Report No. DOT/FAA/RD-82/3

DATA FLOW ANALYSIS FOR THE 9020 COMPUTER REPLACEMENT PROGRAM

FINAL REPORT

S. Toth
D. Swann

January 1982

PREPARED FOR

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Office of Systems Engineering Management
and Systems Research and Development Service
Washington, D.C. 20591
under Contract DOT-FA76WA-3788 "UN"

Technical Report Documentation Page

1. Report No. DOT/FAA/RD-82/3	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Data Flow Analysis for the 9020 Computer Replacement Program		5. Report Date January 1982
		6. Performing Organization Code
7. Author(s) S. Toth and D. Swann		8. Performing Organization Report No. 1326-51-18-2622
9. Performing Organization Name and Address ARINC Research Corporation 2551 Riva Rd. Annapolis, Maryland 21401		10. Work Unit No. (TRAIS)
		11. Contract or Grant No. DOT-FA76WA-3788 -"UN"
12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Aviation Administration Office of Systems Engineering Management and Systems Research & Development Service, Washington, D.C. 20591		13. Type of Report and Period Covered Final Report January 1982
		14. Sponsoring Agency Code FAA-ARD/AEM
15. Supplementary Notes		

16. Abstract

This report contains a description of 9020 remote communications traffic. Statistics at four ARTCCs are examined and data communications profiles for three hypothetical 9020 computers of different sizes are estimated. A verification plan for improving the accuracy of the statistics contained in the report is included.

17. Key Words 9020 Computer Data Communications Traffic Input/Output Communications Traffic	18. Distribution Statement

19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 84	22. Price

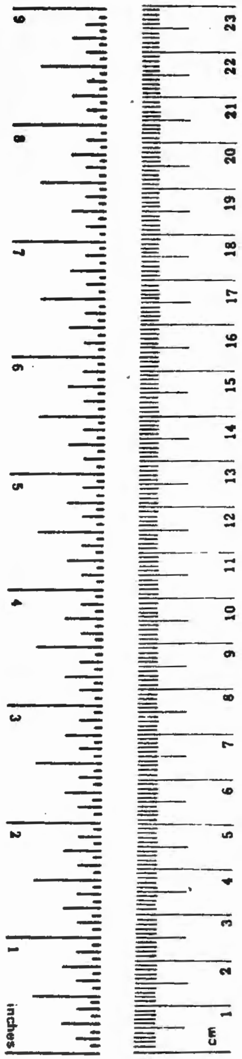
Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

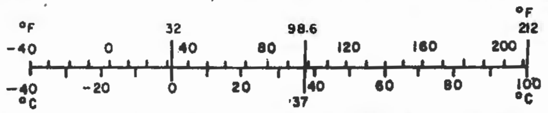
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	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

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



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



SUMMARY

During the past two decades, the 9020 computer has automated many en-route air traffic control (ATC) functions. Growth of the system and planned future enhancements have made necessary the examination of the 9020 computer's operating environment, in part to support the specification and design of the 9020's replacement. Essential to this examination is an understanding of present and future input and output (I/O) communications loading on the computer.

The objective of this study is to characterize existing input and output communications between the 9020 computer and all the remote devices and facilities to which it is linked. No field measurements were conducted during this study, since only existing data were to be used.

The work was accomplished in four subtasks:

- Indexing of all message types that the 9020 computer can now process
- Development of 9020 I/O traffic estimates from available statistics
- Evaluation of the accuracy of the traffic estimates
- Development of plans to supplement presently available data and to validate the conclusions

The first portion of the work required identification of all 9020 connectivities. The computer interfaces with the external world through 19 different port types, as depicted in Figure S-1. Each port type represents a group of connections between the 9020 computer and remote facilities of the same type (e.g., Automated Radar Terminal System [ARTS], Flight Data Entry and Printout [FDEP]), classes of computer peripheral devices (e.g., high-speed printer, tape drive), or generic sector-suite interfaces (e.g., a controller position, display channel computer). The actual number of connections depends upon the number of facilities and devices serviced by the computer.

Three hypothetical Air Route Traffic Control Center (ARTCC) configurations ("minimum site," "typical site," and "maximum site") were defined for use in estimating computer I/O loading. The "minimum site" was configured with the minimum number of links of each remote port type found

among the 20 operational ARTCCs, the "typical site" with the median number of links of each remote port type, and the "maximum site" with the maximum number of links of each port type. All traffic statistics are presented in terms of these three hypothetical facilities.

The communications through any of the 9020's interfaces are documented in National Airspace System Configuration Management Documents (NAS-MDs) that describe over 340 different operational, ATC-related message types distributed over 13 functions performed by the computer. The 13 functions were subsequently mapped into the 7 functional categories defined by the ATC Advanced Computer System Level Specification (FAA-ER-130-003). All statistics are presented in terms of these seven categories.

Since this study encompassed only I/O loading due to operational, ATC-related message activity between the computer and its remote port types, only 100 of the total message types identified in NAS-MDs were considered in detail. The other messages, which include those used for 9020 system control and those routed to or from the sector suites and peripherals, were excluded from detailed analysis in this study. All messages, however, are identified in the message index for the sake of completeness.

Actual non-radar communications traffic statistics were obtained (through the I/O Summaries of the Data Analysis and Reduction Tool [DART] program) from System Analysis and Recording (SAR) tapes prepared at the Denver, Jacksonville, Oakland, and Seattle ARTCCs. The tapes from each center covered an approximate two-hour time interval recorded between June and October 1980. The 25 different non-radar, remote input and 25 different non-radar, remote output message types actually encountered during these two-hour samples are listed in Tables S-1 and S-2, together with relative frequency of occurrence.

Actual radar input traffic statistics were available from the Cleveland ARTCC through the Quick Analysis of Radar Sites (QARS) program applied to two separate two-minute samples of incoming radar data as part of routine radar operation verification procedures. The samples were taken two days apart in October 1981. The computer received nine different radar message types. These message types are listed in Table S-3, together with relative frequency of occurrence.

Actual traffic rate statistics (i.e., messages per hour) extracted from the DART and QARS printouts were compiled for each message type encountered in four port-type groups: remote radar, remote non-radar, peripherals, and sector suite. The remote radar input messages account for over 90 percent of all 9020 communications, the sector suite outputs account for about 6 percent of the total communications, and the peripherals and non-radar remote communications constitute less than 1 percent of the total 9020 I/O traffic. The non-radar I/O is dominated by the sector suite outputs as illustrated in Figure S-2, which depicts the non-radar remote, peripheral, and sector suite I/O traffic volume obtained from the DART I/O summary printouts of the four sampled

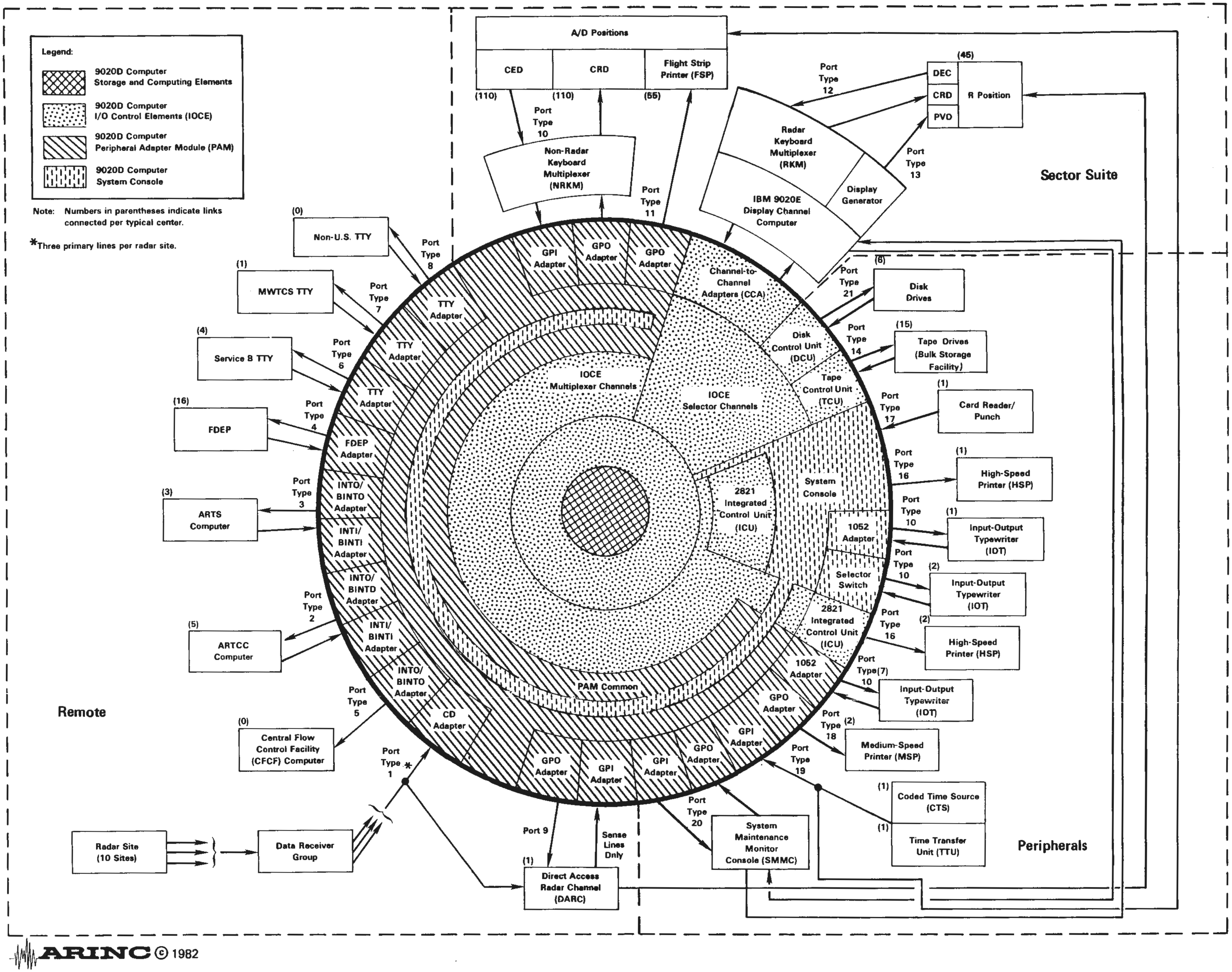


Figure S-1. 9020D I/O DATA SOURCES AND DESTINATIONS

Table S-1. NON-RADAR INPUT MESSAGE TYPES FOUND (BY FUNCTIONAL CATEGORY)

Category	DART ID	9020 ID	Name	Percent of Total Category Traffic
Flight Plan	AM	AM1	Amendment	15.0
	DM	DM	Departure	43.0
	FP	FP1	Flight plan	28.0
	FR	FR1	Flight plan readout request	4.0
	HM	HM1	Hold	0.1
	PR	PR	Progress report	0.4
	PS	PS1	Remove strip	3.0
	SP	SP	Stereo flight plan	3.0
	SR	SR	Strip request	4.0
Total				100.5*
Weather	UM	UM	Upper wind	17.0
	WX	WX1	Weather	83.0
Total				100.0
Traffic Flow Management	DZ	DZ1	Flow control FP departure	79.0
	FZ	FZ1	Flow control FP information	16.0
	RZ	RZ1	Flow control FP cancellation	5.0
Total				100.0
Miscellaneous	DA	DA1	Transmission accepted	26.0
	DR	DR1	Transmission rejected	0.5
	GI	GI1	General information	0.1
	TA	TA1	Accept transfer	6.0
	TB	TB	Terminate beacon code	8.0
	TI	TI1	Initiate transfer	7.0
	TR	TR1	Test message	6.0
	TU	TU1	Track update	47.0
Total				100.6*
Uncategorized	CONTL	15UM2	Unknown	2.0
	CORR	15UM3	Unknown	1.0
	UNDEF	15UM6	Unknown	97.0
Total				100.0

*Total does not equal 100 percent because of rounding errors.

Table S-2. NON-RADAR OUTPUT MESSAGE TYPES FOUND (BY FUNCTIONAL CATEGORY)

Category	DART ID	9020 ID	Name	Percent of Total Category Traffic
Flight Plan	AM	AM2	Amendment	18
	ARR	2AS	Arrival strip	13
	CX	CX	Cancellation/remote strip	2
	DEP	2DS	Departure strip	17
	FP	FP2 et al.	Flight plan readout	37
	FPRDO	FR2	Flight plan readout	2
	OVFLT	2OS	Overflight strip app. cntl.	9
	RS	RS2	Remove strip	3
Total				101*
Weather	WTHRO		Weather	100
Total				100
Traffic Flow Management	DZ	DZ2	Flow control FP departure	79
	FZ	FZ2	Flow control FP information	13
	RZ	RZ2	Flow control FP cancellation	8
Total				100
Miscellaneous	ACCPT	12AX	Accept	2
	DA	DA2	Transmission accepted	28
	DR	DR2	Transmission rejected	2
	DT	DT2	Data test	7
	ERROR	12EX	Error	1
	GI	GI2	General information	1
	REJECT	12RX	Reject	1
	ROGER	R	Roger	2
	TA	TA2	Accept transfer	7
	TI	TI2	Initiate transfer	6
	TU	TU2	Track update	44
Total				101*
Uncategorized	AMIPR		Unknown	95
	DPCOR		Unknown	5
Total				100

*Total does not equal 100 because of rounding errors.

Table S-3. RADAR INPUT MESSAGE TYPES RECEIVED			
Category	9020 ID	Name	Percent of Total Category Traffic
Surveillance	5BS	Beacon strobe	4×10^{-3}
	5PS	Search strobe	4×10^{-4}
	5TB	Beacon RTQC	0.1
	5TQ	Search RTQC	0.1
	5SS	Status	0.1
	5RB	Beacon return	47
	5RP	Search return	49
	5W1	Weather map #1	--
	5W2	Weather map #2	4
Total			100.3*

*Total does not equal 100 because of rounding errors.

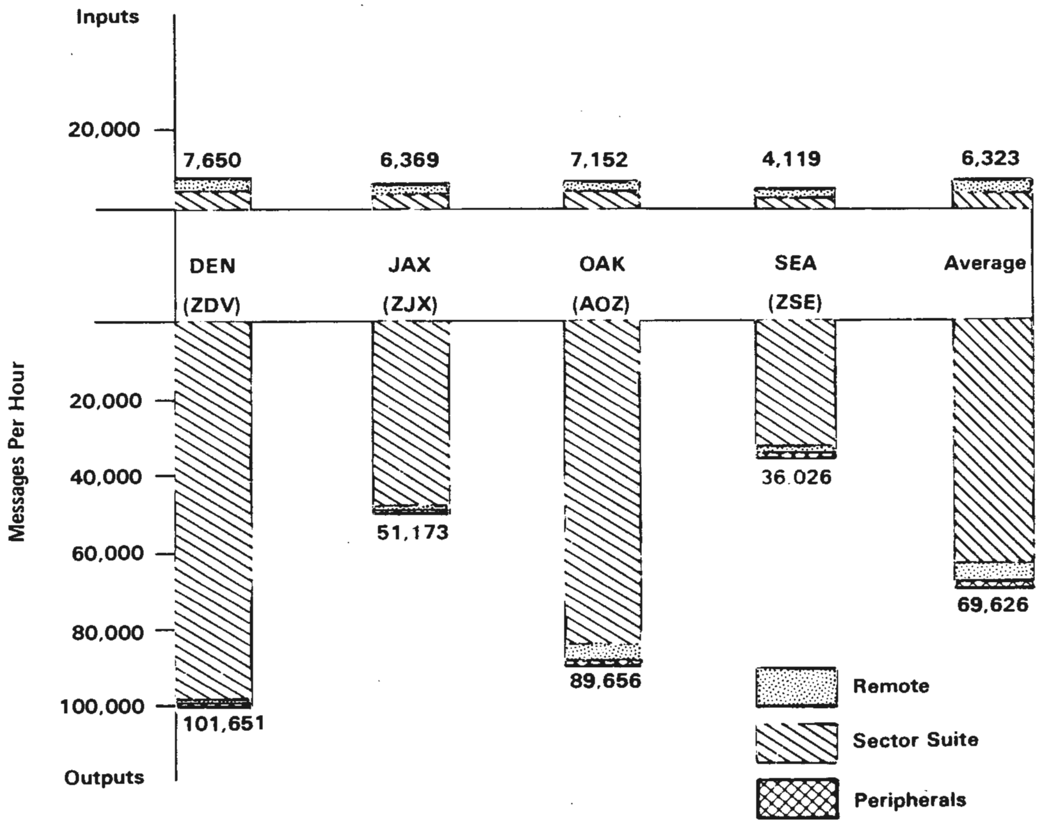


Figure S-2. TOTAL NON-RADAR TRAFFIC

facilities. No apparent correlations were evident in the data analyzed between computer I/O traffic and other parameters such as aircraft controlled, number of sectors, and date of data collection. Communications with peripheral devices and the sector suite were not studied in detail.

The traffic rates for all remote communications (both radar and non-radar) were normalized to obtain estimated average and peak messages per hour per link. Peak message rates per link were summed over the appropriate number of links for each port type in the hypothetical "minimum," "typical," and "maximum" ARTCC configurations. Table S-4 shows the results of these calculations. On the basis of sheer volume the incoming radar data messages overwhelm all other remote I/O traffic by at least a factor of 100:1. Between 80 and 90 percent of the non-radar remote message traffic is routed through the NAS and ARTS port types.

Table S-4. PEAK REMOTE ATC-RELATED TRAFFIC BY PORT TYPE (MESSAGES PER HOUR)

Port Type	Minimum Site				Typical Site				Maximum Site			
	Input		Output		Input		Output		Input		Output	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
NAS	1,358	0.1	1,197	38.0	3,397	0.1	2,996	34.5	4,750	0.1	4,193	27.4
ARTS	1,426	0.1	1,396	44.4	4,274	0.2	4,189	48.2	8,547	0.3	8,379	54.7
FDEP	168	0.01	419	13.3	540	0.01	1,337	15.4	1,014	0.01	2,508	16.4
TTY	261	0.01	135	4.3	298	0.01	169	1.9	396	0.01	236	1.5
ARSR	1,713,439	99.8	--	--	2,447,770	99.7	--	--	3,182,101	99.5	--	--
Subtotal	1,716,652		3,147		2,456,279		8,691		3,196.808		15,316	
Percent of Total		99.8		0.2		99.6		0.4		99.5		0.5
Total	1,719,799				2,464,970				3,212,124			

A similar analysis, in which the I/O traffic loading of the individual message types was summed by message type into functional categories according to Tables S-1 through S-3, yielded the distribution of total center-wide remote traffic for each hypothetical ARTCC by functional category, as presented in Table S-5. The overwhelming dominance of the radar input traffic is clearly evident in this table also, since the surveillance category is composed entirely of radar input message traffic. The miscellaneous category accounts for about 75 percent of the total non-radar remote traffic volume -- indicating that further refinement of the functional categories is required. Note that all the "Uncategorized" messages, messages for which adequate identifiers and descriptions could not be found, account for less than 3 percent of the total non-radar traffic.

Table S-5. PEAK REMOTE ATC-RELATED TRAFFIC BY FUNCTIONAL CATEGORY (MESSAGES PER HOUR)						
Category	Minimum Site		Typical Site		Maximum Site	
	Input	Output	Input	Output	Input	Output
Surveillance	1,713,439	--	2,447,770	--	3,182,101	--
Flight Plan	506	636	1,229	1,841	2,084	3,301
Weather	123	20	154	64	215	120
Traffic Flow	56	36	141	91	197	127
Miscellaneous	2,442	2,387	6,745	6,478	11,744	11,360
Uncategorized	86	68	240	217	467	408
Subtotal	1,716,652	3,147	2,456,279	8,691	3,196,808	15,316
Total	1,719,799		2,464,970		3,212,124	

This fact indicates that in this effort the DART program is a reliable tool for the analysis of computer I/O loading. Estimates of average and peak link utilizations were derived from the traffic statistics extracted from the DART and QARS printouts, estimated message lengths based on the message index, and published data rates for the various port types. The results of these calculations are presented in Table S-6.

