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SOFTWARE IMPACT OF SELECTED EN ROUTE ATC COMPUTER REPLACEMENT S--ETC(U)

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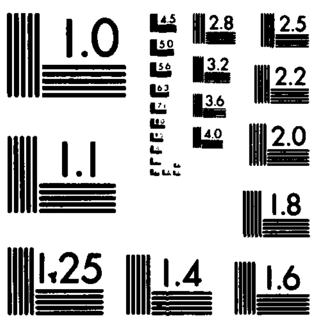

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SOFTWARE IMPACT OF SELECTED EN ROUTE ATC COMPUTER REPLACEMENT STRATEGIES

DECEMBER 1979

FINAL REPORT

U.S. DEPARTMENT OF TRANSPORTATION
Federal Aviation Administration
800 Independence Avenue S.W.
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16. Abstract

The report provides the results of a study of the impacts and software constraints associated with transitioning to a new En Route Air Traffic Control System. The report deals with the functional splitting of existing major system functions (Flight Data Processing and Radar Data Processing) and new system enhancements (En Route Minimum Safe Altitude Warning and Flight Plan Conflict Probe) and implementing them in a new computer system attached to the existing IBM 9020 system via a selector channel. The report also discusses the replacement of the IBM 9020 computer with a modern, instruction-compatible computer system. The report presents the required changes and predicted CPU and intersystem channel loading for each functional split and provides implementation cost estimates.

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1. OVERVIEW

As the IBM 9020 computer system, the computational heart of the NAS En Route System, approaches the limit of its resource capacity, the definition of its replacement is now beginning. There are three basic approaches to developing and implementing the replacement: complete system replacement, staged system replacement, and 9020 hardware replacement.

Complete replacement of the system would call for hardware and software modification of the 9020 system to extend its useful life while a new system is being developed. Examples of modifications now being studied or implemented are the addition of a third selector channel pair and the off-loading of slow speed I/O handling to a minicomputer. Unfortunately these enhancements may end up as throw-away code and hardware. Since it is a one-step changeover, the transition problems are significant. A complete redesign of the system has the advantages, however, that software maintenance costs can be significantly reduced from current levels and the new system can make future enhancements such as Automated En Route Air Traffic Control (AERA) easier to implement.

The staged replacement approach would call for moving large functional blocks from the 9020 system to a new computer tied to the 9020 via selector channels. The first stage of this replacement approach can be implemented faster than complete replacement, meaning that some of the 9020 activities can be off-loaded. Thus the need for throw-away enhancements to the 9020 can be reduced or avoided. However, the success of the staged approach is limited by the capacity of the selector channel used to connect the new system to the 9020. The opportunity to redesign the software transitioned to the new system means that maintenance costs can be lowered. However, significant redesign may not be possible because of the requirement to maintain the interface to the 9020 system. The software risks for the staged replacement are less severe than for the complete replacement since the transition will take place in several steps, probably two to four.

The 9020 replacement approach would call for moving most of the existing software, unchanged, to a modern computer system that is instruction-compatible with the 9020. Current examples of the largest of such systems are the Amdahl 470/V7 and the IBM 3033. The transition problems are minimized with this approach because only a small portion of the software is changed. This same characteristic is also a disadvantage, however, because the existing software has high maintenance costs. Retaining the software means retaining the high costs of supporting the system.

1.1 Study Purpose and Report Contents

The purpose of this study was to determine the impact of the possible replacement approaches so that the FAA may determine which approach to use. The study was composed of three tasks as follows:

- Task 1: Determine the impact of moving major functions in the 9020 system to a new computer system. The major functions selected were Flight Data Processing (FDP) and Radar Data Processing (RDP).

- Task 2: Determine the impact of implementing new 9020 enhancements in a separate computer system. The enchancements chosen for study were Flight Plan Conflict Probe (FPCP) and En Route Minimum Safe Altitude Warning (E-MSAW).

- Task 3: Determine the changes required to move the existing 9020 software to a modern instruction-compatible computer system.

