SYSTEM DEMAND : 22696.99

SUMMARY STATISTICS FOR 1986,PB*2.5,AML=8,TELPAK,43VRS/20DBP

VRS AND DBP SUMMARY

	MINIMAL TO SERVE DEMAND		FAIL SOFT (AT LEAST 2/SITE)		FAIL SAFE (FULLY REDUNDANT)	
NO. VRS UNITS/SITES	NO. OF SITES	NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS
	43	144	5	149	43	187
COST VRS (INCL. MAINT.)	$ 96048.00		$ 99383.00		$ 124729.00	
NO. DBP UNITS/SITES	NO. OF SITES	NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS
	20	25	15	40	20	45
COST DBP (INCL. MAINT.)	$ 50000.00		$ 80000.00		$ 90000.00	
TOTAL EQUIP. COST EST.	$ 146048.00		$ 179383.00		$ 214729.00	
COST OF COMMUNICATION	$ 456813.35		$ 456813.35		$ 456813.35	
SYSTEM COST (MONTHLY)	$ 602861.35		$ 636196.35		$ 671542.35	

NO. COMM. LINES : 3878
NO. SYSTEM MILES : 431075.77
TOTAL SYSTEM DEMAND : 22696.99

SUMMARY STATISTICS FCR 1986,PB*2.5,AML=6,TELPAK,3 ARTCC

VRS AND DBP SUMMARY

	MINIMAL TO SERVE DEMAND		FAIL SOFT (AT LEAST 2/SITE)		FAIL SAFE (FULLY REDUNDANT)	
NO. VRS UNITS/SITES	NO. OF SITES	NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS
	5	19	1	20	5	24
COST VRS (INCL. MAINT.)	$ 12673.00		$ 13340.00		$ 16008.00	
NO. DBP UNITS/SITES	NO. OF SITES	NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS
	3	3	3	6	3	6
COST DBP (INCL. MAINT.)	$ 6000.00		$ 12000.0C		$ 12000.00	
TOTAL EQUIP. COST EST.	$ 18673.00		$ 25340.00		$ 28CC8.00	
COST OF COMMUNICATION	$ 70345.57		$ 70345.57		$ 70345.57	
SYSTEM COST (MONTHLY)	$ 89018.57		$ 95685.57		$ 98353.57	

NO. COMM. LINES : 528
NO. SYSTEM MILES : 63978.75
TOTAL SYSTEM DEMAND : 3991.26

SUMMARY STATISTICS FCR 1986,PB*2.5,AML=6,TELPAK,14 ARTCC

VRS AND DBP SUMMARY

	MINIMAL TO SERVE DEMAND		FAIL SOFT (AT LEAST 2/SITE)		FAIL SAFE (FULLY REDUNDANT)	
NO. VRS UNITS/SITES	NO. OF SITES	NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. CF UNITS
	33	87	9	96	33	120
COST VRS (INCL. MAINT.)	$ 58029.00		$ 64032.00		$ 80040.00	
NO. DBP UNITS/SITES	NO. OF SITES	NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS
	14	15	13	28	14	29
COST DBP (INCL. MAINT.)	$ 30000.00		$ 56000.00		$ 580CC.00	
TOTAL EQUIP. COST EST.	$ 88029.00		$ 120032.00		$ 138040.00	
COST OF COMMUNICATION	$ 248267.33		$ 248267.33		$ 248267.33	
SYSTEM COST (MONTHLY)	$ 336296.34		$ 368299.34		$ 386307.34	

NO. COMM. LINES : 2305
NO. SYSTEM MILES : 221788.97
TOTAL SYSTEM DEMAND : 17341.00

SUMMARY STATISTICS FOR 1986,PB*1.2+PATWAS,06,TELPK,3 ARTCC

VRS AND DBP SUMMARY

	MINIMAL TO SERVE DEMAND		FAIL SOFT (AT LEAST 2/SITE)		FAIL SAFE (FULLY REDUNDANT)	
NO. VRS UNITS/SITES	NO. OF SITES	NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS
	5	15	2	17	5	20
COST VRS (INCL. MAINT.)	$ 10005.00		$ 11339.00		$ 13340.00	
NO. DBP UNITS/SITES	NO. OF SITES	NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS
	3	3	3	6	3	6
COST DBP (INCL. MAINT.)	$ 6000.00		$ 12000.00		$ 12000.00	
TOTAL EQUIP. COST EST.	$ 16005.00		$ 23339.00		$ 25340.00	
COST OF COMMUNICATION	$ 54649.66		$ 54649.66		$ 54649.66	
SYSTEM COST (MONTHLY)	$ 70654.66		$ 77988.66		$ 79989.66	

NO. COMM. LINES : 438
NO. SYSTEM MILES : 49945.57
TOTAL SYSTEM DEMAND : 3108.94

SUMMARY STATISTICS FOR 1986,PB*1.2+PATWAS,06,TELPK,14 ARTCC

VRS AND DBP SUMMARY

	MINIMAL TO SERVE DEMAND		FAIL SOFT (AT LEAST 2/SITE)		FAIL SAFE (FULLY REDUNDANT)	
NO. VRS UNITS/SITES	NO. OF SITES	NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS
	33	75	11	86	33	108
COST VRS (INCL. MAINT.)	$ 50025.00		$ 57362.00		$ 72036.00	
NO. DBP UNITS/SITES	NO. OF SITES	NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS	SITES W/XTRA UNIT	TOTAL NO. OF UNITS
	14	15	13	28	14	29
COST DBP (INCL. MAINT.)	$ 30000.00		$ 5600C.00		$ 580CC.00	
TOTAL EQUIP. COST EST.	$ 80025.00		$ 113362.00		$ 13C036.0C	
COST OF COMMUNICATION	$ 188040.87		$ 188040.87		$ 188040.87	
SYSTEM COST (MONTHLY)	$ 268065.88		$ 301402.88		$ 318C76.88	

NO. COMM. LINES : 1918
NO. SYSTEM MILES : 167271.67
TOTAL SYSTEM DEMAND : 13490.61

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