The statistics presented in this report are based on several snapshots of the NAS system. The snapshots may or may not be fully representative of the 9020's operating environment. Certainly enough variation (three to one) has been noted among the various facilities' non-radar communications traffic patterns to cause one to wonder about the homogeneity of the NAS computer population geographically and temporally. As a minimum, additional non-radar statistics already available from other centers should be reduced, analyzed, and compared to the results of this study.

The radar traffic statistics are based on a miniscule sample (i.e., four minutes), which cannot be readily correlated with the non-radar statistics. This four-minute measurement interval provides a low degree of confidence that peak loading periods are being examined and cannot possibly account for seasonal and daily variations.

The information contained in the DART I/O Summary and Log outputs is insufficient to establish a correlation of non-radar I/O loading with aircraft movements. Such a correlation would help determine

Table S-6. LINK UTILIZATIONS					
Port Type	Average/Peak (Messages per Hour per Link)	Average Message Length (Characters)	Approximate Data Rate (Characters per Second)	Message Duration (Seconds)	Average/Peak Link Utilization (Percentage)
ARSR Input	117,600/ 244,800	90*	7,200.0**	.04	36/67
NAS Input	366/750	83	240.0	.35	3.5/7.2
Output	324/665	88	240.0	.37	3.3/6.8
ARTS Input	491/1,505	83	240.0	.35	4.7/14.5
Output	487/1,402	80	240.0	.33	4.5/13.0
FDEP Input	11/44	35	8.3	4.20	1.3/5.1
Output	33/99	31	8.3	3.72	3.9/11.6
TTY Input	33/76	55	10.0	5.50	5.0/11.6
Output	20/36	32	10.0	3.20	1.8/3.2

*Bits
**Total bits per second over three parallel 2,400 bps lines

future requirements of the 9020R. Further research is necessary to determine (1) what data sources exist that are accurate and applicable and (2) what new data-gathering efforts are possible and practical in correlating aircraft traffic with the message traffic on the basis of message type or functional category.

The NAS-MD documentation exhibits a number of inadequacies and inconsistencies. Message types with multiple names, multiple IDs, or both are common. Descriptions of message functions are often incomplete. The message data flow (i.e., the interaction of a given message with others) is presented in an unsystematic and frequently incomplete manner. Cross-correlation of documentation is difficult. The NAS-MD documentation must be updated, corrected, and supplemented to remove the present impediments to the design of the 9020R.

CONTENTS

CONTENTS (continued)

CONTENTS (continued)

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

The increasing use of automation in the en-route air traffic control (ATC) environment during the past two decades has increased demands on the computer and its associated data communications networks dramatically. The introduction of additional automation requirements into this environment may become a major driving force in the design and specification of a replacement computer and its associated data networks. However, statistics describing traffic flow into or out of the 9020 ATC computers are not readily available and are not organized in a format suitable for use by the designer of the 9020 replacement computer (9020R). Therefore the FAA needs to characterize present data flow and establish a data flow baseline to be used during analyses of future computer requirements.

1.2 STUDY OBJECTIVE

The objective of this study is to characterize present data flow into and out of the 9020 computer. To achieve this objective four major subtasks must be accomplished:

- Preparation of a detailed message index that will provide a structured compilation of all messages that the 9020 computer can process today
- Development of 9020 input/output (I/O) traffic estimates from available statistics to provide a characterization of today's communications requirements for the 9020 computer
- Evaluation of the accuracy of these traffic estimates and assessment of the effect of traffic estimate errors on 9020R I/O requirements. This assessment will also indicate what additional information is needed to specify the replacement system adequately.
- Preparation of a verification plan for reducing traffic estimate errors to an acceptable level

1.3 SCOPE

This study identifies and characterizes the traffic patterns of operational external messages received from or transmitted to locations outside the 9020 computer (e.g., radar sites, other centers, and Automated Radar Terminal System [ARTS] facilities). Internal communications (e.g., messages and flight plans from or to controller or supervisory positions, messages between the 9020 complex and air route traffic control center [ARTCC] local I/O devices such as tape drives, printers, and system console) are not included in this study. Operational messages include all communications related to ATC activities but not system control or status messages or sense-line communications. Unique adaptations such as the En-Route ARTS (EARTS) at Los Angeles and planned future National Air Space (NAS) enhancements such as ARTS II are outside the scope of this study.

No new traffic data were collected in this study. The data flow analyses used information sources currently available, such as existing reports, statistics previously obtained from the 9020 computer itself, FAA 9020 configuration management documents, etc., to calculate data flow patterns. If traffic statistics were unavailable, data flow was estimated by correlation with other known ATC functions.

1.4 TECHNICAL APPROACH

A comprehensive message index was compiled from available FAA documentation. For the most part, this message index was extracted from NAS-MD-311 for inputs, NAS-MD-314 for local outputs, and NAS-MD-315 for remote outputs. Additional references, such as NAS-MD-320 (Radar Data Processing) and NAS-MD-651 (NAS-ARTS Communications), were also consulted for cross-correlation and for additional information. Once the message index was assembled, communications traffic statistics were extracted from the System Analysis and Recording (SAR) tapes previously produced during presumed peak periods at the Denver, Jacksonville, Oakland, and Seattle ARTCCs. Since these SAR tapes did not provide any statistics for incoming radar messages, Quick Analysis of Radar Sites (QARS) reports obtained from the Cleveland ARTCC provided the basis for estimating incoming radar message activity. The raw statistics thus obtained from SAR tapes and QARS reports were matched with the message index previously prepared, and aggregated, as appropriate, to develop the traffic statistics presented in this report.

1.5 ORGANIZATION OF THE REPORT

The remainder of this report is divided into four chapters. Chapter Two contains a functional description of the 9020 computer from an I/O perspective, a description of the detailed procedures used to compile the message index, and a summary description of the content and format of that index. Chapter Three contains a description of the sources of 9020 I/O statistics and a summary of those traffic statistics. Chapter Four contains an evaluation of the effect of remote I/O traffic estimate errors on 9020R. Chapter Five contains a recommended verification plan for refinement of the traffic estimates in this report.

Three appendixes are included. Appendix A lists some of the differences between the 9020 message index, as documented in NAS-MDs, and the DART Users' Guide. Appendix B contains more detailed message traffic statistics, from which the tables in the body of the report were derived. Appendix C lists all the 9020 monitor message types not considered in this study or included in the message index. A fourth appendix, Appendix D, contained in a separate three-ring binder, is the 9020 message index.

CHAPTER TWO

9020 I/O MESSAGE INDEX

This chapter contains a functional description of the 9020 computer, a description of the procedures used to compile the message index, and a summary description of the content and format of that index.

2.1 9020 COMPUTER FUNCTIONAL DESCRIPTION

The 9020 computer supports controllers at an ARTCC by automatically performing selected air traffic control functions (e.g., track update and handoff). These computerized activities are accomplished through operator- and software-controlled application of the computer's data storage and access capabilities, computational and processing capabilities, and input and output communications capabilities. Figure 2-1 is a functional representation of the relationship of these various capabilities within the computer and between the computer and the external world.

The 9020D computer is depicted in Figure 2-1 as a circle (dark line). At the very heart of the computer are the storage and computing elements (cross-hatch in the center), which perform the computer's data manipulation, computation, and processing. The storage and computing elements interface with the I/O Control Elements (dotted area), which transfer data into and out of the storage and computing elements and direct the computer's communications with the external world to assure proper routing and timing of all processed and unprocessed data.

The I/O Control Elements (IOCE) of the 9020D computer are configured to consist of high-speed selector channels and low-speed multiplexer channels. The selector channels have a direct interface with the computer's primary mass storage devices (disk drives and tape drives) through appropriate control units and with the companion 9020E Display Channel Computer, which provides the radar display to and accepts inputs from the radar-controller positions in the ARTCC. The multiplexer channels handle all other communications with the external world via the system console and Peripheral Adapter Modules (PAMs).

The system console is the central monitoring and control position for the 9020D system. It is normally used to perform such functional operations associated with control of the computer as initial program loading, reconfiguration, and executive program control, and is addressable as an I/O device to display the computer's mode of operation, to generate audible alarms, and to display updated system element configurations.

PAMs provide the specific controls and interfaces that permit attachment of different I/O devices within the ARTCC or at remote locations. The controls and interfaces provided by a PAM are contained in two functionally related areas, referred to as PAM common and PAM adapters. PAM common (the inside ring of the PAM) services the IOCE/PAM interface and provides the addressing, priority, configuration, and other miscellaneous controls required to service the multiple adapters connected to the computer. The individual adapters provide all the bit/byte conversions, data controls, message initiation and termination, and electrical and mechanical interfaces necessary for connecting the 9020 computer to the external world.

The 9020 computer has interfaces with the external world through 21 different port types. Each type represents a group of connections between the computer and a group of facilities of the same type (e.g., Automated Radar Terminal System and ARTCC) and for purposes of this study has been assigned a unique numeric port type designator (e.g., 1, 2, 3). The actual number of connections (links, ports) to the 9020 computer depends on the number of facilities of each specific type serviced by the computer. These 21 types fall into three major groups (remote, sector suite, peripheral), as depicted in Figure 2-1 and described in the following subsections.

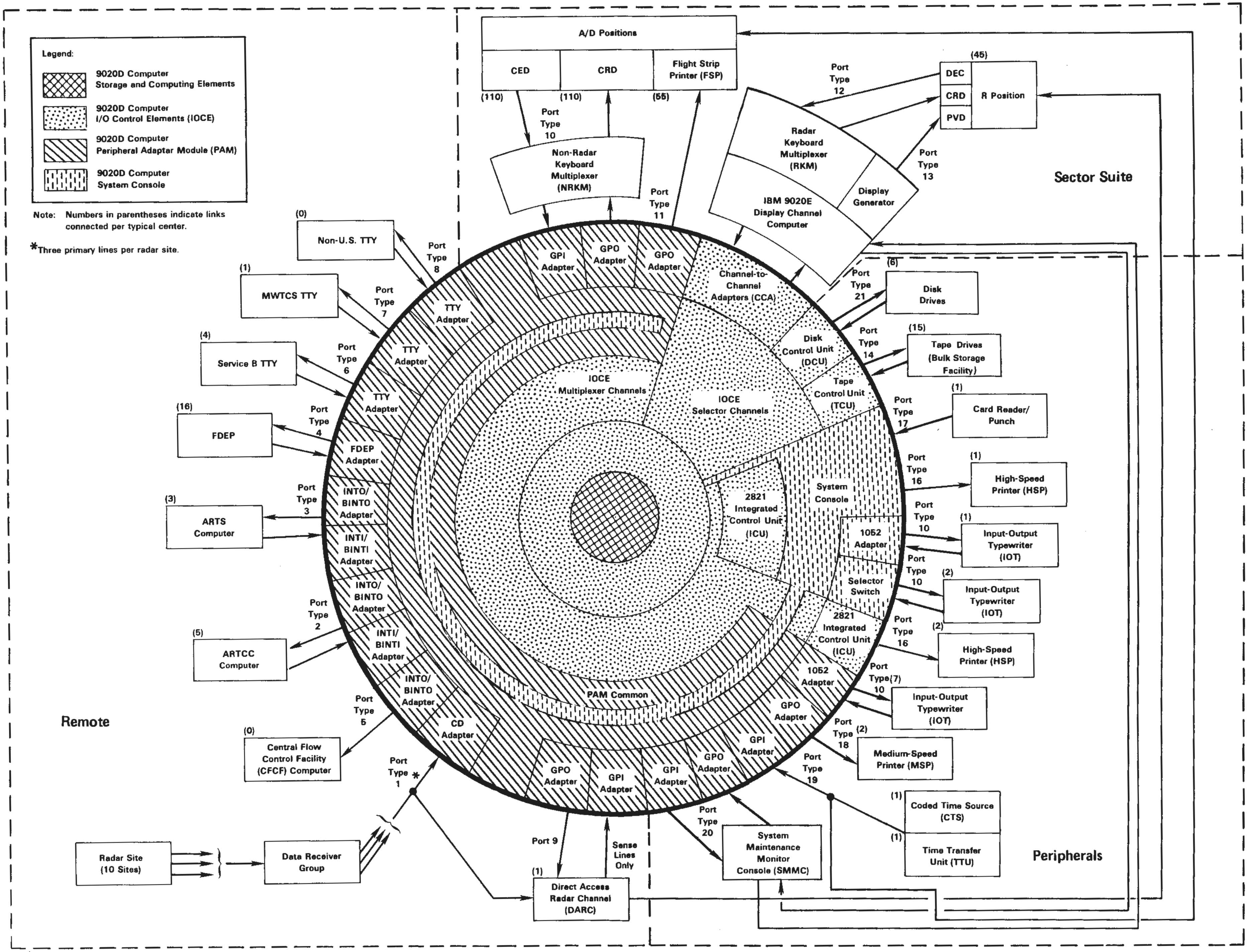
2.1.1 Remote

The 9020 computer communicates with remote facilities through port types 1 through 9. These ports are described in NAS-MD-315, except Port 1, which is described in NAS-MD-320.

Port Type 1 - ARSR. Air Route Surveillance Radars (ARSRs) input all the radar messages to the computer. No other types of messages are inputted from the ARSRs, nor are any messages sent to the radars. An ARTCC may have anywhere between 7 and 13 radar sites inputting data.

Port Type 2 - ARTCC. The computers of adjacent centers are linked by special two-way data communications circuits that transfer flight data messages, interfacility messages, and miscellaneous messages for the control of air traffic flow. The number of such links at an ARTCC ranges from 2 to 7 (excluding FAA Technical Center [FAATC], which is connected to 14 other 9020 computers).

Port Type 3 - ARTS. The ARTS computer provides automated terminal control to aircraft within its airspace. All the ARTS computers within the geographical area of responsibility of an ARTCC are linked by a special two-way data communications circuit to the 9020 computer. These links transfer flight data messages, interfacility messages, and miscellaneous messages required for the control of air traffic flow between the two facilities. The number of ARTS facilities connected to a 9020 computer ranges from 1 at Denver to 6 at Los Angeles and 14 at FAATC.



ARINC © 1982

Figure 2-1. 9020D I/O DATA SOURCES AND DESTINATIONS

Port Type 4 - FDEP. The 9020 computer is connected to remote Flight Data Entry and Printout (FDEP) terminals located at Flight Service Stations (FSSs), major local terminal control facilities (ARTS, TRACAB, TRACON), and airports. These FDEP terminals are used for inputting or modifying the computer's flight data base as well as for obtaining flight data from the computer. The number of such links at the 20 operational ARTCCs ranges from 6 to 30.

Port Type 5 - CFCF. Five 9020 computers in ARTCCs are connected directly to the 9020 computer in the national Central Flow Control Facility (CFCF) located in Jacksonville. Only these five computers, which act as relay centers for flow control information from the other centers to CFCF, are equipped with port type 5. All other computers transmit their flow control messages over port type 2 to relay 9020 computers located at Salt Lake City and New York ARTCCs. With the exception of those relay sites, there is only one-way (output) flow control communications traffic. Figure 2-2 is a representation of the central flow control (CFC) data communications network.

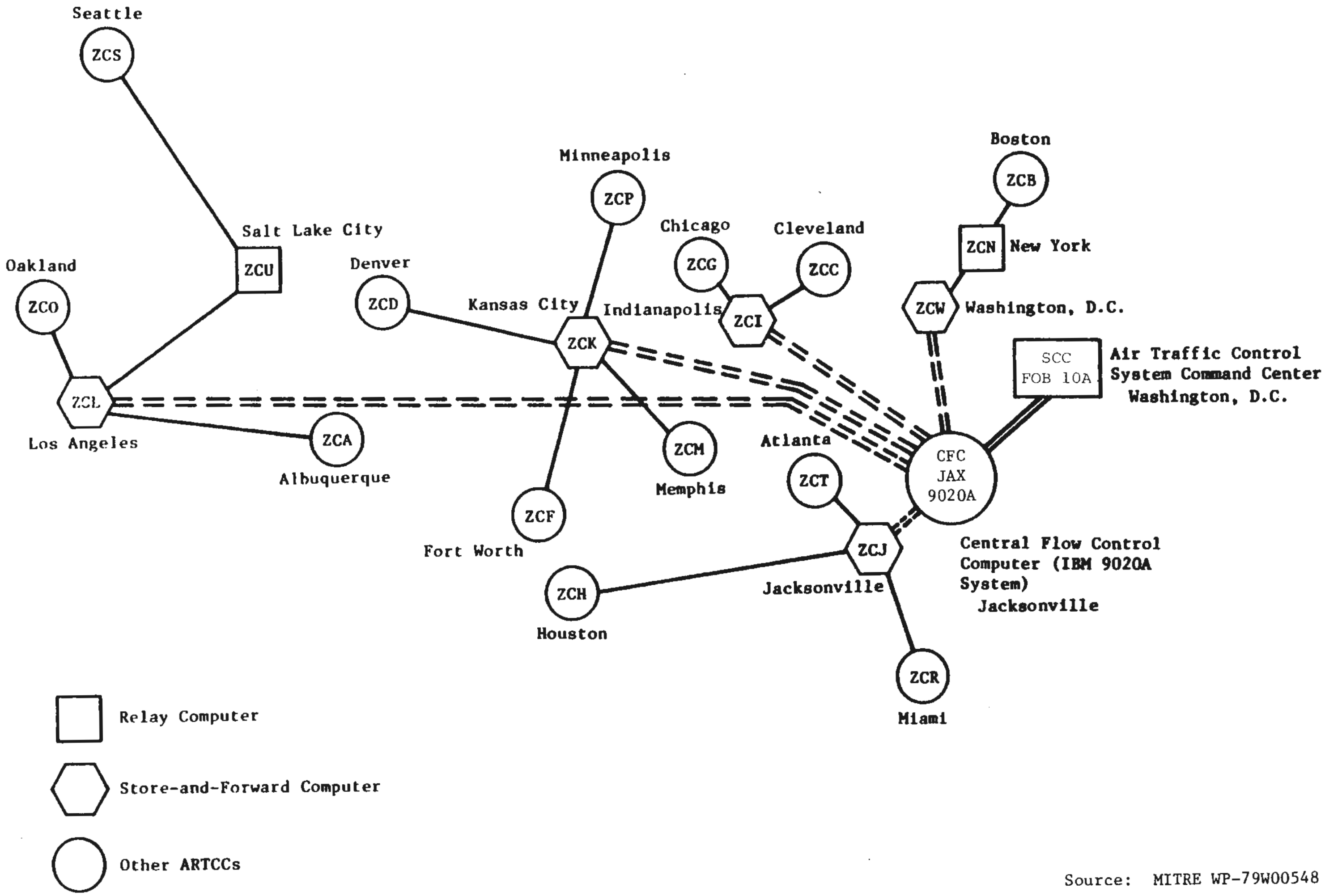
Port Types 6 and 7 - TTY. The 9020 computer is capable of either receiving or transmitting flight data, bulk flight data, weather-related information, or other miscellaneous messages over the FAA's Service B and Modernized Weather Teletype Communications System (MWTCS) teletype networks. The 20 operational ARTCCs have between three and six Service B terminations and only one or no MWTCS connection. (FAATC is equipped for 14 such connections combined in any proportion.)

Port Type 8 - Foreign TTY. A two-way communications port may be provided for transfer of flight data and other miscellaneous information between domestic ARTCCs and neighboring foreign (manual) ARTCCs/Air Traffic Services (ATS). This link is a teletype link similar to the Service B ports, but modified to satisfy international standards and protocols. However, none of the 20 operational ARTCCs are equipped with such a port today, since international communications are accomplished via Service B to AFTN and on to foreign destinations.