This report contains the results of the study performed for the three tasks. The report is composed of the following sections:

Section 1: Overview
Section 2: Approach
Section 3: Functional Split of Existing Functions
Section 4: Functional Split of New Functions
Section 5: 9020 Compatible Replacement
Section 6: Other Recommendations

The remainder of this section presents a summary of the results obtained in the study.

1.2 Summary

At first glance, the thought of splitting major functions out of the 9020 or implementing new functions in a separate computer is a formidable, if not impossible, undertaking. This system, composed of several hundred tables, programs, and subroutines, has many cross-linkages between the 14 applications subsystems, which would imply a very high selector channel load between the two computer systems to keep data up-to-date on both sides. The results of Logicon's study, however, reveal that a systematic approach to the movement of programs and tables yields a definition of a functional split that has a surprisingly low channel utilization. This indicates that after more than 10 years of continual modification, the En Route software is still surprisingly very well organized along functional lines. Table 1 presents a summary of the numerical results of the study. Included in the table are the reduction in 9020 CPU loading, intersystem channel loading, and estimated implementation costs of the four functional splits studied.

The intersystem channel loading for the RDP functional split, 29.9%, is the one item in Table 1 indicating a possible problem with this split. However, 24.1% of this loading is due to the intersystem transfers of one table, TW. A detailed look at Table TW reveals that almost exactly half of the table is composed of items which are referenced only by the RDP system. Thus the table can be split into two tables, one which is used only by the RDP system and does not have to be transferred to the other system, and one which must be shared. Making this change reduces the intersystem channel loading for the RDP split to approximately 17.8%.

Examination of the replacement of the 9020 by a modern instruction-compatible computer system also provided some interesting results. The power of an Amdahl 407/V7 or IBM 3033, for example, is sufficient to allow the specification of a single processor system for En Route air traffic control which has

TABLE 1. SUMMARY OF STUDY RESULTS

	FDP Split	RDP Split	E-MSAW Split	FPCP Split	9020 Replacement
9020 Applications Memory Reduction (words)	97,584	66,344	4,908	N/A	N/A
9020 Table Memory Reduction (words)	8,620	19,708	0	N/A	N/A
CPU Reduction in 9020 (% of 1 CE)	65.07	66.89	N/A	N/A	N/A
Split System Program Size (words)	138,853	101,630	4,908	59,522 est	N/A
Split System Table Size (words)	135,626	184,431	5,000 est	108,528 est	N/A
Intersystem Channel Load (%)	5.4	29.9*	.09	7.8	N/A
Affected Programs	88	75	18	74	40 est
Implementation Cost Estimate (man-months)	222	177	29	46	186

*Can be reduced to 17.8% by splitting Table TW between 8.6 and 3.9 times the power of the existing 9020, depending upon whether the replacement is a 9020A or 9020D installation, respectively.

Since it is a single-processor replacement, the need for the special instructions in the 9020 computer is eliminated. Thus the replacement processor requires no modification. The one exception to this is the MVW instruction, which is not used frequently in the 9020. Its use may be replaced by use of the MVC subroutine in the replacement system. A second backup processor is used to provide fail-safe capabilities. Providing a suitable set of peripherals available to the backup processor allows full scale testing, maintenance, and training activities to be performed on the backup processor without affecting the operational system.

2. APPROACH

This section presents Logicon's approach to determining the impact of placing existing or new functions in a separate computer system interfaced with the 9020 computer system. The paragraphs below discuss the steps required to determine the split of programs between the two systems and the resulting intersystem communications and table data changes required to accomplish the split. Also discussed are several assumptions made with respect to the nature of the hardware and software of the two computer systems after splitting.