Port 9 - DARC. Although the 9020 DARC interface is physically located within the ARTCC, NAS-MD-315 classifies it as a "remote output." The 9020 computer provides a high-speed output to the Direct Access Radar Channel (DARC). If adapted to do so, the computer can send flight data to DARC, but this adaptation is not "turned on." Communications from DARC to the computer are accomplished via sense (e.g., DC control) lines, since there is no data path from DARC to the 9020. The FAA plans to install such a path within the next few years.

2.1.2 Sector Suite

The sector suite interfaces consist of all the ports that link the 9020 computer with the various input and output devices installed in the A, D, and R positions on the floor of the ARTCC. In particular, the sector suite consists of port types 10 through 13. Detailed analysis of sector suite I/O was outside the scope of this study and is not included in this report.



Source: MITRE WP-79W00548

Figure 2-2. CENTRAL FLOW CONTROL (CFC) INTERFACE DIAGRAM

Port Type 10 - CED/CRD. Each D and A sector controller position is provided with a computer entry device (CED) equipped with an alphanumeric keyboard and quick action keys to enter data into the computer. An associated cathode ray tube (Computer Readout Device [CRD]) also is provided for display of output messages. Flight data, track data, information requests, and miscellaneous messages may be processed at this port. Review of the control room floor plans for New York, Cleveland, and Washington indicates that one would typically expect about 55 A and 55 D positions per ARTCC.

Port Type 11 - Flight Strip Printer. Each D position is equipped with a Flight Strip Printer (FSP) for printing flight progress strips and non-flight-plan-related messages that overflow the response area of the CRD, certain routed messages, and messages rerouted from CRDs as a result of a hardware error or an unacknowledged flight plan information update message. The number of FSPs ranges from 28 to 61 at the 20 operational ARTCCs.

Port Type 12 - DEC/CRD. Each R position is equipped with special Data Entry Controls (DECs) that include an alphanumeric keyboard, quick action keys, trackball, and category function controls. This position is also equipped with a CRD for readout of alphanumeric data such as computer response messages to inputs within the ARTCC, requested display messages, flight plan information updates, and controller alerts. Review of the control room floor plans for Cleveland, New York, and Washington indicates that one would typically expect 45 R positions per ARTCC.

Port Type 13 - PVD. Each R position is equipped with a Plan View Display (PVD) for graphic presentation of radar data, display of the track data block including a position symbol, data block accent symbol, leader and velocity vectors. The PVD is also used to display departure, inbound hold, group suppression, and conflict alert lists, as well as lost radar data, current time, CA status, and routes.

2.1.3 Peripheral Devices

The 9020 computer is provided with numerous I/O ports within the ARTCC for initiating, maintaining, or terminating data processing, and inputting or outputting data. All the following I/O devices (port types 14 through 21) fall into the peripheral category. Detailed analysis of peripheral devices was outside the scope of this study and is not included in this report.

Port Type 14 - Tape Drives. The 9020 computer is equipped with numerous tape drives for inputting, storing, and recording data en masse. A particular tape drive, designated the "Bulk Storage Facility" (BSF), is used to load bulk flight plans stored on tape into computer memory. Tape drives are also used for other purposes associated with computer operations, but these activities are essentially internal in nature or off-line, non-operational tasks that are not applicable to input/output communications traffic analyses. Therefore, Port Type 14 will be synonymous with BSF for purposes of this study.

Port Type 15 - 1052 IOT. Each General A, Supervisory A, System Maintenance Monitor Console (SMMC), Watch Supervisor/Flow Controller, and CCC position is provided with an IBM 1052 printer/keyboard input/output typewriter (IOT). These devices can process all types of messages except track, radar, and interfacility messages.

Port Type 16 - High-Speed Printer (HSP). The high-speed printer is used to print flight plan summaries periodically, and to record certain inputs and outputs to and from and within the ARTCC. The flight plan summaries provide a basis from which manual operations may commence in case of a system failure.

Port Type 17 - Card Reader (CR). A card reader/puncher is available for entry of mission flight plans, supervisory messages, and some other miscellaneous messages.

Port Type 18 - Medium-Speed Printer (MSP). The computer is equipped with a medium-speed printer, located at the SMMC.

Port Type 19 - Clock. The 9020 computer receives its master clock signals from the coded time source or the time transfer unit. Although messages relevant to this study are not processed through this port, the port has been identified in Figure 2-1 for the sake of completeness.

Port Type 20 - System Maintenance Monitor Console (SMMC). The SMMC is used to display or change computer configuration, operating mode, and power status from the controller floor. The SMMC, included here only for the sake of completeness, is equipped with a printer and an IOT. SMMC input-output communications are included under Port Types 10 and 18 in the remainder of this report.

Port Type 21 - Disk Drives. The computer is equipped with numerous disk drives used for program and data storage. The activities associated with disk drives are internal to the computer, hence input and output communications with the drives are not addressed in this report.

2.1.4 Hypothetical ARTCC Configuration Baselines

The I/O traffic of the 9020 computer depends in part upon the connectivity configuration of the computer. Therefore, three hypothetical ARTCC configurations will be used in the remainder of this report for estimating total 9020 I/O traffic. These configurations are based upon an inventory of 9020 connectivities compiled by MITRE Corporation (MITRE Working Paper WP-80W00523, dated 25 July 1980). Only remote port types were considered in the classification process, and connectivities at FAATC were discarded. The "minimum ARTCC" is defined as a hypothetical center having the fewest remote links of each type found anywhere within the 20 operational centers. The "typical ARTCC" is defined as a hypothetical center having the median number of remote links of each type found within the 20 operational centers. The "maximum ARTCC" is defined as the hypothetical center having the most remote links of each type found anywhere within the 20 operational centers. The configuration of each of these hypothetical centers is listed in Table 2-1.

Table 2-1. CONFIGURATION OF HYPOTHETICAL CENTERS							
Facility Size	Number of Links by Port Types						
	ARSR	NAS	ARTS	FDEP	CFCF	TTY	DARC
Minimum ARTCC	7	2	1	5	0	4	1
Typical ARTCC	10	5	3	16	0	5	1
Maximum ARTCC	13	7	6	30	1	7	1

2.2 FUNCTIONAL MESSAGE CATEGORIZATION

As a result of detailed search of the NAS-MD documentation, 338 different 9020 computer input and output message types with various names, 9020 IDs, formats, functions, and input and output paths have been organized in a message index divided into 13 functional categories (based on the NAS-MDs) representative of the types of tasks the 9020 computer performs. Each message type has been included in one of these categories.

The primary reference for the functional categorization process is NAS-MD-311, which organizes the input message types by functions. Initial categories were established according to the functions defined by NAS-MD-311. Since the output message types in the NAS-MDs (primarily NAS-MD-314 and -315) are categorized not by function but rather by port, output message types were correlated and categorized with the input message types that triggered them. Output message types that did not correlate well were included in new functional categories derived from the output functions or other relevant NAS-MD documentation. If no NAS-MD references could be used for guidance in categorizing a particular message type, the type was included in the category most closely representing the use of that type. The general scheme for categorizing the 9020 message types is shown in Table 2-2. Exact definitions of the contents of each category follow.

Category 1. Not Used.

Category 2. Flight Data Messages (Input and Output). These messages establish, update, or output the computer's flight data base. Messages may contain flight plans and related information, data concerning the progress or status of particular flights, or other supplementary information required in ATC activities. Flow control messages are not included in this category but fall into Category 15, "Miscellaneous."

Category 3. Track Messages (Input Only). These messages are used to control aircraft flight tracks and type of tracking used, and to transfer control from one sector to another. Track messages originate only from the sector suite and are therefore excluded from this report.

Table 2-2. GENERAL SCHEME FOR CATEGORIZING 9020 I/O MESSAGES			
	Functional Category	NAS-MD-311 Input References*	NAS-MD-314 Output References*
1	Not Used	--	--
2	Flight Data Messages (Input and Output)	• Chapter Two, "Flight Data Message"	• Par. 4.3 (FP-Related strips) • Computer outputs uniquely resulting from Category 2 inputs
3	Track Messages (Input Only)	• Chapter Three, "Track Control Message"	• Computer outputs uniquely resulting from Category 3 inputs
4	Interfacility Messages (Input and Output)	• Chapter Seven, "Intercenter and Interfacility Messages"	• Classified per NAS-MD-311 • Also see NAS-MD-315
5	Radar Messages (Input Only)	• Ref. NAS-MD-320	• No outputs
6	Bulk Storage File Maintenance Messages (BSF) (Input and Output)	• Chapter 10, "Bulk Storage File Maintenance Message"	• Computer outputs uniquely resulting from Category 6 inputs
7	Display Control Messages (Input Only)	• Chapter 4, "Display Control Action"	• No outputs
8	Information Request Messages (Input Only)	• Chapter 5, "Information Request Messages"	• No outputs (See Category 9)
9	Information Display Messages	• No inputs (See Category 8)	• Par. 2.2.4 (Requested displays) • Par. 2.3.4 (Requested display) • Par. 5.3 (Requested data) • Computer outputs uniquely resulting from Category 8 inputs
10	Not Used	--	--
11	Computer Display (Output Only)	• No inputs	• Par. 2.3.5 (Computer-initiated updates) • Par. 5.4 (Program-initiated messages)
12	Computer Response Messages (Output Only)	• Par. 1.7, "Computer Acknowledgments"	• Par. 2.2.3 (Computer response) • Par. 2.3.3 (Computer response) • Par. 5.2 (Computer response)
13	Supervisory Messages (Input and Output)	• Chapter Six, "Supervisory Messages"	• See NAS-MD-317 • Computer outputs uniquely resulting from Category 13 inputs
14	Dynamic Simulation (Input and Output)	• See NAS-MD-323	• See NAS-MD-323
15	Miscellaneous Messages (Input and Output)	• Chapter Eight, "Miscellaneous Input Messages" • Messages not falling into any above category	• Computer outputs uniquely resulting from Category 15 inputs • Messages not falling into any above category

* Within each category, bulleted items are listed in order of priority.

Category 4. Interfacility Messages (Input and Output). These messages are special response messages used exclusively in the two-way communications between 9020 computers and between 9020 and ARTS computers.

Category 5. Radar Messages (Input Only). These messages input radar data to the computer directly from the air route surveillance radars (ARSRs).

Category 6. Bulk Storage File (BSF) Maintenance Messages (Input and Output). These messages are used to establish, update, or output the bulk flight plan data base on a direct-access storage facility. The bulk flight plan data base contains only inactive prefiled and prestored (e.g., airline) flight plans. Each flight plan is transferred internally within the computer to the active flight data base upon activation. The bulk flight plan data base is loaded into the computer periodically from a tape drive. Since all activities regarding the BSF either are computer internal or utilize only a peripheral device (i.e., tape drive), these messages are excluded from this report.

Category 7. Display Control Messages (Input Only). These messages are used to control the presence, absence, or arrangement of data on the Plan View Display (PVD) and the CRD at the various controller positions. These are strictly sector-suite messages and therefore are excluded from this report.

Category 8. Information Request Messages (Input Only). These messages are used by controllers and computer operators to request a display or printout of data from the established data base.

Category 9. Information Display Messages (Output Only). These messages are used to display information requested by an operator (see Category 8) either at the requesting I/O device or some other output device. Sometimes the computer will display ATC-related messages without prompting. These self-initiated messages are included under a separate category called "Computer Display." Messages concerned with display of system status, requested or not, are also excluded from this category and classified under the "Supervisory" group. The electronic mail capability of the computer (e.g., the general information message) is included in Category 15, "Miscellaneous." Information uniquely displayed in response to Category 2 inputs is classified under Category 2.

Category 10. Not Used.

Category 11. Computer Display (Output Only). All ATC-related, computer-initiated messages that are not clearly flight data, track, computer response or dynamic simulation messages that are outputted to a man-machine interface (e.g., IOT, CRD) are included in this category. Messages related to computer system operation (e.g., supervisory messages) are excluded from this category. Messages that may output either as information display responses to an information request or as computer-initiated outputs are not included in this category but are grouped under information display. Examples of typical messages in this category are computer update messages such as controller alerts or advisories. These messages involve only the sector suite and the peripheral devices or both and therefore are excluded from this study.

Category 12. Computer Response Messages (Output Only). These messages are transmitted by the computer to an I/O device to acknowledge an input command, request, or message receipt (e.g., from FDEP) and to notify the operator or controller of the action taken by the computer as a result of that initial output.

Category 13. Supervisory Messages (Input and Output). These messages provide system control and establish, modify, or display the operating environment and status of the program, the computer, or any of its associated I/O devices. All message types except messages designated RB and GO3 in the message index are excluded from this study.

Category 14. Dynamic Simulation (Input and Output). These messages are associated with the function keys on the radar controller console. These messages are associated with the determination of the status of the ATC system and therefore are excluded from this study.

Category 15. Miscellaneous Messages (Input and Output). All messages that do not fall into one of the above categories are included in this one. For the most part these messages are used to transmit non-flight-related data, weather data, flow control data, and information of a general nature between the computer and its various inputs and outputs.

These categories represent one way (based on NAS-MDs) to organize the 9020 message index. Another scheme of categorization, using eight functional groups, has been presented in the ATC Advanced Computer System Level Specification (FAA-ER-130-003) released in draft form in August 1981. Since no functional definitions of these eight categories exist in the system level specification, a correlation was developed between the two approaches on a category-name basis. The correlation is shown in Table 2-3.

Some NAS-MD-derived categories map into the system specification categories on a one-to-one basis (e.g., Track to Track), and others correlate only partially (e.g., Miscellaneous to Traffic flow management). The weather map messages (5W1 or 5W2) are subjected to both surveillance and weather processing by the computer and could fall into either functional category; the surveillance category was chosen to indicate the function performed first. The "Track" and "Output control" categories of the system specification are composed of messages that are outside the scope of this study and have therefore been excluded. Similarly, other NAS-MD-derived categories (such as Dynamic simulation, Bulk storage, Supervisory, and Computer display) have also been mostly or totally excluded. The contents of the Data management category in the system specification are undefined and cannot be correlated with any of the NAS-MD-derived categories. Traffic statistics in the remainder of this report will be presented under the system specification categories of "Surveillance," "Flight plan," "Weather," "Traffic flow management," and "Miscellaneous."

2.3 9020 MESSAGE INDEX

A major task in this study was the development of a message index that identifies and describes each message type individually and uniquely. The NAS-MD documentation identifies many (but not all) input-output message types with a multiletter message type designator and in many instances uses the same designator for multiple message types or multiple designators for a single message type. Therefore the task first required the development of a unique 9020 identification (ID) scheme for all message types. Another set of similar (but not identical) designators is used in the 9020 DART program. Both designators are pertinent to this study and have been retained. A description of each ID type follows.

Table 2-3. COMPARISON OF FUNCTIONAL CATEGORIES

System Specification Category*	Corresponding NAS-MD-Derived Category	Exceptions and Limitations**
Surveillance	5 - Radar	--
	14 - Dynamic simulation	--
Track	3 - Track	--
Flight Plan	2 - Flight data	--
	8 - Information request	Except weather messages UR, WR1, WR2
	9 - Information display	Except weather messages 9WR, 9WX1, 9WX2, 9WX3, 9AS1, 9AS2, 9AS3
Weather	8 - Information request	Only messages WR1, WR2, UR
	9 - Information display	Only messages 9WR, 9WX1, 9WX2, 9WX3, 9AS1, 9AS2, 9AS3
	15 - Miscellaneous	Only messages UW, WX, AS, 15WR
Output Control	7 - Display control	--
Traffic Flow Management	15 - Miscellaneous	Only messages DZ1, DZ2, FZ1, FZ2, RZ1, RZ2
Miscellaneous	4 - Interfacility	--
	6 - Bulk storage	--
	11 - Computer display	--
	12 - Computer response	--
	13 - Supervisory	--
	15 - Miscellaneous	Except weather messages AS, 15WR, WX, UW and flow control messages DZ1, DZ2, FZ1, FZ2, RZ1, RZ2
Data Management	?	

*Ref. FAA-ER-130-003, dtd August 1981
**See ARINC Research Message Index for details of specifically identified messages (e.g., UR, WR1).

2.3.1 9020 ID

The 9020 ID is obtained, for the most part, from relevant NAS-MD documentation. The designator typically consists of two letters, although a few messages such as International Civil Aviation Organization (ICAO) flight plan and departure messages and special output printouts have three- or four-letter designators. These message designators are under FAA configuration control and in many instances are unique to a particular message. In such situations the NAS-MD designator is retained without alteration.

In some instances, however, the FAA may have assigned a single message designator to several different messages. These messages are distinguished for purposes of this study by a numeral following the designator. For example, the "assigned altitude" input message designated by the FAA as "QT" is called "QT1," and the "coast track" input message, also designated by the FAA as "QT," is called "QT2."

Some messages with multiple sources or destinations also may be assigned two or more different message designators in the NAS-MDs. Selection of specific designators at a site is discretionary and depends on local adaptation. All the designators associated with each message type are maintained individually throughout the remainder of this study, as appropriate. For example, both the "FR" and "QF" designators are maintained for the "flight plan readout request" input message.

When the NAS-MDs do not assign any message designators, as in the case of radar messages, a unique message identifier has been selected for each message. This identifier consists of a numeral followed by two or three letters, such as 2RP, 2RB, 2PS. For convenience in locating the message descriptors, the numeral corresponds to the functional category of the message per Table 2-2. This three-step procedure allows traceability and uniqueness in isolating particular message types.

2.3.2 DART ID

The 9020 computer NAS Operational Support System (NOSS) can provide statistics on the computer's I/O traffic. NASP-9247-16 describes the DART program used to obtain these traffic statistics. Unfortunately, the message identifiers in that program are not necessarily identical to those maintained by the NAS-MDs. The DART program is also not maintained at the strict level of configuration management found in the NAS-MDs. Furthermore, not all the message identifiers used in the program are described in the user's manual, and the program frequently groups several different message types under a single, new designator. Whenever correlation between the NAS-MDs (9020 ID) and the DART ID was achievable through similarity of message name or message designator, the DART ID was separately recorded in the message index. In all other instances, the DART ID remained blank. In addition, a significant number of DART IDs listed in the DART User's Manual remain uncorrelatable with the NAS-MDs. These DART IDs are presented in Appendix A.

2.3.3 Message Descriptor Forms

All the raw data of the 9020 message index are contained in message descriptor tables of the form shown in Figure 2-3. The following information is included in each message type:

- Functional message category (number and name) (See Table 2-2)
- Unique message name
- Input or output port type routings (See Section 2.1)
- Message ID, 9020 nomenclature (See Section 2.3.1)
- Message ID, DART nomenclature (See Section 2.3.2)
- Functional description, detailing the purpose of the message type
- Format, including the various field types (corresponding to NAS-MD-311, Appendix E), their length in characters, the total range of characters contained in the message type, and the communication data rate (if available)
- Conversation, detailing whether any messages caused this one to occur (Q = Query) or whether any messages or actions result from the receipt of this message (R = Response)
- Trigger event, indicating any events (not messages) that caused the initiation of this message
- Traffic parameters, including average character count, average duration, peak, and average number of messages per hour (extracted from the chosen sample period)
- Notes, including miscellaneous comments and, if a message is not to be included in this study, a statement to that effect
- References, including NAS-MD documents that reference this particular message
- An asterisk if the message or port is excluded from this study

Typically, one form has been prepared for each message type for each port through which the message may enter or exit the 9020 computer. However, if the descriptor forms were found sufficiently similar for several ports or messages, only a single form was completed describing the integrated ports or message IDs as specifically noted on the form. The total 9020 message index comprises such forms in a separate loose-leaf notebook organized by functional category, I/O, and alphabetically by 9020 ID. For ease of differentiation between input and output message types and for easy separation of master forms from photocopied forms, inputs are printed on blue paper and outputs on tan paper.

Message Category: 2 - Flight Data
Message: Amendment
Input/Output Port: 2 - ARTCC

9020 ID: AM1
DART ID: AM

Functional Description:

This is a second-order flight data message and is used to amend field data within a previously transmitted flight plan message.

Format:

Total characters: 13-39
Data rate:

Port	Field	Characters
	00	4
	01	2
	02	6-11
	12	1-2
	(17)	1-20

Conversation:

Query/Response	Message	Characters	Port
R	RS for all sectors bypassed as a result of amendment.		
R	New flight strips at all affected sectors.		
R	Appropriate update messages at all affected sectors.		
R	Flight Plan Data Print-out to high speed printer (See NAS-MD-314).		
R	Amendment (AM2) to any affected adjacent NAS (See NAS-MD-311, Par. 2.1.5, 3.11).		
R	DA2	17	Source
R	DR2	19	Source
R	DX2	13	Source

Trigger Event:

1. A change to the original flight plan message is required.
2. Entry of the departure message.
3. Hold is XLL'd or terminated.
4. LTA change $\geq$ posted time update interval (PTUI) minutes.

Traffic Parameters:

Ave. Char. count:
Ave. Duration:
Peak Period:
Peak Traffic: 97 "msgs./hr."
Ave. Traffic: 57 "msgs./hr."

Notes:

This message is valid only from the originator (NAS) of the first-order message.

References:

NAS-MD-	Paragraph
315	2.2.2
311	2.1

Figure 2-3. SAMPLE MESSAGE DESCRIPTOR FORM

2.3.4 Computerized Data Base

Portions of the information contained on each of the message descriptor forms also are resident in a computerized data base that consists of the following:

- Input or output file (I/O)
- Functional message category (number) (See Table 2-2)
- Message name
- Message ID, 9020 nomenclature (See Section 2.3.1)
- Message ID, DART nomenclature (See Section 2.3.2)
- Input or output port type routings (See Section 2.1)
- NAS-MD documentation reference paragraph (e.g., NAS-MD-311, Paragraph 3.2.1)
- Messages or I/O port types not included in this study are noted by an asterisk.

This computerized data base may be sorted and displayed according to various formats listed in Table 2-4. Examples of Sort C, with references and port types displayed, are presented in Figure 2-4 and Figure 2-5. A complete set of these two sorts portrays all the information in the computer data base.

Table 2-4. AVAILABLE INDEX SORTS

Sort	First Parameter	Second Parameter	Third Parameter	Remarks
A	I/O	Category	Name*	With ports displayed
B	I/O	Name*		
C	I/O	Category	9020 ID	
D	I/O	9020 ID		
E	I/O	Port		
F	I/O	DART ID		
G	I/O	Category	Name*	With references displayed
H	I/O	Reference 1	Alphanumeric	
I	I/O	Reference 2	Alphanumeric	
J	I/O	Reference 3	Alphanumeric	
K	I/O	Reference 4	Alphanumeric	

*Listed alphabetically

SORTED LISTING BY CATEGORY AND ID 13:38 11/25/81 ID

I/O	CATEGORY:	NAME		9020	DART	REFERENCE 1	REFERENCE 2	REFERENCE 3	REFERENCE 4
0	9	ALTITUDE LIMITS	*	9AL	ALTLM	314-2.2.4.3			
0	9	ALTIMETER SETTING PRINTOUT	*	9AS1	ALTPO	314-4.2.2.4	314-5.3.2		
0	9	ALTIMETER SETTING	*	9AS2		314-2.3.4.1			
0	9	ALTIMETER SETTING	*	9AS3		314-2.2.4.2			
0	9	PERMANENT ECHO VERIFICATION PRINTOUT	*	9EV		314-5.3.26			
0	9	AUTO HANDOFF INHIBIT LIST	*	9HI	HDOIN	314-2.2.4.4			
0	9	PVD CODE SELECTION LIST	*	9PV	CDSEL	314-2.2.4.1			
0	9	RADAR SORT BOX READOUT	*	9RB	RSBRO	314-2.2.4.6			
0	9	ROUTE READOUT	*	9RR	RTERO	314-2.3.4.4	314-5.3.7		
0	9	TRACKBALL COORDINATES READOUT	*	9TC	TBCRO	314-2.2.4.7			
0	9	WIND READOUT	*	9WR	WNDRO	314-2.3.4.6	314-5.3.6		
0	9	WEATHER	*	9WX1		314-2.3.4.5	314-4.2.2.6	314-5.3.2.1	311-5.9
0	9	REQUESTED WMSC WEATHER	*	9WX2		311-5.9.6	314-5.3.21		
0	9	WEATHER UPDATE	*	9WX3		314-2.3.4.5	311-8.1.5		
0	9	ANALYSIS UNDERWAY REPORT	*	AURP	AURP	314-5.3.17	314-7.2		
0	9	BEACON REGISTRATION PRINTOUT	*	BRPO	BERP	314-5.3.14	314-7.2		
0	9	FLIGHT PLAN READOUT		FR2	FPRDO	314-5.3.1	314-2.3.4.2	314-2.2.3.5	314-4.2.2.3
0	9	RADAR COLLIMATION PRINTOUT	*	RCPO	RCAP	314-5.3.15	314-7.2		
0	9	TRACK RECORDING STATUS REPORT	*	TRSR	TRSR	314-5.3.19	314-7.2		

Figure 2-4. EXAMPLE OF SORT C, REFERENCES DISPLAYED

SORTED LISTING BY CATEGORY AND ID 13:28 11/25/81 ID PORTS

I/O	CATEGORY:	NAME		9020	DART	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
0	9	ALTITUDE LIMITS	*	9AL	ALTLM												*						
0	9	ALTIMETER SETTING PRINTOUT	*	9AS1	ALTPO											X				X			
0	9	ALTIMETER SETTING	*	9AS2											D								
0	9	ALTIMETER SETTING	*	9AS3													X						
0	9	PERMANENT ECHO VERIFICATION PRINTOUT	*	9EV																X			
0	9	AUTO HANDOFF INHIBIT LIST	*	9HI	HDOIN												*						
0	9	PVD CODE SELECTION LIST	*	9PV	CDSEL												X						
0	9	RADAR SORT BOX READOUT	*	9RB	RSBRO												X						
0	9	ROUTE READOUT	*	9RR	RTERO										X					X			
0	9	TRACKBALL COORDINATES READOUT	*	9TC	TBCRO												X						
0	9	WIND READOUT	*	9WR	WNDRO										X					X			
0	9	WEATHER	*	9WX1											D	X				X			
0	9	REQUESTED WMSC WEATHER	*	9WX2											D	X				X			
0	9	WEATHER UPDATE	*	9WX3												X							
0	9	ANALYSIS UNDERWAY REPORT	*	AURP	AURP															X			X
0	9	BEACON REGISTRATION PRINTOUT	*	BRPO	BERP															X			X
0	9	FLIGHT PLAN READOUT		FR2	FPRDO				X						X	X	*			X			
0	9	RADAR COLLIMATION PRINTOUT	*	RCPO	RCAP															X			X
0	9	TRACK RECORDING STATUS REPORT	*	TRSR	TRSR															X			X
						1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18

Figure 2-5. EXAMPLE OF SORT C, PORT TYPES DISPLAYED

Each "X" under a particular port type indicates that the message type may go to or come from that particular device. A "D" under port 11 (Local CED/CRD device) indicates that the message may be routed to or from the D controller position only. An asterisk next to the 9020 ID indicates that the message type has been excluded from this study. An asterisk under a port type indicates that only occurrences of a particular message type routed to or from the asterisked port are excluded from this study.

2.4 9020 MESSAGE INDEX STATISTICS

The search of the NAS-MD documentation has resulted in the definition of 156 unique input and 182 unique output message types. Their distribution across the functional categories, illustrated in Table 2-5, is dominated by the "Miscellaneous" category (56 percent) and the "Flight plan" category (22 percent). Any of the message types (input or output) in each category may be routed to or from the sector suite, peripherals, or remote facilities. Since the sector suite and the peripherals are outside the scope of this study, only a portion of the total possible message types is considered here. Table 2-5 reflects this limited number of message types. Each of the 77 uncategorized DART message types that could not be correlated with message types found in the NAS-MDs could be within the scope of this study and therefore was considered for further analysis.

Table 2-5. CATEGORY STATISTICS

Functional Category	NAS Input Message Types		NAS Output Message Types	
	Total Possible	Considered*	Total Possible	Considered*
Surveillance	26	16	2	0
Track	8	0	0	0
Flight Plan	34	16	41	16
Weather	6	6	8	5
Traffic Flow Management	3	3	3	3
Miscellaneous	62	15	128	20
Output Control	17	0	0	0
Total Categorized Message Types	156	56	182	44
Total Uncategorized DART Message Types**	23	23	54	54

*Message types routed to and from remote facilities
**Identity cannot be correlated with message types found in NAS-MDs; see Appendix A.

CHAPTER THREE

9020 I/O MESSAGE TRAFFIC

This chapter contains a description of the traffic data sources for 9020 I/O traffic statistics and of the derivation procedures used in data analyses. 9020 I/O traffic estimates also are included.

3.1 EXISTING TOOLS FOR COLLECTING TRAFFIC STATISTICS

Two primary tools are available to the would-be collector of 9020 I/O traffic statistics. The Data Analysis and Reduction Tool (DART) program uses SAR tapes prepared by the computers at each ARTCC to provide a variety of statistics on the computer's operation, including I/O traffic for some non-radar message types. The QARS program analyzes the radar data received by the NAS computer and provides some aggregated statistics on that incoming radar traffic.

3.1.1 DART Program

Each 9020 computer produces Systems Analysis Recording (SAR) tapes of all its activities, including input and output messages received and transmitted. These tapes then can be processed at FAATC with the Data Analysis and Reduction Tool of the NAS Operational Support System (NOSS). The NOSS system, including the DART program, was developed to provide an evaluation tool for program development, testing, and change-over. NOSS can collect and analyze air traffic statistics and maintenance statistics and can produce detailed ATC operational information for use in proceedings and investigations. The DART program in particular can provide fourteen different types of reports, of which the Log and I/O Summary reports are of primary interest to this study. The Log program prints the time and the content of each message. The I/O Summary program sorts and sums messages in different ways to provide summary statistics by port, message type, user, etc. Neither the Log nor the I/O Summary program is designed to provide statistics on all possible message types, although the former provides more detailed coverage. All message types that the program does not recognize are lumped into an "Undefined" category, so that the total proportion of unrecognized messages can be estimated.

It would be helpful to verify message length estimates for each identified message type in the 9020 message index. Although the total message length information is available from each SAR tape record, the DART program used during this study did not have the capability to extract the length parameter. The DART program, however, has been modified recently to provide average message length statistics on all messages routed to and from remote ports and could be used in the future to obtain such information.

It also may be desirable to understand the relationship between NAS I/O traffic patterns and aircraft traffic. The Aircraft option of the DART I/O Summary program can provide a report of the number of aircraft controlled by each sector. This statistic is determined by totalling the number of aircraft IDs input from or output to the A, D, and R positions in each sector. However, if one wanted to determine the I/O traffic generated per aircraft controlled in the sector, one would have to manually extract and correlate messages with aircraft IDs because the Log program only has the capacity to extract specific messages related to specific aircraft, without maintaining any cumulative statistics. Operation and use of the DART program is described in NASP-9247-16. Outputs may be obtained in printed form or on computer tape.

3.1.2 QARS

The Quick Analysis of Radar Sites (QARS) program is used locally at each ARTCC to monitor the performance of the center's radar systems. QARS is a local adaptation-controlled program that provides real-time, on-line monitoring and analysis of radar site performance. The program consists of the radar data analysis routine and the Common Digitizer (CD) quality precheck routine. The latter is particularly useful in gathering statistics on incoming radar messages. The CD quality precheck routine prints a continuous scan-to-scan summary of the following for each radar site for a specified interval:

- Total beacon, search, map, and status messages per scan
- Total messages received and number of erroneous messages detected
- Status of beacon and search real-time quality control (RTQC) messages
- Percentages of radar-reinforced beacon messages received

The QARS, however, cannot differentiate between the various map messages (fixed, sensitive, normal, weather #1, weather #2) and it does not report the number of strobe messages (search or beacon) received by the computer, typically as a result of jamming, or excessive fruit combined with heavy aircraft traffic. The QARS report is available only in printed form, as described in the QARS user's manual (FAS-4306N-4).

3.2 STATISTICS AVAILABLE AND USED

3.2.1 DART Data

Approximately a year ago the FAA prepared SAR tapes for 16 centers; these tapes are listed in Table 3-1 and reflect peak period data. They are still available for analysis using the DART program, and each tape covers a period of approximately two hours. DART I/O Summary printouts were obtained for the Denver, Jacksonville, Oakland, and Seattle ARTCCs. In addition, a Log printout was obtained for the Jacksonville center. Six separate one-minute samples of the Log results were selected, key-punched onto cards, and computer-processed to obtain statistics on the minute-by-minute variations of 9020 I/O traffic. All non-radar traffic statistics presented in this report are based upon a manual extraction from the I/O Summary reports or the computerized analysis of the Log report samples.

3.2.2 QARS Data

Every center routinely runs the QARS program at least daily to verify proper operation of the radar subsystem. These reports are discarded within one to two weeks after the QARS run is performed and consequently are difficult to obtain. However, two QARS printouts were obtained from the Cleveland ARTCC. The reports represent two samples of incoming radar data. Each sample, measured at about 9 A.M. on October 20 and 22, 1981, was two minutes in duration. The radar traffic statistics presented here reflect the reported message traffic converted to messages per hour and increased by 33-1/3% to compensate for the drop in aircraft traffic as a result of the controllers' job action.

3.3 9020 I/O TRAFFIC STATISTICS

The message index identified in Chapter Two contains a total of 338 possible I/O message types, of which only 100 are considered within the scope of this effort. Of these 100 message types (56 input and 44 output), only 54 were encountered during the sampled intervals, as presented in Table 3-2. These 54 message types represented each of the functional categories of interest (track and output control message types were not studied). Additionally, five DART message IDs that could not be correlated with NAS-MDs were encountered during the test intervals. The remainder of this section will present traffic statistics on these 59 message types (54 categorized plus 5 uncategorized): their frequency of occurrence, routing through port types, queueing and arrival patterns, and predictability of behavior.

3.3.1 Total Non-Radar Traffic

Figure 3-1 depicts the non-radar traffic volume obtained from the DART I/O summary printouts of the four sampled facilities. The remote

Table 3-1. DART DATA AVAILABLE				
Center	Number of SAR Tapes	Collected	Zulu Time	Local Time
Albuquerque (ZAB)	3	6/17/80	1504-1838	0904-1238
Atlanta (ZTL)	7	8/01/80	1858-2116	1458-1716
Boston (ZBW)*	1	7/16/80	2019-2234	1619-1834
Chicago (ZAU)	12	1/22/81	2251-0109	1651-1909
Cleveland (ZOB)	7	6/27/80	1927-2125	1527-1725
Denver (ZDV)	3	8/05/80	1741-1810	1141-1210
Ft. Worth (ZFW)	-	--	--	--
Houston (ZHU)	-	--	--	--
Indianapolis (ZID)	5	7/10/80	2113-2325	1613-1825
Jacksonville (ZJX)	1	6/25/80	1339-1602	0939-1202
Kansas City (ZKC)	5	7/08/80	1302-1509	0802-1009
Los Angeles (ZLA)	10	6/19/80 7/19/80	1653-1806 1807-1911	1053-1206 1207-1311
Memphis (ZME)	4	6/17/80	1310-1512	0810-1012
Miami (ZMA)	-	--	--	--
Minneapolis (ZMP)	4	6/19/80	1914-2124	1414-1624
New York (ZNY)	10	7/02/80	2002-2204	1602-1804
Oakland (ZOA)	2	10/24/80	1905-2245	1205-1345
Salt Lake (ZLC)	-	--	--	--
Seattle (ZSE)	1	8/18/80	1614-1931	0914-1231
Washington (ZDC)	5	7/23/80	1805-2024	1105-1324

*Tape defective in middle.

I/O traffic at these four facilities accounts for a relatively small portion (approximately 7%) of the total non-radar messages processed, because the output message activity to the sector suite (which is outside the scope of this study) swamps all other non-radar computer communications. The inputs from the remote facilities account for approximately 40% of all non-radar messages received by the computer. These remote inputs may have an importance far in excess of their volume, because the computer's processing and memory resources are allocated partially in response to the type and quantity of input messages received.

Table 3-2. CATEGORY STATISTICS

Functional Category	Input Message Types			Output Message Types		
	Total Possible	Considered	Actually Encountered	Total Possible	Considered	Actually Encountered
Surveillance	26	16	9	2	0	-
Track	8	0	-	0	0	-
Flight Plan	34	16	9	41	16	8
Weather	6	6	2	8	5	1
Traffic Flow Management	3	3	3	3	3	3
Miscellaneous	62	15	8	128	20	11
Output Control	17	0	-	0	0	-
Total	156	56	31	182	44	23
Total Uncategorized DART Message Types*	23	23	3	54	54	2

*DART IDs cannot be correlated with message types found in NAS-MDs; see Appendix A.

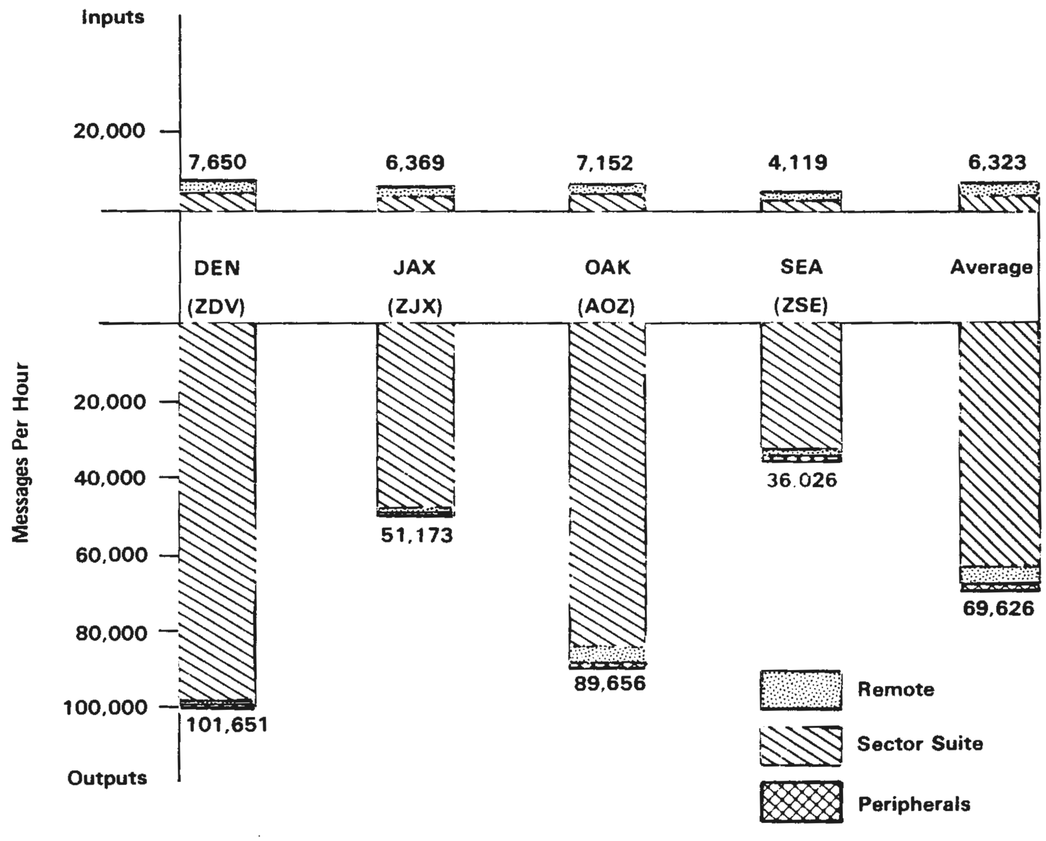


Figure 3-1. TOTAL NON-RADAR TRAFFIC

Figure 3-1 also depicts significant total traffic volume variations encountered at the four ARTCCs. Table 3-3 displays some key facility parameters that may account for some of these variations. With the possible exception of local time of collection, no correlation factors were apparent in the data analyzed. The column entitled "Total A/C - Messages" was obtained from the Aircraft option of the DART program and represents the total number of different aircraft identifiers included in the messages entering or leaving the 9020 computer. This column, therefore, is indicative of the total number of aircraft controlled at the sector but is not necessarily an accurate count of those aircraft.