2.1 Selection of Functional Splits

The first step is to determine the criteria to be used to select the programs and subprograms constituting the split function. The following criteria were used for this study:

- Simple intersystem interface
- Minimum Monitor communications
- Minimum change to existing programs
- Minimum intersystem data flow

A simple intersystem interface is needed to make maximum efficient use of the limited resources of the selector channel, which is the only means of communicating with the 9020. The selector channel has a maximum transmission rate of 400 Kbytes but will operate somewhat slower during operational usage due to the sharing of the total IOCE bandwidth of 800 Kbytes between multiplexor channels and up to three selector channels. Additionally, the initial implementation of the functional split will run more smoothly and subsequent software maintenance will be easier if the interface is kept as simple as possible.

Monitor communications should be minimized so that system overhead due to the functional split is as small as possible. It can be expected that the overhead associated with system locks will increase substantially with separated computer systems due to the need for simultaneous locks on both systems for tables common to the two systems. This means that no new Monitor interfaces should be established which are not essential to the existence of the second computer system. Thus programs or subroutines that are now CALLed or GOTOed directly should not be moved across the intersystem interface so that a data transfer both for program initiation and program return would be required. Programs activated via DEMAND, SEND, etc., may be separated across the intersystem interface since they now require Monitor communications for their initiation. This choice also has relevance to response-time performance of the split system in that Monitor-initiated programs already have built-in delays in their execution depending upon their priority and other concurrent system activities. Keeping the Monitor out of direct CALLed or GOTOed situations will help preserve the existing timing of those subprogram activities.

Minimum changes of the existing programs in the En Route system is a natural result of the two criteria discussed above. To satisfy the need for a minimum of Monitor communications and to keep the intersystem interface simple, multiple copies of some of the programs will be required. That is, the 9020 system will have copies of some of the programs in the second system and vice versa. To minimize the software maintenance costs of the resulting system, these copied programs should be functionally identical. It follows then that the higher-level programs using the copied programs should have the same interfaces with the lower-level programs.

The final criterion for selecting the programs in the split function is that the intersystem data flow across the selector channel is minimized because, as stated above, this system resource is limited. The minimization of intersystem data flow becomes particularly important when one sees that the selector channels can easily become overloaded in the existing 9020 system when system loads are high. Once the programs in the functional split are identified, care must be taken to transmit only necessary data between the two computer systems. Item-by-item data transfers should be avoided except in situations where either the frequency of occurrence is very low or operational considerations dictate that it be done. One example of a valid item-by-item transfer would be changes to the System Parameter table (SY), which are typically very low in frequency. Entry-by-entry data transfers would be the preferred method of moving data between the two systems; however, full-table transfers might be used in low-frequency instances or in cases where a substantial portion of the table requires updating. The update of the Airspace Index table (AN) after a resectorization might be one example of a full-table transfer. Maximum advantage should also be taken of data transfers which need only be made one way.

2.2 Table Data Usage

Once the composition of the functional split is determined, the usage of table data is examined to determine what, if any, software changes are needed and what tables will exist on either or both of the two computer systems. The source of the table usage data is the Subprogram Design Data (SDD) documents, which detail the design of the programs making up the various subsystems and the NAS XREF. The initial analysis effort determines what tables are set and/or used by the programs in each computer system. The set/use information is then separately combined for each of the two systems to develop the total set/use picture for each computer system. Where expected payoffs exist, individual table item set/use information may be examined for the possibility of breaking up a table so that only part of it is subject to intersystem transfer. The goal of this analysis activity is to determine which tables are unique to each system, which tables are either set or use only in a given system, and which tables must be shared. The following paragraphs discuss the development of this information and its implications on the data flow between the two computer systems.

2.2.1 Unique Tables

The set of tables unique to either system is determined by comparing the lists of tables referenced by the two systems. Any case of a table referenced in one list but not in the other is a case of a table unique to that system. This means that there will be only one copy of the table in the system where it is used and the table need not exist in the other system. If the table is of the use only variety, the system startup/startover mechanism will be responsible for establishing the table contents. The startup/startover mechanism may operate independently on the two systems or it may operate in the 9020 and load the other system's unique use only tables via the selector channel interface.

Once the unique tables have been determined, the remaining tables referenced by the two systems are those that are shared. In general this means that two copies of the tables will exist.