The message rates presented in Figure 3-1 represent the average values of a constantly fluctuating I/O load. These average values "smooth" the effects of instantaneous variations, since the measurement interval is approximately two hours long. Therefore, six separate one-minute intervals were selected at the Jacksonville center, and the total traffic during these six intervals was calculated by counting the number of messages per interval. The mean total traffic in these six intervals agreed closely with the two-hour mean (61,000 messages per hour vs. 57,500), and the standard deviation of the six samples was 8% of the mean. This behavior indicates that there is little variation in total traffic volume on a minute-by-minute basis and therefore total computer I/O traffic appears to be a smooth, slowly varying function of time with good predictability of short-term behavior.

3.3.2 Non-Radar Remote I/O Traffic Patterns

DART I/O Summaries of the selected time periods for Denver, Jacksonville, Oakland, and Seattle provided traffic statistics for analyzing the occurrences of specific message types. Information was extracted from the I/O Summary printouts on each of the 31 input types and 23 output message types in the format shown in Table 3-4. The table contains the actual total number of messages per hour per message type per port type for each of the four centers. The amendment (AM) message occurred on all ARTCC-ARTCC links 65 times at Denver, 88 times at Jacksonville, 58 times at Oakland, and 19 times at Seattle. Only port type 2 (ATCC) messages are shown in the table; similar matrices were prepared for each port type. The I/O Summaries do not provide any indication of traffic distribution between links of the same port type at a center. The most commonly used distribution to model-time-dependent variation of communications traffic between links, given total traffic and independence of message routing, is the non-homogeneous multinomial distribution. (In the case of two links this distribution reduces to the well-known Poisson distribution.) Assuming a multinomial non-homogeneous distribution, in which n messages are transmitted over a period of time over L different links, the probability that m_i messages are transmitted through link i (i = 1,2,3,...L) is defined by the multinominal parameter p_i, which is a slowly varying function of time such that it remains essentially constant during the interval of measurement. To define this multinomial distribution for L links, one must know values for L-1 p_i's. The p_i's are unique for each ARTCC and may be derived only through facility visits, detailed review of

Table 3-3. SUMMARY OF KEY FACILITY PARAMETERS

Facility	Total Message I/O per Hour	Remote I/C per Hour	Total A/C Messages	Total Sectors	Total FDEP	Date/Day Collected	Local Time Collected
Denver (ZDV)	109,301	6004	1107	50	5	8/28/80 (Th)	11:41
Jacksonville (ZJX)	57,542	6427	1872	50	19	6/25/80 (W)	9:39
Oakland (ZOA)	96,808	6196	1668	38	19	10/24/80 (F)	12:05
Seattle (ZSE)	40,145	3034	1579	34	9	10/08/80 (W)	9:14

Table 3-4. MESSAGES PER HOUR (BY MESSAGE TYPE AND PORT TYPE) FROM/TO ADJACENT ARTCCs

Message Type	Denver 5 Links		Jacksonville 5 Links		Oakland 3 Links		Seattle 2 Links		Average $\bar{X}$	Peak $\bar{X} + 3\sigma$
	Total*	Per Link**	Total*	Per Link**	Total*	Per Link**	Total*	Per Link**	Per Link**	Per Link**
Amendment (AM)	65	13	88	18	58	19	19	10	15.3	25.8
Departure (DM)	0	0	0	0	0	0	0	0	0	0
Flight Plan (FP)	121	24	160	32	81	27	28	14	26.0	43.7

*Actual value extracted from I/O summary
**Calculated value

operating procedures, geographical layout, and aircraft traffic patterns. Not having available within the scope of this study the data that would allow definition of all necessary p_i's for all 95 non-radar remote links at the four centers studied, we have assumed them all to be equal across all links of a particular port-type at each facility. Therefore, each total (e.g., AM messages in Denver) then was divided by the number of links (ports) for each port type at the center (5 ARTCC-ARTCC in Denver) to estimate the hourly message rate per link (e.g., 13 in Denver). Each of these message rates per link was summed link by link across all links in all centers (each link received equal weighting), and average and peak (three times the standard deviation plus the average) hourly message rates were calculated for the message type. In this example, the average rate for the AM message across all of the centers was 15.3 occurrences per hour per link and the peak rate was 25.8 messages per hour per link.

Similar information was compiled for the other port types (ARTS, FDEP and TTY) to obtain the average and peak message rates per link per port type for each message type.

An analysis of the traffic data indicated that message types entering or leaving through the same port type tended to peak concurrently. Therefore average and peak message rates were summed vertically across message types by functional category to calculate the average and peak message rate per functional category on a port-type by port-type basis. The functional category totals thus obtained for each port type were multiplied by the average number of links of that port type for the four centers examined to give the four-center average per hour per port type. The messages per hour per port type were also calculated for "minimum, "typical," and "maximum" ARTCCs by using the number of links per port type defined for each of these hypothetical facilities in Chapter Two, and multiplying them by the messages per hour per link per port type. These statistics are contained in raw form in Appendix B and summarized in Tables 3-5 and 3-6.

Combining horizontally across different port types is not as straightforward a procedure, because message activity does not peak simultaneously at the different port types. Averages are additive across port types, because the average traffic for each port type represents a time interval covering both traffic maxima and minima, thereby cancelling out the effects of non-simultaneous peaking. However, instantaneous ARTCC-wide total traffic is affected by time of peaking. For example, ARTCC-ARTCC activity may be peaking while FDEP activity is low. Because of the mathematical complexity of statistically combining the I/O traffic loading on the computer from the different port types without *a priori* knowledge of the long-term behavior of the traffic volume (e.g., what percentage of peak is ARTCC I/O when FDEP peaks?), a simple summation of the peak values per port type was used to obtain the "worst case" situation that could be encountered at any given ARTCC. These summations are presented in the right-hand columns for the "minimum," "typical," and "maximum" facilities defined in Chapter Two.

Table 3-5. PEAK NON-RADAR MESSAGES PER HOUR BY CATEGORY								
Category	4-Site Average		Minimum Site		Typical Site		Maximum Site	
	Input	Output	Input	Output	Input	Output	Input	Output
Flight Plan	946	1,349	506	636	1,229	1,841	2,084	3,301
Weather	146	53	123	20	154	64	215	120
Traffic Flow	105	68	56	36	141	91	197	127
Miscellaneous	4,419	4,307	2,442	2,387	6,745	6,478	11,744	11,360
Not Categorized	158	180	86	68	240	217	467	408
Subtotal	5,774	5,957	3,213	3,147	8,509	8,691	14,707	15,316
Total	11,731		6,360		17,200		30,023	

Table 3-6. PEAK NON-RADAR MESSAGES PER HOUR BY PORT								
Port Type	4-Site Average		Minimum Site		Typical Site		Maximum Site	
	Input	Output	Input	Output	Input	Output	Input	Output
ARTCC	2,545	2,246	1,358	1,197	3,397	2,996	4,750	4,193
ARTS	2,494	2,443	1,426	1,396	4,274	4,189	8,547	8,379
FDEP	446	1,108	168	419	540	1,337	1,014	2,508
TTY	289	160	261	135	298	169	396	236
Subtotal	5,774	5,957	3,213	3,147	8,509	8,691	14,707	15,316
Total	11,731		6,360		17,200		30,023	

Careful examination of the functional message traffic distribution in Table 3-5 reveals that the miscellaneous category accounts for the vast majority of both input and output total message traffic (75-80 percent). This situation indicates that the categories need to be refined, because they are too broad to reflect functional traffic patterns accurately.

Traffic distribution across port types also is uneven. The 15 ARTCC and ARTS ports contribute roughly 80 percent of input and 90 percent of output traffic activity at the four centers investigated. The remainder is distributed amongst 53 FDEP and 19 TTY ports (72 in all) at the four centers. This situation reflects low FDEP terminal activity - one would expect considerably more total FDEP traffic, because of the large number of FDEP links serviced by the computer.

3.3.3 Individual Link Utilization, Non-Radar Remote I/O

An estimate of link utilization for each non-radar port type was made, based on the statistics derived in Section 3.3.2, estimated message length extracted from the message index, and known data rates. Message length estimates were derived by choosing a character count corresponding to the middle of the range of message lengths, as determined from the NAS-MD documentation. Data rates were obtained from FAA documents. Link utilization was calculated separately for inputs and outputs per port types. The results are shown in Table 3-7.

Table 3-7. NON-RADAR LINK UTILIZATION BY PORT TYPE

Port Type and Direction		Average/Peak (Messages per Hour per Link)	Average Message Length (Characters)	Approximate Data Rate (Characters per Second)	Message Duration (Seconds)	Average/Peak Link Utilization
ARTCC	Input	366/750	83	240	.35	3.5%/7.2%
	Output	324/665	88	240	.37	3.3%/6.8%
ARTS	Input	491/1505	83	240	.35	4.7%/14.5%
	Output	487/1402	80	240	.33	4.5%/13.0%
FDEP	Input	11/44	35	8.33	4.20	1.3%/5.1%
	Output	33/99	31	8.33	3.72	3.9%/11.6%
TTY	Input	33/76	55	10	5.5	5.0%/11.6%
	Output	20/36	32	10	3.2	1.8%/3.2%

All link utilizations are quite low, with a maximum average value of 4.7 percent (ARTS - Input). The maximum utilization for peak traffic is only 14.5 percent (ARTS - Input). These utilization figures (even for peak traffic) indicate that each individual non-radar remote input remains idle over 90 percent of the time.

3.3.4 Radar Messages

Sixteen potential input message types from radar sites were identified in the message index. Of these 16, four (5MA, 5MG, 5MH, and 5MN) are not used by the FAA or are stripped from the data stream before they reach the 9020 PAM. Of the remaining 12 message types, five (5BS, 5MF, 5PS, 5TP, and

5MS) are not used under normal circumstances or occur so infrequently that they can be ignored. The remaining seven consist of three message types generated regularly once per radar revolution and four variable rate message types that represent radar data. The constant rate messages, 5TB, 5TQ, and 5SS, arrive once every 10 seconds or 360 times per hour. (The FAA also uses some 12 seconds/scan radars, but almost 90 percent are 10 seconds/scan.) The four variable rate message types are 5RB (beacon return), 5RP (search return), 5W1 (weather map #1), and 5W2 (weather map #2).

The QARS program measures and prints the total beacon (5RB), search (5RP), and map (5W1 + 5W2 + 5MS) messages received by the 9020 in each scan of each radar connected to the computer. A total of about 45 scans' data covering two separate data collection intervals at the Cleveland ARTCC were averaged to estimate incoming message traffic per radar site. Peak traffic per radar site was calculated as the mean plus three sigma value. Since the beacon and search message rates reflect aircraft traffic activity, which, on the basis of news media reports, is estimated to be running at 75 percent of 1980 levels, incoming message rates for beacon and search messages were adjusted by 33-1/3 percent to compensate. Map message rates were unadjusted.

Radar input traffic rates obtained by the above procedure are listed in Table 3-8 and should be multiplied by 7 to obtain total radar traffic at a "minimum ARTCC," by 10 for a "typical ARTCC," and 13 for a "maximum ARTCC," as defined in Chapter Two. Since a typical ARTCC is connected to 10 different radar sites, the total volume of incoming radar message traffic (1.2 million messages per hour per ARTCC average, 2.5 million peak) dwarfs all other 9020 I/O traffic, including the sector suite (100,000 messages peak per hour per ARTCC).

At these traffic rates the radar input ports are significantly more heavily utilized than the non-radar ports. Each radar site has the capacity to transmit data on three parallel 2,400 bps links to the computer. Radar messages come in two lengths: short ones of 52 bits each and long ones of 91 bits each. Given the short-to-long message ratios depicted in Table 3-7, circuit utilization is 36 percent under average operating conditions and peaks at 67 percent.

3.3.5 Priority Assignment

The 9020 computer system uses a two-dimensional I/O capacity priority assignment scheme in which one set of priorities governs intra-link message transmission sequencing and another set of priorities governs inter-link message I/O sequencing.

Intra-link priority assignments are uniform for all 9020 computers and are defined in NAS-MD-315 and 320. Each port type behaves according to its particular priority procedures, which in general do not correlate with the procedures applied for all other port types. As evidenced by Table 3-9, there is little correlation between the intra-link priority assigned to a message and its functional category.

Table 3-8. RADAR INPUT TRAFFIC RATES PER RADAR SITE				
Message Type		Traffic Rate* (msg/hr)		Comment
ID	Name	Average	Peak	
5MA	AIMS	0	0	Military, not FAA
5MG	Gap filler	0	0	Not implemented yet
5MH**	Height	0	0	Military, not FAA
5MN	Normal map	0	0	Not enabled at radar site
5BS	Beacon strobe	0	10***	Infrequently encountered
5MF	Fixed map	0	0	Not normally enabled at radar site
5PS	Search strobe	0	1***	Infrequently encountered
5TP	Search test	0	0	Used for maintenance only
5MS	Sensitive map	-	-	Traffic included under "map"
5TB**	Beacon RTQC	360	360	Once per scan
5TQ	Search RTQC	360	360	Once per scan
5SS	Status	360	360	Once per scan
5RB**	Beacon return	80,376	115,927	Fairly constant and predictable
5RP	Search return	35,192	119,925	Highly volatile
5W1 5W2	Weather map #1 Weather map #2	954	7,834	
Total		117,602	224,777	
Port utilization		0.36	0.67	

*Based on traffic experienced during controller job action in 1981 and adjusted by 33-1/3% to compensate for reduced aircraft traffic levels as compared to pre-job action conditions in 1980.
**Long message. All others short format.
***Estimated value. See message index for details.

Table 3-9. INTRA-LINK NON-RADAR OUTPUT TRANSMISSION PRIORITIES														
	Port Type and NAS-MD Reference													
Priority	1-ARSR Ref. NAS-MD-320, Par. 1.0		2-NAS Ref. NAS-MD-315. Par. 2.1.5		3-ARTS Ref. NAS-MD-315, Par. 7.1.2		4-FDEP Ref. NAS-MD-315, Par. 4.9		5-CFCF Ref. NAS-MD-315, Par. 3.1.2		6, 7, 8-TTY		9-DARC Ref. NAS-MD-315, Par. 9.1.2	
	Qty.	Cat.	Qty.	Cat.	Qty.	Cat.	Qty.	Cat.	Qty.	Cat.	Qty.	Cat.	Qty.	Cat.
1	2	Surveillance (Target returns)	3	Miscellaneous	1	Flight plan	1 1	Flight plan Miscellaneous	All	First in First out	All	First in First out	2	Flight plan
2	14	Surveillance (all others)	2 4	Miscellaneous Flight plan	2	Flight plan	9	Flight plan					1 2	Flight plan Miscellaneous
3			1	Miscellaneous	3	Miscellaneous	1 3	Flight plan Miscellaneous						
4			2	Miscellaneous	4	Miscellaneous								
5					1	Miscellaneous								

Inter-link priority assignments for I/O traffic are non-uniform throughout the 20 ARTCCs and depend upon local configuration and adaptation. Specifically, priority controls in PAM Common determine which link will receive service. These priority controls are adapter-address dependent, with the lowest address codes having highest priority. Therefore, to determine whether a particular ARTCC-ARTCC link has priority over a particular FDEP link, one must examine the detail port assignment configurations at the center.

In addition to this two-dimensional I/O priority assignment, a third level of priority assignments exists for processing incoming messages accepted by the PAM. This third level of priority is encoded in the 9020 software in the form of subroutine priority assignments. Take for example a situation in which two messages, A and B, are received and accepted by the PAM simultaneously. Message A automatically invokes the initiation of subroutine #1, and message B automatically invokes subroutine #2. Given that the available resources will only support the execution of one subroutine and that subroutine #1 has a higher priority than subroutine #2, message B will not be acted upon until after message A is processed. Therefore message B effectively receives a lower priority than message A. A concrete example of such a situation involves processing of radar data. According to NAS-MD-320 and -325, two levels of radar data processing priorities have been established: Priority #1 contains the 5RB and 5RP target return messages. Priority #2 contains all other radar input messages. If a beacon return and map message are received concurrently, the beacon return will be processed and the map message may be lost.

The complexity and time-dependence of the priority assignment functions demand a separate, more detailed analysis of I/O priorities for the following reasons: (1) The functional categories defined in the specification are too broad; therefore there is no readily apparent priority scheme that could be assigned to I/O traffic according to these functional classifications. (2) Port type priorities depend upon local adaptation and require detailed review of the configuration of each of the 20 centers. (3) Assignment of priorities on the basis of the adaptation operating system is outside the scope of this report.

3.4 SUMMARY OF 9020 I/O TRAFFIC

9020 I/O traffic statistics derived in Paragraph 3.3 were grouped on the basis of source and destination, as follows:

- Remote (radar) - Port type 1
- Remote (non-radar) - Port types 2 through 9
- Sector suite - Port types 10 through 13
- Peripheral devices - Port types 14 through 21

The estimated distribution of I/O traffic across these groups is plotted in Figure 3-2. All non-radar traffic statistics represent the four-center average obtained directly from DART printouts for the Denver, Jacksonville, Oakland, and Seattle ARTCCs. The radar traffic volume is derived from message rates presented in Table 3-8, given an average of nine radar sites at the Denver, Jacksonville, Oakland, and Seattle ARTCCs.

The 9020's message loading is dominated by incoming radar data messages, which account for approximately 90% (93% derived) of all 9020 input plus output communications. The second most significant communications load on the 9020 is the sector suite output, which makes up 6% or more (6% derived) of the total input and output. Since all radar communications are incoming only, the sum of all inputs to the 9020 computer overwhelms the number of total outputs approximately according to this same proportion. The remaining message traffic (i.e., non-radar remote inputs and outputs, sector suite inputs, peripheral inputs and outputs) accounts for less than 1% of the total traffic volume loading on the computer.*

*The distribution pattern in Figure 3-2 is a composite of non-radar statistics compiled at the Denver, Jacksonville, Oakland, and Seattle centers, and radar statistics from the Cleveland center. The computed radar line utilizations of Table 3-8 are similar to results obtained at other centers and likely to be representative of the Denver, Jacksonville, Oakland, and Seattle centers taken as a group. Furthermore, the variance is so small (30 to 60%) that is will have a minimal effect on the proportions presented in the figure. For example, if radar traffic were 50% lower than measured, the sector suite outputs would still account for only 12% of total traffic instead of 6%, and all other communications would remain between 1% and 2% of the total. Conversely, if radar traffic estimates were 50% higher than measured, the sector suite would make up 3% of the total and all other communications less than 1%.

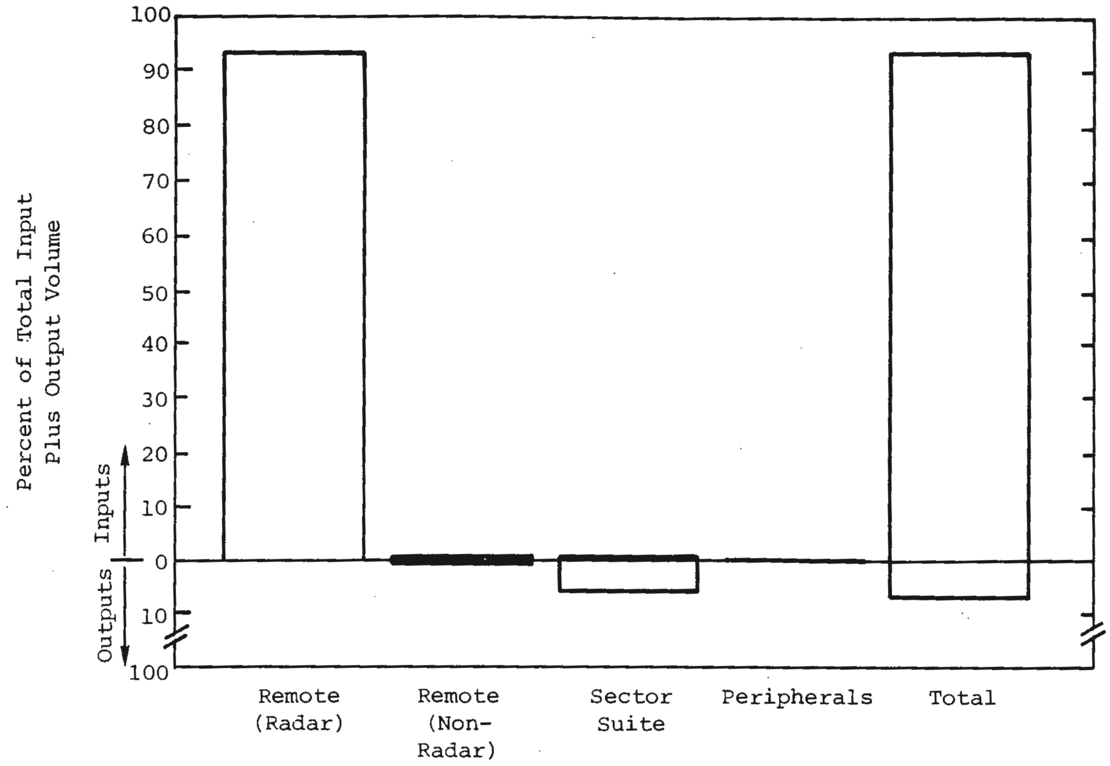


Figure 3-2. DISTRIBUTION OF TOTAL 9020 I/O TRAFFIC BY PORT TYPE GROUP

CHAPTER FOUR

ERROR ANALYSIS

This chapter examines the sources and magnitude of errors in the I/O traffic estimates derived as part of this study and indicates their effect on the design of the 9020 replacement computer (9020R).

4.1 SOURCES OF ERROR

Errors may creep into message traffic estimates from erroneous input data, mathematical approximations in data analysis, and display errors (e.g., roundoff of numbers on a computer printout and scale and figure plotting inaccuracies). Display errors typically are on the order of one percent or less, are considered negligible, and will not be discussed further. Errors resulting from the data analysis procedures cannot be ignored totally but are much less significant than errors resulting from uncertain or improper input data; these latter two sources of error are addressed in the following subsections.

4.1.1 Limited Samples of Data

The communications traffic estimates derived in this study are based on snapshots of the NAS system and may or may not be representative of the 9020's operating environment. One has no assurance that any conclusions drawn from the samples truly reflect 9020 I/O loading.

For example, non-radar traffic estimates were based on an examination of approximately two hours' information gathered at each of four ARTCCs. Since each center has its own unique configuration, operating procedures, and performance requirements, one cannot be assured of statistically valid homogeneity between the sample examined and the total ARTCC population. Furthermore, the raw information analyzed had initially been collected with another objective in mind, and no explanation exists for the selection of collection times or intervals. To our best knowledge, the information represents "peak traffic" conditions at each center. "Peak traffic" in communications engineering has traditionally meant maximum utilization or maximum number of messages per unit of time per communications link. However, the meaning of "peak traffic" for purposes of collecting the raw data used in this study remains vague: it could refer to peak aircraft traffic, peak controller activity (e.g., peak sector-suite I/O traffic), peak communications traffic, or any of several other possible parameters commonly referred to by the term "peak traffic." To complicate the issue even more, traffic across different port types (e.g., ARTCC, ARTS, FDEP) appears to peak at different parts of the workday, and hence any single overall peak I/O traffic period may not represent true maxima. This uncertainty regarding the validity of the samples is reinforced by the significant variations in traffic (up to a factor of three) noted between the different facilities examined. We have not been able to identify causes of such differences nor have we been able to deduce long-term traffic variations from the limited samples.

The radar traffic estimates are no more reliable than the non-radar estimates. The radar traffic estimates were derived from two samples of two minutes' duration each at a single ARTCC. The time and duration of sampling were not determined by the needs of the data collection effort but by equipment maintenance and verification procedures. Furthermore, the non-radar statistics were collected in 1980 and the radar statistics in 1981, when significantly different conditions existed in NAS because of the controllers' job action. Hence it is difficult to correlate the radar and non-radar traffic estimates derived in this study.

4.1.2 Voids in Data Collection Tools

Most of the information compiled in this study utilized statistics obtained from SAR tapes by the DART program. Because of lapses in programming or documentation or both, some message types present in the system cannot be identified definitively and may have been analyzed improperly or missed entirely. The DART program found less than 5 percent total traffic volume it could not identify positively, and there may be at most another 5 to 10 percent in message traffic resulting from messages improperly cross-referenced between the DART and 9020 nomenclatures. Therefore, errors resulting from voids in data collection probably account for no more than a 15 percent error in total traffic loading.

4.1.3 Data Analysis Approximations Used to Calculate Traffic Volume

All the traffic volume estimates compiled in this study assume equally divided message traffic per message type per link across all links of a particular port type. That is, all ARTCC-ARTCC links at a center were assumed to carry $\bar{X}$ messages per hour rather than X_1 to $ARTCC_1$, X_2 to $ARTCC_2$, etc., with an overall average of $\bar{X}$. This assumption does not distort the estimate of average traffic unless the inventory of links was incorrect. However, the calculation can distort the estimate of peak traffic (average plus three sigma) if traffic load is unequally divided across all links of a particular port type. Sample calculations indicate that in this latter situation, the estimated standard deviation of the total traffic could be understated by around 20 percent. Such an understatement of the standard deviation corresponds to an approximately 15 percent understatement of estimated peak traffic, according to sample calculations.

On the other hand, the procedures used to estimate peak traffic centerwide tend to overestimate maximum loading. Review of the data indicated that traffic to and from each port type peaks independently of the traffic level at the other port types. Hence maximums per port-type link must be combined statistically to provide an accurate assessment of anticipated peak total traffic across all port types. This procedure is cumbersome and requires a statistical understanding of link traffic characteristics not derivable from the information available during the study. Therefore peak centerwide traffic was calculated by summing the peaks for each port-type link, on the assumption that summing represents a "worst-case" situation. In actuality the probability of occurrence of a worst-case situation is practically zero, and total centerwide traffic loading is overstated. The magnitude of this overstatement cannot be estimated with present data.

4.1.4 Message Length Approximations Used in Data Analysis

Since actual measurements of message lengths for non-radar communications were not available during this study, estimates were used in the port-utilization analyses. Utilization estimates are directly proportional to message length and therefore could be in error accordingly. The magnitude of message length estimate error is probably less than 30 percent but cannot be determined without additional information.

4.2 IMPACT OF ERRORS IN THIS STUDY ON 9020R

4.2.1 Radar Inputs

Incoming radar data overwhelm all other sources of input or output traffic in the number of messages processed per hour. Errors of as little as 10 percent to 15 percent in the incoming radar data traffic volume equal total traffic volume between the computer and all the other inputs and outputs combined. The most significant source of error in estimating radar loading on the computer results from the small number of samples investigated. In fact, the radar traffic has been estimated by on-site personnel continuously monitoring radar and computer operations to vary as much as a factor of two or more from the levels observed in our samples. These types of variations are well within the communications-link capabilities of the 9020-ARSR circuits, because utilization at the time of measurement was about 36 percent per link. The other sources of error do not affect radar input traffic estimates, because (1) voids in data collection were nonexistent, (2) the data analysis approximation techniques discussed were not used, and (3) message lengths were exactly defined.

4.2.2 Non-Radar Remote I/O

The non-radar remote I/O loading comprises perhaps 1 percent of the total 9020 messages with the external world. The primary source of error for these communications, once again, is the limited sample of data analyzed. All the other error sources combined (voids in data collection tools, data analysis approximation, and message length approximations) represent a total error of approximately 30 to 40 percent at most. The primary effect of these latter errors, and particularly message length errors, would be on I/O queue-sizing, which is much more sensitive to the large traffic variations due to insufficient sample size than any of the other parameters.

4.3 OTHER I/O-TRAFFIC-RELATED ISSUES SIGNIFICANTLY AFFECTING 9020R

4.3.1 Sector-Suite Loading

The second most significant source of I/O traffic results from the sector suite. Although this traffic volume is an order of magnitude less than the incoming radar message volume, the sector-suite loading on the computer is still an order of magnitude larger than all non-radar remote I/O combined. Since these sector-suite communications are longer and more complex than the incoming radar data, the 9020R cannot be sized for either I/O, processing, or memory requirements without accurate characterization of sector-suite loading. Such a characterization (based on the SAR data used in this report) would be subject to the same error sources that the non-radar remote I/O is subject to, particularly the small number of samples of data.

4.3.2 CPU- and Memory-Intensive Inputs

Most input messages cause the computer to allocate scarce computing and dynamic storage resources for subsequent processing. Some input messages cause the computer to perform extremely complex CPU- and memory-intensive programs. A disproportionate occurrence of such messages could cause (and in fact has been known to cause) computer processor and memory overloads. The issue of CPU- and memory-intensive inputs was not addressed in sufficient detail as part of this study. A review of the adaptation operating system (which allocates these resources) combined with the traffic statistics in this report could be used to highlight the traffic parameters for those messages that initiate resource-consuming subroutines and consequently can significantly affect computer design and sizing.

4.3.3 Prediction of Long-Term I/O Traffic Parameters

The information contained in this study is insufficient to establish multiyear I/O loading estimates, correlation with aircraft movements, or other tools necessary to allow system sizing of sufficient capacity for the 1990s. Further research is necessary to determine (1) what data sources with long statistical history exist that are accurate and applicable to I/O demand prediction, and (2) what new data-gathering efforts are possible and practical in correlating aircraft traffic with the message traffic on the basis of message type or functional category.

Furthermore, the traffic estimates derived in this report are based on the existing NAS configuration. The introduction of new systems and new air traffic control procedures into NAS, such as those contemplated in the FAA's future ATC scenarios, will significantly alter the communications patterns with the ARTCC computer and hence will dramatically change the I/O, processing, and memory requirements for the 9020R. Consequently, the results of this study cannot be directly extrapolated to future years on the basis of aircraft traffic without a more detailed study of the impact of proposed new systems and procedures on the world of the 9020R.

4.3.4 Clarification of 9020R Performance Requirements Documentation

The NAS-MD documentation for the 9020 computer and the draft 9020R system specification exhibit a number of inadequacies. Message types with multiple names or multiple IDs or both are common. Different message types are referenced by the same name or ID. Descriptions of message functions are often incomplete. The message data flow (i.e., the interaction of a given message with others) is often presented in an unsystematic manner and contains voids in the functional specifications. Cross-correlation of various NAS-MDs with each other is difficult; cross-correlation between the NAS-MDs and the draft 9020R system specification is even more difficult. Therefore, the existing documentation is suspect as a design reference for the engineer unfamiliar with details of present ATC operations and NAS documentation. In the near future, the documentation must be updated, corrected, and supplemented if the present impediments to the design of the 9020R are to be removed.

CHAPTER FIVE

VERIFICATION PLAN FOR REFINEMENT OF 9020 I/O TRAFFIC ESTIMATES

This chapter contains a description of the program recommended for refinement of the traffic estimates derived in this study.

5.1 OVERVIEW

The non-radar traffic estimates presented in this report were based on data tapes obtained from four different ARTCCs. The radar estimates were derived from two short samples at a single ARTCC. Consequently, the traffic statistics may not truly represent the total ARTCC population or peak traffic periods for the computer; their reliability and accuracy are severely limited by the smallness of the sample sizes.

The primary objective of this verification plan is to reduce the possible errors in the estimates of 9020 I/O traffic through expansion of the sample size to longer intervals and more ARTCCs. However, the schedule requirements of the 9020R program are such that a program of long-term measurement and analysis would provide results too late to be of value in initial computer replacement sizing activities. A three-part program is recommended. The program is structured to provide a continuing improvement of 9020 traffic estimates as rapidly as possible; ultimately the program will evolve into a permanent tool that will be able to predict 9020 I/O traffic loads with reasonable accuracy as a function of anticipated changes in the NAS environment. Part I will provide short-term results. Part II is a medium-term effort bearing fruit approximately one year after initiation. Part III consists of activities continuing for the next two or three years.

Additionally, one of the key findings of this study indicates that the non-radar remote I/O of the 9020 computer represents only 1 percent of total input and output loading, and the sector-suite interface accounts for approximately 10 percent. Detailed analysis of this sector-suite interface was outside the scope of this study. However, since the sector-suite I/O forms a critical portion of the computer's I/O workload, the messages coming from and going to the A, D, and R positions (including the flight strip printer) should be examined in more detail. The recommended procedure for such an examination is included in Part IV of the recommended verification program.

5.2 PART I - ADDITIONAL ANALYSES USING EXISTING DATA

5.2.1 Objectives

The objectives of additional analyses are (1) to eliminate as quickly as possible inconsistencies present in the 9020R documentation, (2) to refine the 9020 I/O traffic estimates in this study by analysis of additional data samples, (3) to lay the groundwork for comparing 1980 and 1981 traffic patterns, and (4) to initiate the development of a permanent tool for the evaluation of data communications traffic into and out of the 9020 computers on a continuing basis.

5.2.2 Summary of Activities

Part I should build upon work previously performed and resolve incomplete issues and errors by repeated application of the procedures described in Chapters Two and Three of this report. First, the message descriptors identified in the draft 9020R system specification should be updated and corrected through comparison of the message index prepared in this study with the draft specification. Second, existing SAR tapes at FAATC for the Cleveland, New York, and Washington ARTCCs should be subjected to the same analyses that have been completed for the Denver, Jacksonville, Oakland, and Seattle centers. Third, since both activities are manual, time-consuming, and labor-intensive, an approach should be recommended for simplifying and automating the data reduction and analysis process. These three activities are described in more detail in the following sections.

5.2.2.1 Clarify 9020R Documentation

The 9020R documentation should be clarified to ensure that the draft 9020R system specification is complete, accurate, and consonant with the minimum requirements currently placed on the 9020 computer. FAA-ER-130-003, dated August 1981, should be reviewed and every input and output message type listed in it should be compared with the message index compiled from NAS-MDs. A detailed message-by-message cross-reference between the NAS-MDs and the draft system specification should be prepared. Those messages existing in the NAS-MDs and not in the draft specification and those in the draft specification but not the NAS-MDs should be researched and, if possible, matched on the basis of function.

Once the cross-reference is complete, a brief functional description should be prepared for all message types listed in either documentation set. Flow descriptors should be prepared to highlight the interrelationships between message types with complex input and output relationships (e.g., weather messages). Unique message IDs should be assigned to ensure unambiguous referencing of specific messages within the text of the draft system specification.

5.2.2.2 Analyze Traffic at Additional ARTCCs

Traffic at additional ARTCCs should be analyzed to reduce some of the errors in I/O traffic estimates resulting from the analysis of only four

ARTCCs. Additionally, the data obtained as part of this activity could permit an assessment (in Part II of the program, Section 5.3.2.5) of the effect of the controllers' job action on 9020 communications traffic and the sensitivity of that traffic to unanticipated external influences. SAR tapes already available at FAATC for the Cleveland, New York, and Washington ARTCCs should be subjected to the analytical procedures previously employed to derive traffic statistics for the Denver, Jacksonville, Oakland, and Seattle centers. The previously obtained traffic estimates should be refined and the estimate errors reduced by integration of the two sets of results.

5.2.2.3 Recommend Improvements for Data Reduction and Analysis Process

Techniques should be identified that will expedite the data reduction and analysis required to obtain I/O traffic statistics from SAR tapes. If automation appears to be the most desirable approach, a program specification should be developed to implement the program on an IBM 4341 computer at FAATC. This program specification should be a single document combining the Overall Computer Program Description (OCPD) and the Computer Program Functional Specification (CPFS) defined in FAA Report No. FA-SRDS-140-SDS-1. If automation does not appear to be the most desirable approach, then appropriate manual or semiautomatic procedures should be defined so that all future statistics will be directly comparable and obtainable by means of a standard set of calculations.

5.3 PART II - ADDITIONAL ANALYSES USING NEWLY COLLECTED DATA

5.3.1 Objective

The 9020 I/O traffic estimates should be refined by obtaining new samples of longer duration at selected ARTCCs. Measurements should be accomplished through existing measurement systems, which will be installed at the Cleveland, New York, and Washington ARTCCs. The new statistics thus derived should be compared with previously collected data to evaluate the effect of the controllers' job action on communications loading.

5.3.2 Summary of Activities

The FAA is installing communications traffic measurement systems at the Cleveland, New York, and Washington ARTCCs in early 1982. These measurement systems can be augmented easily to provide activity profiles on each individual remote 9020 communications link. The profiles can be used to identify peak periods of radar and non-radar communications activity. The peak periods can be examined in more detail and compared to the previously obtained traffic estimates with the use of SAR tapes and the associated data reduction procedures defined in Part I. Finally, a recommended approach for continuing data traffic measurement should be prepared. The activities of this part are described in more detail in the following sections.

5.3.2.1 Expand Communications Measurement System

A system should be developed to verify through measurement the traffic loading estimates previously compiled. The communications measurement systems being installed at the Cleveland, New York, and Washington ARTCCs should be expanded and equipped with high-speed digital analyzer (HSDA) units designed specifically to measure and record activity on 9020 I/O data lines. The HSDA should be connected to all remote links of the 9020 computer, as specified in FAA Report No. FAA-TF4-1-82, Volume II. The HSDA-equipped measurement system should provide statistics on the number of messages processed per link and the total occupancy of each link. Measurements should be made continuously for at least three months to assure data collection in varied weather and aircraft traffic conditions.

5.3.2.2 Characterize Radar Input Traffic

To confirm the accuracy of the radar loading estimates in this report, the communications traffic measurement should be configured to provide statistics on frequency of occurrence for beacon (long), search (short), and map (coded short) radar messages. These statistics should be analyzed and correlated with Instantaneous Aircraft Count (IAC), aircraft movements, or other parameters such as bad weather when appropriate. Periods of peak activity should be identified and the communications traffic characteristics of that period should be defined.

5.3.2.3 Identify Peak Non-Radar Traffic Activity Periods

To identify the optimum periods for detailed non-radar data traffic analysis, computer I/O traffic patterns should be evaluated and periods of peak activity for each port type identified, and measurements should be correlated with known external conditions (e.g., weather, IAC) so that projected periods of peak traffic loading can be identified with a high degree of confidence.

5.3.2.4 Obtain Non-Radar Peak Period Traffic Parameters

To characterize non-radar peak traffic characteristics definitively, SAR tapes should be prepared for the peak non-radar communications traffic loading intervals and should be reduced and analyzed, per the procedures defined in Part I (Section 5.2.2.2), for occurrence of specific messages, I/O port activity, and other traffic parameters of interest to the 9020R designer.

5.3.2.5 Compare Old and New Statistics

Old and new statistics should be compared to derive a relationship between 9020 communications traffic loads experienced under widely differing conditions and thereby evaluate the sensitivity of 9020 communications traffic loading to external influences. The data traffic parameters obtained for the Cleveland, New York, and Washington centers in Part I (Section 5.2.2.2) and Part II (Section 5.3.2.4) will be compared in detail. Biases resulting from any time-dependent, clearly definable traffic variations will be removed and the ratio of the two samples will be calculated. This ratio will provide a definite indication of the effect of future traffic growth on 9020 I/O loading compared to the present reduced loading conditions.