2.2.2 Use Only Tables

Once the unique tables have been identified, the use only tables in the split function are determined. This set of tables falls into two classes. The first class is the set of tables that are use only for the entire system. These tables need only be loaded into the split system at startup/startover and require no further attention. Since they are shared, there will be a copy of each table with identical contents in each of the two systems.

The second class of tables are those that are used only within the split function but are set in the 9020 system. These tables will generally require initialization in the split system at startup/startover, as was the case for the first class of tables. However, in this case the 9020 system will have to transmit updated entries in the tables to the split system as they are generated. As was stated above, item-by-item transfers may be performed but should be avoided where possible, and there may be cases where the transfers of complete table contents should be made.

2.2.3 Set Only Tables

The tables which are only set by the split function are handled similarly to the use only tables. In this case, however, the entry-by-entry transfers are made only from the split system to the 9020 system. Since these tables are set only within the split system, there is no requirement for initialization of them within the split system. However, there may be a requirement for initialization in the 9020 system at startup/startover. This initialization would be accomplished via the selector channel interface.

2.2.4 Fully Shared Tables

The remaining tables are both set and used by both systems in general. These tables should be considered then as a data base which must be kept updated with identical contents in both systems. These tables can be divided into two groups as discussed in the following paragraphs.

2.2.4.1 Communications Tables: The communications tables are those used specifically to pass information between pairs of programs. For example, the JI table is used by any program wanting to pass execution requests to the Beacon Code program, CBC. Used in this manner, these tables can be considered as extended calling sequences. If the requesting program is in one system and the serving program is in the other system, the table entry constructed for the request in one system is transferred across the interface and stored in the same table in the other system. Most of the communication table usages are unidirectional so that the table request entry need not and cannot be stored in the table in the requesting system. There would be no mechanism for deleting request entries after servicing without other system changes. For bidirectional communication table linkages, software changes will be required to keep the tables in both systems the same.

2.2.4.2 Fully Shared Data Base Tables: All tables remaining in this class exist in both computer systems and will require intersystem transfers in both directions whenever the tables are updated. If the number of tables in this group is high or the transmission frequencies of the tables are high, the individual items in the tables should be examined to determine if table splitting can be accomplished to put some of the items into set only or use only tables.

2.2.4.3 Independent Shared Tables: Because of the cross-copying of programs discussed in Section 2.1, certain communications tables that may be independently maintained will be duplicated in the two systems. These are communication tables where both the builder of a table entry, the requestor, is in the same system as the user of the table. For example, if program SBB (Table MW Management) resided in both computer systems, table MK (SBB communications) would be required in both systems. However the uses of MK in the two systems to supply information to the two copies of SBB would be independent and would not require coordination of the contents of MK between the two systems.

2.3 Assumptions

Several assumptions were made in the determination of the criteria used to split functions between two computer systems and in making decisions regarding the treatment of specific programs and tables for this study. These assumptions are discussed below.

All external communications with the En Route system were assumed to remain with the 9020 system. One exception to this is that for a split of the RDP functions into a separate computer, the radar input data would be moved with the RDP function to the new computer. This assumption was made so that the intersystem interface load would be minimized. If some or all of the slow speed I/O were moved to the new system, the supporting subsystems would also have to be moved; this would probably require that the display software be moved. By the time this is done, a split of RDP functions becomes a reverse split of FDP functions and vice versa.

The selector channel was assumed to be the only method of interface between the two systems. This is in fact true as there is no other high-speed communication link to the 9020 system. To use the selector channel as the intersystem interface, a third selector channel will have to be implemented. Tests determining the capability for successfully doing this are currently being performed at NAFEC. The maximum transmission rate of the third selector channel is 150 Kbytes. To achieve this, all current use of Command Chaining and Program Controlled Interrupts will have to be deleted from the existing 9020 programs.

For the study it was assumed that the 9020 table structures remain the same but that the table structures and word sizes could be different in the split computer system. If the split system is different with respect to these items, it will be responsible for reformatting table data to and from 9020 format as necessary. It should be noted, however, that allowing differences in table structures means that programs resident in both systems will have to be separately maintained until all programs have been transitioned out of the 9020.