5.3.2.6 Develop an Approach for Continuing Data Traffic Measurement at ARTCCs

The objective of the last step in Part II is to develop the conceptual design of a recommended capability within the FAA for continuing collection of computer I/O loading values at ARTCCs. This capability could take several forms. One approach would continue to use the three existing measurement systems on a rotating basis at all ARTCCs. Another would equip all ARTCCs with such equipment, either as part of the 9020R computer or as stand-alone units similar to the three existing units. Still another approach would use a specific set of ARTCCs as a representative sample of the whole population and depend on the statistics collected at those centers only. This activity should evaluate the technical pros and cons of each such alternative, weigh the costs and benefits associated with each approach, and recommend the appropriate course of action for future implementation.

5.4 PART III - LONG-TERM I/O TRAFFIC DEMAND PROJECTION

5.4.1 Objectives

The objectives of Part II are to provide a set of tools for anticipating future I/O traffic loads on the 9020R and to apply those tools within the context of the long-range (1990) ATC scenarios of the FAA. This activity should obtain an assessment of the effect of these scenarios on the computers' I/O loading in the future. The tools, in particular, should include a combination of equipments and procedures to actually measure fluctuation in data communications traffic and programs to analyze that data. The long-range assessment should predict changes in message traffic patterns based on changes in the ATC environment.

5.4.2 Summary of Activities

Part III should be viewed as the culmination of the activities conducted in Parts I and II. Part I provides initial traffic estimates and a specification for one of the key tools (Section 5.2.2.3) of data analysis. Part II refines the traffic estimates from Part I and provides the proof of concept for a traffic measurement system that could be used on a continuing basis. Part III integrates those two achievements through four activities described in the following sections.

5.4.2.1 Implement Recommended Data Reduction and Analysis Improvements

Improved data reduction and analysis are needed to simplify the involved data reduction and analysis procedures that had to be applied in

Parts I and II for the derivation of traffic statistics. If automation appears to be the most cost-effective approach to long-term computer data traffic measurement, a program specification will have been prepared in Part I (Section 5.2.2.3) of this program. This activity should prepare, document, and validate the program implementing that program specification. The program typically should read edited SAR tapes on the FAATC IBM 4341 computer and provide output parameters such as the following:

- Queueing
- Message activity per aircraft
- Message activity by message type groupings
- Message length distributions

Once developed, the program should be validated by means of one of the SAR tapes from a center already analyzed. Once validated and operational, the program should be documented by a software design document (SDD) and a user's manual per FAA Report No. FAA-SRDS-140-SDS-1.

5.4.2.2 Implement Continuing Data Traffic Measurement at ARTCCs

To implement the communications traffic measurement equipment and procedures defined in Part II (Section 5.3.2.6) of this program, equipment should be designed, purchased, and installed as recommended, and detailed procedures should be prepared and executed on a continuing basis to compile the desired traffic statistics over an extended period of time.

5.4.2.3 Develop a Technique for Predicting Computer Traffic Loading

A tool should be developed for predicting the effect of changes in the ATC environment on the I/O demands of the computer. The long- and short-term statistics compiled in Parts I and II of this program should be compared analytically with the basic NAS-MD documentation and alternate sources of statistics on NAS operations so that correlations and dependencies can be identified with a high degree of confidence. The correlations and dependencies between the external environment of the computer and I/O message loading should be used to prepare a technique for predicting data traffic on the basis of ATC status.

5.4.2.4 Apply the Predictive Tool

The predictive tool should be used to assess the effect of major new ATC activities or functions on 9020R I/O requirements. One of the most significant possible drivers is the use of data links, which should be explored in great detail.

5.5 PART IV - CHARACTERIZATION OF 9020 SECTOR-SUITE I/O TRAFFIC

5.5.1 Objective

Existing 9020 sector-suite I/O traffic statistics should be analyzed to provide a more detailed understanding of the I/O traffic requirements of the sector suite.

5.5.2 Summary of Activities

The four centers already examined for remote traffic (Denver, Jacksonville, Oakland, Seattle) should be examined in detail for sector-suite message characteristics and traffic patterns. The study should be based on the I/O summaries presently available.

5.6 SCHEDULE

Figure 5-1 presents the recommended schedule for activities described in this chapter. Parts I, II, and IV of this program should be implemented immediately. Initiation of Parts I and IV is required to obtain data necessary for release of the 9020R RFP. Initiation of Part II is required to take advantage of special discounts associated with purchasing the communications traffic measurement systems, to accommodate the 90- to 120-day delivery being quoted for the systems, and to allow the engineering and design activities to be completed in time for a projected April 1981 system turn-on. Although Part III activities need not be initiated until fiscal year 1983, the FAA's lengthy procurement process dictates that procurement action be initiated as soon as possible to assure timely completion of all tasks described under Part III.

Section	Activity	Jan 1982	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan 1983
	Part I													
5.2.2.1	Clarify 9020R documentation	■	■	■	■	■								
5.2.2.2	Analyze traffic at additional ARTCCs					■	■	■						
5.2.2.3	Recommend improvements for data reduction and analysis process							■	■	■				
	Part II													
5.3.2.1	Expand communications measurement system	■	■	■										
5.3.2.2	Characterize radar input traffic				■	■	■							
5.3.2.3	Identify peak non-radar activity periods						■	■	■					
5.3.2.4	Obtain non-radar peak period traffic patterns								■	■	■			
5.3.2.5	Compare old and new statistics										■	■		
5.3.2.6	Develop an approach for continuing data traffic measurement at ARTCCs											■	■	■
	Part III													
5.4.2.1	Implement recommended data reduction and analysis improvements	■	■	■										
5.4.2.2	Implement continuing data traffic measurement		■	■	■	■	■	■	■	■				
5.4.2.3	Develop a technique for predicting computer traffic loading					■	■	■	■	■				
5.4.2.4	Apply predictive tools										■	■	■	■
	Part IV													
5.5.2	Characterize 9020 sector-suite I/O traffic	■	■	■										

Task Milestones by Month (Calendar Contract)

Figure 5-1. RECOMMENDED VERIFICATION PLAN SCHEDULE

APPENDIX A

CORRELATION OF DART IDs WITH NAS-MDS

We have reviewed the DART User's Manuals (NASP-9247-16), dated 6 July 1978 and 17 December 1980, to determine what message traffic data is available through the NAS Operational Support System (NOSS). As part of this effort, we have compared the message types that DART can measure with our listing of 9020 messages compiled from various NAS-MD documents. This comparison consisted of the following steps:

- We compared and entered all identical DART/9020 message mnemonics into our files. We obtained the DART message mnemonics from Table 5-3 of NASP-9247-16.
- We compared DART/9020 message descriptors (message names). For all messages with similar descriptors (but different mnemonics), we added the DART mnemonic to our files. We obtained DART message descriptors from Tables 4-4 and 4-5 of NASP-9247-16.

We were not able to correlate numerous messages listed in NASP-9247-16 with our message inventory. These mnemonics and message descriptions are listed in Table A-1. For the most part each entry represents a likely addition to our message inventory or an unclear DART/9020 message descriptor correlation. The remaining entries are totally unidentifiable (e.g., DDC message) or are examples of inconsistencies in the DART documentation (e.g., alert message).

The questions posed by Table A-1 regarding DART/9020 correlation and message identification should be answered before our message inventory can be considered complete.

Table A-1. DART MESSAGES NOT CORRELATED WITH NAS-MD DOCUMENTATION			
ID	I/O	Message Name or Remark***	References Our ID
AKDAT	O	FP Data Printout (AK Disk Error) 4-5 (#46)	2FD?
AMIPR	O	Amendment in Progress 4-5 (#126)	
BERCS	O	Beacon Registration/Radar Collimation Summary 4-5 (#102)	
BKPAK	O	Proposed Route Record File Status 4-5 (#101)	
CLEAR	O	CRD Clear or Message Waiting Light 4-5 (#94, 141)	
CMPAT	O	Compatibility Message to D-CRD 4-5(#125)	
CONTL*	I	Σ (BP,CF,CM,CP,CS,DC,DD,DI,FE,FI,FO,FT,GO, RB,RP,TO)**	
CORR	I	Correction 4-4 (#97)	CM+CR+15CR ?
DATUP	O	A/C Type Update 4-5 (#119)	
DCC	I	4-4 (#110)	
DPCOR	O	Departure Coordination Strip 4-5 (#7)	2AC?
CANCL	I,O	IOT Cancelled 4-4 (#96), 4-5 (#211)	
CDCAL	O	Display Channel Alert (Ref.DART Table 4-5 #113)	11DC?
DTMUP	O	Proposed Departure Update	2DU?
EJECT	O	Flight Strip Eject (Blank Strip) 4-5 (#100)	
FDB-N	O	PVD Full Data Block 4-5 (#105)	
FP*	I,O	Σ (inputs E,FP,FPL,N,plus outputs FP-E,FP-N, FPLAN)**	
E	I	(Log Only)	
N	I	(Log Only)	
FP-E	O	E Type FP 4-5 (#35) (Log Only)	
FP-N	O	NType FP 4-5 (#34) (Log Only)	
FPSAP	O	FP Analysis Subsystem Diagnostic Message 4-5 (#134)	
FTDSS	O	Flat Tracking Data Set Summary 4-5 (#133)	
HO	I	4-4 (#24)	
INCRT	O	Incomplete Route Update 4-5 (#111)	
INHRO	O	Inhibit Request Readout 4-5 (#128)	

*Available in I/O Summary only.
**Individual message types available in Log only.
***Code at end of name references location in DART manual: e.g., 4-5 (#46) references Table 4-5, Value #46.

(continued)

Table A-1. (continued)			
ID	I/O	Message Name or Remark***	References Our ID
J-SIM*	I	Σ (JA,JB,JC,JD,JE,JH,JM,JO,JS)**	
LDB	O	PVD Limited Data Block 4-5 (#106)	
MASOV	O	Massive Code Overflow to FSP 4-5 (#55)	
MD	I	4-4 (#112)	
MISCL	I	(I/O Summary only) = CRDAK (Log Only) 4-4 (#95)	
CRDAK	I	(Log Only) 4-4 (#95)	
MISON*	O	Σ (Mission Arrival, Departure, and Enroute Strips)	
MSARR	O	Mission Arrival Strip (Log Only) 4-5 (#10)	
MSDEP	O	Mission Departure Strip (Log Only) 4-5 (#5)	
MSENR	O	Mission Enroute Strip (Log Only) 4-5 (#2)	
MON-S	O	Solicited Monitor Response Messages 4-5 (#92)	
MON-U	O	Unsolicited Monitor Messages 4-5 (#93)	
MONTR	I	Monitor Input (e.g., SMOD, SETT)	
MSDPC	O	Mission Departure Coordination Strip 4-5 (#6)	
MSGCX	O	Message Cancellation Printout 4-5 (#56)	PXX?
MSGEX	O	Update Message Expired 4-5 (#95)	
NONUS	O	Foreign Strip 4-5 (#14)	
ORDER	I,O	Order Word 4-4 (#108) 4-5 (#127)	
QO?		Conflict Data Block Suppression, R-CRD 4-4 (#120)	
RA	I	4-4 (#52)	
RD*	O	Σ (RD, ARSAT)	
RECON	O	Reconstitution Status 4-5 (#129)	
RRIND	O	Reroute Indicator Message (R-CRD) 4-5 (#62)	
RSUP	O	Remove Strips Update (Log Only) 4-5 (#112)	
SEEPR	O	See printer to D-CRD 4-5 (#96)	
SH	I	4-4 (#63)	
SI	I	4-4 (#109)	
UNDEF	I,O	Undefined, unrecognizable message	
WTHRO	O	Weather Request Output 4-5 (#74)	9WX1 or 9WX2?

*Available in I/O Summary only.
**Individual message types available in Log only.
***Code at end of name references location in DART manual: e.g., 4-5 (#46) references Table 4-5, Value #46.

(continued)

Table A-1. (continued)			
ID	I/O	Message Name or Remark***	References Our ID
Y-MSG*	I	Σ (YM,YR,YS)**	
Z-MSG*	I	Σ (ZA,ZC,ZM,ZR,ZS,ZT)**	
FPUPD	O	(Log only, Ref. Table 4-5 #32)	
RERUP	O	(Ref. Table 4-5 #31)	
FRWRD	O	(Ref. Table 4-5 #29)	
QO	I		
WMSC	O	4-5 (#28)	15WR?
SG	O	Was in old† DART Table 4-5 #121, but not in new Table 4-5 or Table 5-3	
SG	I	In new† DART Table 4-4 #121, but not in Table 5-3	SG
ALERT	O	In new DART Table 4-5 #110, but not in Table 5-3	
DEL	O	In new DART Table 4-5 #136, but not in Table 5-3	2DF
ADD	O	In new DART Table 4-5 #137, but not in Table 5-3	2AF
AVFR	O	In new DART Table 4-5 #138, but not in Table 5-3	
FVFR	O	In new DART Table 4-5 #139, but not in Table 5-3	
TEST	O	In new DART Table 4-5 #140, but not in Table 5-3	
CLEAR	O	In new DART Table 4-5 #141, but not in Table 5-3	
CPUS	O	In new DART Table 4-5 #143, but not in Table 5-3	13RU
CPUW	O	In new DART Table 4-5 #144, but not in Table 5-3	13CU
LA	I	In new DART Table 4-4 #125, but not in Table 5-3	
LA	O	In new DART Table 4-5 #145, but not in Table 5-3	
LB	I	In new DART Table 4-4 #126, but not in Table 5-3	
LB	O	In new DART Table 4-5 #146, but not in Table 5-3	
LC	I	In new DART Table 4-4 #127, but not in Table 5-3	
LC	O	In new DART Table 4-5 #147, but not in Table 5-3	
EMSAW	O	In new DART Table 4-5 #148, but not in Table 5-3	15MA
ESTAT	O	In new DART Table 4-5 #149, but not in Table 5-3	13EM?
CPUU	I	In new DART Table 4-4 #128, but not in Table 5-3	
CA	O	Conflict Alert - Printout? We have only CA input.	11AP?
ZT	I	4-4 (#84)	
CODOV & CDOVF	O	4-5 (#57) 4-5 (#59) What is the difference between the two?	
CSDEL	O	Typo in Table 5-3? Same as CDSEL in Table 4-5 (#68)?	

*Available in I/O Summary only.
**Individual message types available in Log only.
***Code at end of name references location in DART manual: e.g., 4-5 (#46) references Table 4-5, Value #46.
†The adjectives "old" and "new" refer to NASP-9247-16, dated 6 July 1978, and its revision, dated 17 December 1980, respectively.

APPENDIX B

DETAILED MESSAGE TRAFFIC STATISTICS

The following tables contain non-radar traffic statistics extracted from the DART I/O Summary printouts. The tables are organized by functional category and list all I/O message types under consideration that actually occurred at any one of the four centers. Each message type is described by its DART ID, 9020 ID, and name, all of which correspond to the message descriptor sheets found in Appendix C. The average and peak values of the number of messages per hour per link for each port type (ARTCC, ARTS, FDEP and TTY) are listed. Also included are the average and peak number of messages per hour for the four-site average, the hypothetical minimum, typical, and maximum site configurations.

A detailed description of the derivation process, with an example, is found in Section 3.3.2 of this report. Flow control messages are contained within the ARTCC port type on the forms. No communications with DARC were observed because DARC was not enabled.

Table B-1. 9020 NON-RADAR INPUT MESSAGE TRAFFIC
(CATEGORY: FLIGHT PLAN)

Message Types			Average/Peak Messages/Hour/Link/Port Type				Average/Peak Messages/Hour/Site			
DART ID	9020 ID	Name	ARTCC	ARTS	FDEP	TTY	4-Site Average	Minimum Site	Typical Site	Maximum Site
AM	AM1	Amendment	15.3/25.8	0/0	1.6/3.7	0/0	79/146	39/70	102/188	155/292
DM	DM	Departure	0/0	28.7/86.7	4.0/17.7	0/0	103/386	49/175	150/544	292/1051
FP	FP1	Flight plan	26.0/43.7	0/0	0.3/0.5	15.6/27.5	176/301	116/200	213/364	300/513
FR	FR1	Flight plan readout request	0/0	0/0	0.7/2.8	0/0	0/0	0/0	0/0	0/0
HM	HM1	Hold	0/0	0/0	0.02/0.1	0/0	0.3/1	0.1/0.45	0.3/1	1/3
PR	PR	Progress report	0/0	0/0	0.06/0.3	0/0	1/4	0.3/2	1/5	2/9
RS	RS1	Remove strip	0.3/1.4	0/0	0.6/1.6	0/0	9/26	4/11	9/33	20/58
SP	SP	Stereo flight plan	0/0	0/0	0.08/0.4	2.6/7.6	13/41	11/32	14/44	21/65
SR	SR	Strip request	0/0	0/0	1.5/3.1	0/0	20/41	8/16	24/50	45/93
Category Total Messages/Hour/Link			41.6/70.9	28.7/86.7	8.9/30.2	18.2/35.1				
4-Site Average Messages/Hour/Site			156/266	50/152	118/398	77/130	401/946			
Minimum Site Messages/Hour/Site			83/142	29/87	45/150	70/127		227/506		
Typical Site Messages/Hour/Site			207/355	85/260	141/483	80/131			513/1229	
Maximum Site Messages/Hour/Site			290/496	172/520	267/906	107/162				836/2084

Table B-2. 9020 NON-RADAR INPUT MESSAGE TRAFFIC
(CATEGORY: WEATHER)

Message Types			Average/Peak Messages/Hour/Link/Port Type				Average/Peak Messages/Hour/Site			
DART ID	9020 ID	Name	ARTCC	ARTS	FDEP	TTY	4-Site Average	Minimum Site	Typical Site	Maximum Site
UW	UW	Upper wind	0/0	0/0	0/0	0.7/5.1	4/24	3/21	4/26	5/36
WX	WX1	Weather	0/0	0/0	0/0	12.6/25.6	60/122	50/102	63/128	88/179
Category Total Messages/Hour/Link			0/0	0/0	0/0	13.3/30.7				
4-Site Average Messages/Hour/Site			0/0	0/0	0/0	64/146	64/146			
Minimum Site Messages/Hour/Site			0/0	0/0	0/0	53/123		53/123		
Typical Site Messages/Hour/Site			0/0	0/0	0/0	67/154			67/154	
Maximum Site Messages/Hour/Site			0/0	0/0	0/0	93/215				93/215

Table B-3. 9020 NON-RADAR INPUT MESSAGE TRAFFIC
(CATEGORY: TRAFFIC FLOW MANAGEMENT)

Message Types			Average/Peak Messages/Hour/Link/Port Type				Average/Peak Messages/Hour/Site			
DART ID	9020 ID	Name	ARTCC	ARTS	FDEP	TTY	4-Site Average	Minimum Site	Typical Site	Maximum Site
DZ	DZ1	Flow control F. P. Departure	4.1/22.3	0/0	0/0	0/0	15/84	8/45	21/112	29/156
FZ	FZ1	Flow control F. P. information	0.8/4.3	0/0	0/0	0/0	3/16	2/9	4/22	6/30
RZ	RZ1	Flow control F. P. cancellation	0.13/0.7	0/0	0.02/0.2	0/0	1/5	0.4/2	1/7	2/11
Category Total Messages/Hour/Link			5.1/27.3	0/0	0.02/0.2	0/0				
4-Site Average Messages/Hour/Site			19/102	0/0	0.2/3	0/0	19/105			
Minimum Site Messages/Hour/Site			10/55	0/0	0/1	0/0		10/56		
Typical Site Messages/Hour/Site			26/138	0/0	0.3/3	0/0			26/141	
Maximum Site Messages/Hour/Site			36/191	0/0	1/6	0/0				37/197

Table B-4. 9020 NON-RADAR INPUT MESSAGE TRAFFIC
(CATEGORY: MISCELLANEOUS)

Message Types			Average/Peak Messages/Hour/Link/Port Type				Average/Peak Messages/Hour/Site			
DART ID	9020 ID	Name	ARTCC	ARTS	FDEP	TTY	4-Site Average	Minimum Site	Typical Site	Maximum Site
DA	DA1	Transmission accepted	101.1/172.2	129.3/302.5	0/0	0/0	605/1175	332/647	893/1769	1484/3020
DR	DR1	Transmission rejected	0.9/3.0	2.1/5.6	0/0	0/0	7/21	4/12	11/32	19/55
GI	GI1	General information	0.07/0.4	0/0	0.08/0.3	0/0	1/5	1/2	2/7	3/12
TA	TA1	Accept transfer	24.9/41.4	24.4/61.0	0/0	0/0	136/262	74/144	198/390	321/656
TB	TB	Terminate beacon code	0/0	51.0/178.9	0/0	0/0	89/313	51/179	153/537	306/1073
TI	TI1	Initiate transfer	26.1/42.2	25.4/79.8	0/0	0/0	142/298	78/164	207/450	335/774
TR	TR1	Test message	0.07/0.36	60.4/130.9	0/0	0/0	106/230	61/132	182/395	363/788
TU	TU1	Track update	188.7/320.9	163.0/520.0	0/0	0/0	993/2115	540/1162	1433/3165	2299/5366
Category Total Messages/Hour/Link			341.8/580.5	455.6/1278.7	0.08/0.3	0/0				
4-Site Average Messages/Hour/Site			1282/2177	797/2238	1/4	0/0	2080/4419			
Minimum Site Messages/Hour/Site			684/1161	456/1279	1/2	0/0		1141/2442		
Typical Site Messages/Hour/Site			1710/2904	1368/3836	1/5	0/0			3079/6745	
Maximum Site Messages/Hour/Site			2393/4063	2735/7672	2/9	0/0				5130/11,744

Table B-5. 9020 NON-RADAR INPUT MESSAGE TRAFFIC
(CATEGORY: UNCATEGORIZED)

Message Types			Average/Peak Messages/Hour/Link/Port Type				Average/Peak Messages/Hour/Site			
DART ID	9020 ID	Name	ARTCC	ARTS	FDEP	TTY	4-Site Average	Minimum Site	Typical Site	Maximum Site
CONTL	15UM2	Unknown	0/0	0/0	0/0	0.3/1.0	2/5	1/4	2/5	2/7
CORR	15UM3	Unknown	0/0	0/0	0.02/0.09	0.11/0.38	1/3	1/2	1/3	1/5
UNDEF	15UM6	Unknown	0/0	8.9/59.3	0.13/3	0.3/1.3	19/150	11/80	30/232	59/455
Category Total Messages/Hour/Link			0/0	8.9/59.3	0.15/3.1	0.71/2.7				
4-Site Average Messages/Hour/Site			0/0	17/104	2/41	3/13	22/158			
Minimum Site Messages/Hour/Site			0/0	9/60	1/15	3/11		13/86		
Typical Site Messages/Hour/Site			0/0	27/178	2/49	4/13			33/240	
Maximum Site Messages/Hour/Site			0/0	52/355	5/93	5/19				62/467

Table B-6. 9020 NON-RADAR OUTPUT MESSAGE TRAFFIC
(CATEGORY: FLIGHT PLAN)

Message Types			Average/Peak Messages/Hour/Link/Port Type				Average/Peak Messages/Hour/Site			
DART ID	9020 ID	Name	ARTCC	ARTS	FDEP	TTY	4-Site Average	Minimum Site	Typical Site	Maximum Site
AM	AM2	Amendment	10.1/34.8	13.0/51.3	0/0	0/0	61/220	33/121	90/328	149/551
ARR	2AS	Arrival strip	0/0	0/0	6.7/15.0	0/0	89/199	34/75	107/240	201/450
CX	CX	Cancellation/Remove strip	0/0	3.3/9.6	0/0	0/0	6/17	3/10	10/29	20/58
DEP	2DS	Departure strip	0/0	0/0	10.2/19.8	0/0	135/262	51/99	163/317	306/594
FP	FP2 et. al.	Flight plan readout	29.0/52.6	58.1/132.4	0/0	0.5/4.0	213/448	118/252	322/680	556/1191
FPRDO	FR2	Flight plan readout	0/0	0/0	0.6/1.8	0/0	8/24	3/9	10/29	18/54
OVFLT	2OS	Overflight strip	0/0	0/0	4.7/10.5	0/0	62/139	24/53	75/168	141/315
RS	RS2	Remove strip	0.8/2.3	0/0	1.8/2.4	0/0	27/40	11/17	33/50	60/88
Category Total Messages/Hour/Link			39.9/89.7	74.4/193.3	24.0/49.5	0.6/4.0				
4-Site Average Messages/Hour/Site			150/336	130/338	318/656	3/19	601/1349			
Minimum Site Messages/Hour/Site			80/179	74/193	120/248	2/16		277/636		
Typical Site Messages/Hour/Site			200/449	223/580	384/792	3/20			810/1841	
Maximum Site Messages/Hour/Site			279/628	447/1160	721/1485	4/28				1451/3301

Table B-7. 9020 NON-RADAR OUTPUT MESSAGE TRAFFIC (CATEGORY: WEATHER)

Message Types			Average/Peak Messages/Hour/Link/Port Type				Average/Peak Messages/Hour/Site			
DART ID	9020 ID	Names	ARTCC	ARTS	FDEP	TTY	4-Site Average	Minimum Site	Typical Site	Maximum Site
WTHRO		Weather	0/0	0/0	0.08/4.0	0/0	1/53	0.4/20	1/64	2/120
Category Total Messages/Hour/Link			0/0	0/0	0.08/4.0	0/0				
4-Site Average Messages/Hour/Site			0/0	0/0	1/53	0/0	1/53			
Minimum Site Messages/Hour/Site			0/0	0/0	0.4/20	0/0		0.4/20		
Typical Site Messages/Hour/Site			0/0	0/0	1/64	0/0			1/64	
Maximum Site Messages/Hour/Site			0/0	0/0	2/120	0/0				2/120

Table B-8. 9020 NON-RADAR OUTPUT MESSAGE TRAFFIC
(CATEGORY: TRAFFIC FLOW MANAGEMENT)

Message Types			Average/Peak Messages/Hour/Link/Port Type				Average/Peak Messages/Hour/Site			
DART ID	9020 ID	Name	ARTCC	ARTS	FDEP	TTY	4-Site Average	Minimum Site	Typical Site	Maximum Site
DZ	DZ2	Flow control F. P. departure	4.5/14.3	0/0	0/0	0/0	17/54	9/28	23/72	32/100
FZ	FZ2	Flow control F. P. information	0.7/2.4	0/0	0/0	0/0	3/9	1/5	4/12	5/17
RZ	RZ2	Flow control F. P. cancellation	0.3/1.4	0/0	0/0	0/0	1/5	1/3	2/7	2/10
Category Total Messages/Hour/Link			5.5/18.1	0/0	0/0	0/0				
4-Site Average Messages/Hour/Site			21/68	0/0	0/0	0/0	21/68			
Minimum Site Messages/Hour/Site			11/36	0/0	0/0	0/0		11/36		
Typical Site Messages/Hour/Site			29/91	0/0	0/0	0/0			29/91	
Maximum Site Messages/Hour/Site			39/127	0/0	0/0	0/0				39/127

Table B-7. 9020 NON-RADAR OUTPUT MESSAGE TRAFFIC
(CATEGORY: WEATHER)

Message Types			Average/Peak Messages/Hour/Link/Port Type				Average/Peak Messages/Hour/Site			
DART ID	9020 ID	Names	ARTCC	ARTS	FDEP	TTY	4-Site Average	Minimum Site	Typical Site	Maximum Site
WTHRO		Weather	0/0	0/0	0.08/4.0	0/0	1/53	0.4/20	1/64	2/120
Category Total Messages/Hour/Link			0/0	0/0	0.08/4.0	0/0				
4-Site Average Messages/Hour/Site			0/0	0/0	1/53	0/0	1/53			
Minimum Site Messages/Hour/Site			0/0	0/0	0.4/20	0/0		0.4/20		
Typical Site Messages/Hour/Site			0/0	0/0	1/64	0/0			1/64	
Maximum Site Messages/Hour/Site			0/0	0/0	2/120	0/0				2/120

Table B-8. 9020 NON-RADAR OUTPUT MESSAGE TRAFFIC (CATEGORY: TRAFFIC FLOW MANAGEMENT)											
Message Types			Average/Peak Messages/Hour/Link/Port Type				Average/Peak Messages/Hour/Site				
DART ID	9020 ID	Name	ARTCC	ARTS	FDEP	TTY	4-Site Average	Minimum Site	Typical Site	Maximum Site
DZ	DZ2	Flow control F. P. departure	4.5/14.3	0/0	0/0	0/0	17/54	9/28	23/72	32/100
FZ	FZ2	Flow control F. P. information	0.7/2.4	0/0	0/0	0/0	3/9	1/5	4/12	5/17
RZ	RZ2	Flow control F. P. cancellation	0.3/1.4	0/0	0/0	0/0	1/5	1/3	2/7	2/10
Category Total Messages/Hour/Link			5.5/18.1	0/0	0/0	0/0				
4-Site Average Messages/Hour/Site			21/68	0/0	0/0	0/0	21/68			
Minimum Site Messages/Hour/Site			11/36	0/0	0/0	0/0		11/36		
Typical Site Messages/Hour/Site			29/91	0/0	0/0	0/0			29/91	
Maximum Site Messages/Hour/Site			39/127	0/0	0/0	0/0				39/127

Table B-9. 9020 NON-RADAR OUTPUT MESSAGE TRAFFIC (CATEGORY: MISCELLANEOUS)

Message Types			Average/Peak Messages/Hour/Link/Port Type				Average/Peak Messages/Hour/Site			
DART ID	9020 ID	Name	ARTCC	ARTS	FDEP	TTY	4-Site Average	Minimum Site	Typical Site	Maximum Site
ACCPT	12AX	Accept	0/0	0/0	4.4/9.1	0/0	58/121	22/46	70/146	132/273
DA	DA2	Transmission accepted	92.1/145.8	122.1/352.2	0/0	0/0	559/1163	306/644	827/1786	1377/3134
DR	DR2	Transmission rejected	0.93/2.2	4.9/32.9	0/0	0/0	12/66	7/37	19/110	36/213
DT	DT2	Data Test	0.1/0.4	56.7/149.0	0/0	0/0	99/262	57/150	170/449	341/897
ERROR	12EX	Error	0/0	0/0	0.6/1.7	1.1/3.3	14/38	8/22	16/43	27/74
GI	GI2	General information	0.1/0.4	0/0	0.6/2.0	0.3/2.2	10/38	4/20	11/45	21/78
REJCT	12RX	Reject	0/0	0/0	1.3/3.4	0.5/1.9	20/54	9/25	23/64	43/115
ROGER	R	Roger	0/0	0/0	0.1/0.3	17.1/22.3	83/110	69/91	87/116	123/165
TA	TA2	Accept transfer	26.5/43.1	25.6/79.6	0/0	0/0	144/301	79/166	209/454	339/779
TI	TI2	Initiate transfer	26.1/44.2	26.0/61.6	0/0	0/0	143/274	78/150	209/406	339/679
TU	TU2	Track update	149.0/255.1	191.6/527.8	0/0	0/0	894/1880	489/1036	1320/2859	2193/4953
Category Total Messages/Hour/Link			294.8/491.2	426.9/1203.1	7.0/16.5	19.0/29.7				
4-Site Average Messages/Hour/Site			1106/1842	747/2105	93/219	90/141	2036/4307			
Minimum Site Messages/Hour/Site			590/982	427/1203	35/83	76/119		1128/2387		
Typical Site Messages/Hour/Site			1473/2456	1281/3609	112/264	95/149			2961/6478	
Maximum Site Messages/Hour/Site			2066/3438	2562/7219	210/495	133/208				4971/11,360

Table B-10. 9020 NON-RADAR OUTPUT MESSAGE TRAFFIC
(CATEGORY: UNCATEGORIZED)

Message Types			Average/Peak Messages/Hour/Link/Port Type				Average/Peak Messages/Hour/Site			
DART ID	9020 ID	Name	ARTCC	ARTS	FDEP	TTY	4-Site Average	Minimum Site	Typical Site	Maximum Site
AMIPR		Unknown	0/0	0/0	1.3/12.9	0/0	17/171	6/64	21/206	39/387
DPCOR		Unknown	0/0	0/0	0.3/0.7	0/0	4/9	2/4	5/11	9/21
UNDEF		Messages not identified	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Category Total Messages/Hour/Link			0/0	0/0	1.6/13.6	0/0				
4-Site Average Messages/Hour/Site			0/0	0/0	21/180	0/0	21/180			
Minimum Site Messages/Hour/Site			0/0	0/0	8/68	0/0		8/68		
Typical Site Messages/Hour/Site			0/0	0/0	26/217	0/0			26/217	
Maximum Site Messages/Hour/Site			0/0	0/0	48/408	0/0				48/408

APPENDIX C

MONITOR MESSAGE TYPES

All monitor message types are "Supervisory" (Category 13). None are included in this study or the message index compiled as part of this study. Lists of these monitor message types follow:

INPUTS

Message Type	ID	Ref.NAS-MD-317 Par.
Add	ADDE	6.1.1
Change State of Non-Operational Elements	CHST	6.1.2
Connect Non-Operational Elements	CNCT	6.1.3
Delete Element	DELE	6.1.4
Mandatory Replacement of an Operational Element	MREP	6.1.5
Output Configuration-Related Data	OUTP	6.1.6
Replace and Operational Element	REPL	6.1.7
Set Address Translation Register of a Non-Operational Element	SATR	6.1.8
Set Configuration Control Register of a Non-Operational Element	SCON	6.1.9
Set Non-Operational Elements Available	SETA	6.1.10
Set Non-Operational Elements Unavailable	SETU	6.1.11
Operational System Startover	STVR	6.1.12
Request Logical Device Assignment	ASGN	6.1.13
Set Date	DATE	6.1.14
End of Initialization Inputs	ENDI	6.1.15
Inquire Assignment of Logical Devices	ISGN	6.1.16
No-Op I/O on Logical Device	NPIO	6.1.17
Set Active Recording Category	SARC	6.1.18
Set Time of Day	TIME	6.1.19
Op I/O on a Logical Device	OPIO	6.1.20
Use Recovery Data	USRE	6.1.21
I/O Check Report Summary Interval	CRSI	6.1.22
Inhibit Poll	INHP	6.1.23
Inquire Assignment of Physical Device	DSGN	6.1.24
Resume Poll	RSMP	6.1.25
NRKM Status Update	NRKU	6.1.26
NRKM Reconfiguration Request	NRKR	6.1.27

INPUTS (continued)

Message Type	ID	Ref.NAS-MD-317 Par.
Inhibit Disk	IDSK	6.1.28
Use Disk	UDSK	6.1.29
Request Full Summary Report	UDSK	6.1.30
Initiate Selective Rejection of Equipment Identities for SMMC	IMMC	6.1.31
Resume Change Message Processing of Equipment Identities for SMMC	RMMC	6.1.32
SMMC Status	SMMC	6.1.33
Set Surveillance Tie-Off	SSTO	6.1.34
CPU Status	CPUU	6.1.35
IOCE Offloading Status	OFLD	6.1.36
Change Message		8.1.2
Check Message		8.1.3
Summary Read-In Message		8.1.4
Element Summary Report		8.1.5
Reconfiguration Command Message	RCON	9.1.1
Maintenance Reconfiguration	MCON	9.1.2
Test Pattern Request	TSTP	9.1.3
Unit Configuration Status Request	UCON	9.1.4
Disable Configuration Control Module	TORU	9.1.6
Request Startover New Data Base	STVN	9.1.7
CDC Auto Abort Request Message	CBRT	9.1.11
CCC to CDD Clear Test Message		9.2.1
Test Pattern Request		9.2.2

OUTPUTS

Message Type	ID	Ref.NAS-MD-317 Par.
Intervention Required	INT REQ	6.2.1
Primary Failed - Backup Failed		6.2.2
Configuration Summary		6.2.3
Failed to Load System from Physical Device		6.2.4
Insufficient Elements Available		6.2.5
System Waiting		6.2.6
Monitor Messages Lost/Discarded		6.2.7
Operational Processing Suspended, Terminated, or Resumed		6.2.8
System Restart Required		6.2.9
Ready New Tape		6.2.10
Operational Reconfiguration		6.2.11
Degraded Mode-Insufficient Elements		6.2.12
Element Configured I/O of System		6.2.13
No Redundancy Available		6.2.14
Date and Name of System File		6.2.15
Recovery Aborted Due to Element Failure		6.2.16

OUTPUTS

Message Type	ID	Ref.NAS-MD-317 Par.
I/O Error Table Full		6.2.17
CTS Down		6.2.18
Save SAR Tape		6.2.19
System Analysis Recording Suspended		6.2.20
Enter Initialization Inputs		6.2.21
Successful Startup		6.2.22
Unsuccessful Startup		6.2.23
Unsuccessful Startover		6.2.24
Successful Startover		6.2.25
Recovery Logical Device Failed		6.2.26
Recovery Data Unavailable for Startover		6.2.27
Program Element (PE) Abort		6.2.28
I/O Check Report		6.2.29
Element Check Report		6.2.30
CTS Time Drift		6.2.31
Element Looping on I/O Interrupts		6.2.32
APULS Failing to Poll LDN		6.2.33
NRKM Configuration Summary Printout		6.2.34
Intervention Cleared		6.2.35
NRKM Reconfiguration Notice Printout		6.2.36
NRKM Reconfiguration Due to GPI Adapter Failure		6.2.37
NRKM Automatic Reconfiguration Attempt Unsuccessful		6.2.38
NRKM Error Printouts		6.2.39
Time Span of SAR Loss		6.2.40
Monitor Abort		6.2.41
Failed to Load Recovery Data		6.2.42
System Abort		6.2.43
Date and File IDs of System Data Sets		6.2.44
Dynamic Buffer Storage Inventory		6.2.45
IOCE Processor Abort		6.2.46
Purpose		6.3.1
SMMC Change Message Printout		8.2.1
SMMC Check Message Printout		8.2.2
SMMC Summary Read-In (SRI) Message Printout		8.2.3
SMMC Summary Report Printout		8.2.4
Exceptional Status Summary Report	ESSR	8.2.5
RCRD to CCC Message		9.3.1
Startup/Startover Message		9.3.2
Startup/Startover Advisories and Error Printouts		9.3.3
Site Parameter Error Printout		9.3.4
Reconfiguration Message (see Table 9-2)		9.3.5
CDC Reconfiguration Message Printouts		9.3.6

OUTPUTS (continued)

Message Type	ID	Ref.NAS-MD-317 Par.
Configuration Status Report		9.3.7
Unit Failure Report		9.3.8
CDC Performance Report		9.3.9
Invalid Data From the CDC		9.3.10
Summary Message Processing		9.3.11
Common Requirement		9.4.1
DCC Performance Report		9.4.2
Site Parameter Error Printout		9.4.3
Invalid DCC Order Word Printout		9.4.4
DCC to CCC Clear Text Message		9.4.5
Summary Message Processing		9.4.6
Startup Timeout Error Printout		9.5.1
CDC Non-Response to Startup/Startover Data		9.5.2
Initial Configuration Error Printout		9.5.3
Auto-Assign to Single Channel Mode		9.5.4
CDC Is Down		9.5.5
CDC IS Up Again		9.5.6
Auto-Assign to Dual Channel Mode		9.5.7
Intervention Required - CDC/CCC Have Lost		9.5.8
Summary Message Printouts		9.5.9
CCC/DCC Communication Paths		9.6.1
Reconstitution Message		9.7