The use of pointers in table entries cannot be tolerated in the split system because identical load addresses for tables and buffers cannot be assured. All present uses of pointers will have to be eliminated and replaced by table entry numbers that are assumed to be constant between systems. Likewise, any table data that are address numbers of any sort, such as the disk address of a flight plan, must either be eliminated or separated from the existing tables and maintained independently in the two systems. Such an item exists in the Core Resident Flight Plan Index table (FPCR).

Monitor programs were not addressed by the study as these would generally have to be rewritten for the split system. Significant modifications of the monitor routines in the 9020 would only be required in dispatching and queue management.

For the development of resource utilization changes caused by the functional split, the standard 50% load case (Test Area 602) was assumed as a basis. It was also assumed that there is no DYSIM activity, the system is not saturated, and there are no hardware malfunctions. The 50% load case represents a maximum load for the 9020A system. SPAR-64, a report of program execution frequencies in the A3d2.1 system, was used to determine table access frequencies. SPAR-64 results are also based upon the 50% load case. Table size estimates used in this report were obtained from the Universal Data Set (UDS) for the A3d2.8 system at NAFEC.

The usage of system locks and Test and Set locks is assumed to be essentially the same for the operation of the two systems except that the locking mechanism must lock the tables on both systems before table access is allowed.

Figure 1 presents a flowchart of such a locking mechanism. The figure shows the process of requesting a lock on the 9020 system and later releasing it. The locking process must be symmetric; the same LOCK/UNLOCK sequence must be processed in the same manner if it is initiated from the second computer system.

The split function system was assumed to also have the following characteristics implemented similarly to the 9020 system:

- Separate recovery recording
- Separate SAR/TAR facility
- Support library
- Queue management

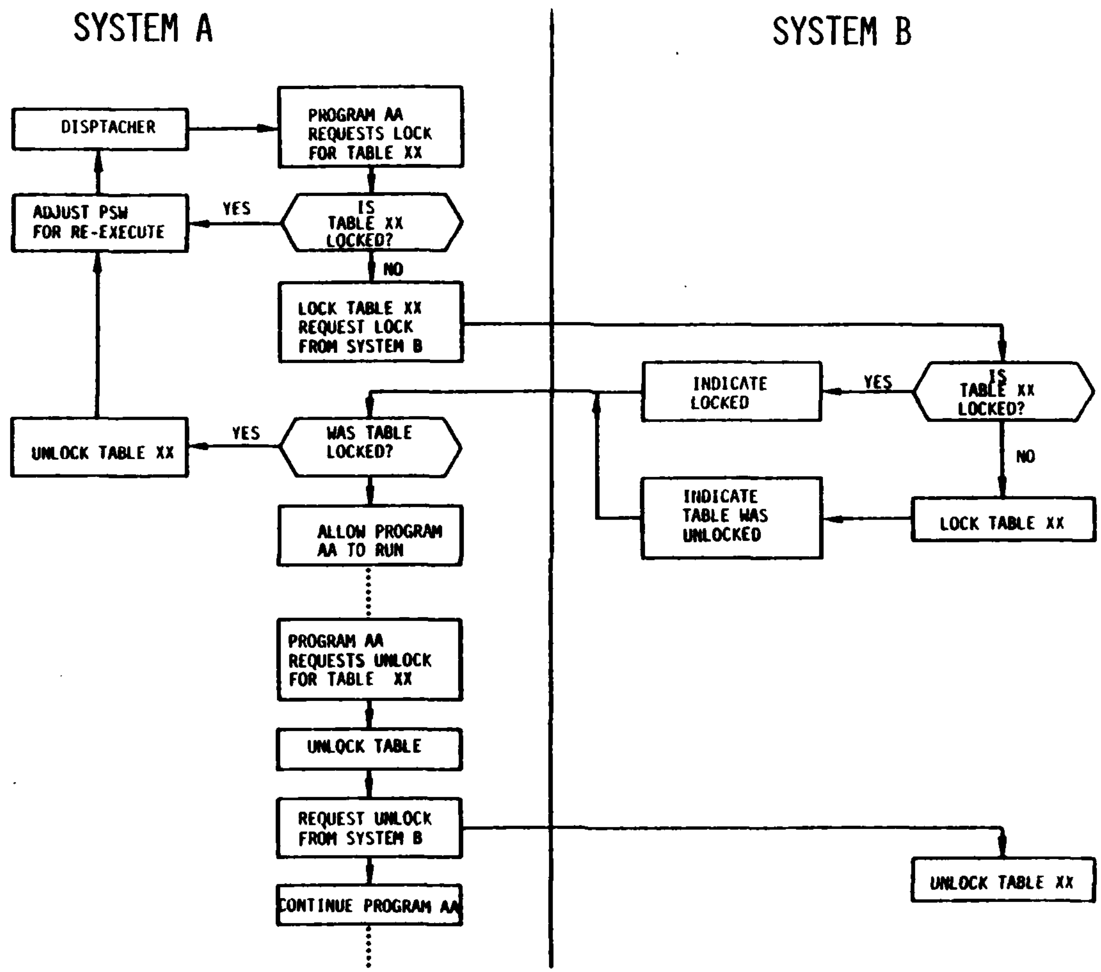


FIGURE 1. DUAL SYSTEM TABLE LOCK MECHANISM

3. FUNCTIONAL SPLIT OF EXISTING FUNCTIONS

For the study, two large functional splits of the existing En Route system were examined in detail. Large splits were chosen both because previous attempts at studying small splits had not proven promising and because the time schedule for the necessary replacement of the 9020 system indicates that the transition should be made in large steps. The Flight Data Processing (FPD) and Radar Data Processing (RDP) functions were chosen because one of these two functional areas will probably be the first split made if this strategy for transition to a new En Route computer is used. The study treated the two splits independently. That is, if FDP were the first functional split, the split of RDP would not be in addition to the FDP split and vice versa. The following paragraphs detail the results of the examination of these two functional areas.

3.1 FDP Functional Split

The definition of the FDP function selected for movement to a new computer system is the collection of programs which process all flight plans and related mesages such as amendments, holds, progress reports, mission flight plans, etc., and those programs which are responsible for maintenance of the flight plan data base. This gives rise to the natural selection of the programs in the following four subsystems as the set of programs to move to the new computer system:

Subsystem	Number of Words
Route Conversion	36,316
Posting Determination	33,182
Flight Plan Processing	53,042
Flight Plan Analysis	2,512
Total	125,052

The 74 programs making up these four subsystems are detailed in Table 2, which also gives their descriptions and memory size in words. It should be noted that the programs in the Preliminary Processing subsystem could have been included in the list of programs to move. However, movement of these programs would have resulted in higher data rates between the two systems and could have adversely affected response time performance more than the selected set of programs.

Since there are many cross calls between the programs in the various subsystems of the En Route program, the list of programs in Table 2 is incomplete. Examination of the calling sequence trees of the programs both in the FDP function and in the programs left on the 9020 system make both direct CALL- or GOTO-type and Monitor-initiated-type calls upon programs in the other system. Since we have limited intersystem program initiations to those that are already performed by the Monitor, this means that copies of some of the FDP programs will need to also reside in the 9020 system. Similarly, some of the remaining 9020 programs will need to also reside in the second system. The calling sequence trees also show that one of the FDP programs is never activated by any FDP program. This program, PCA, is only activated by CSF, which will remain on the 9020 system. Since PCA makes no calls upon any other FDP program, it can be left on the 9020 system. Table 3 details the FDP programs that will also reside on the 9020 system and Table 4 details the remaining 9020 programs that will also reside on the split system.

Using the sizing data in these tables and noting that PCA will remain in the 9020 system, the application programs memory size changes for the two systems are as follows:

9020 System decrease	97,584 words
FDP System	138,853 words

TABLE 2. FDP PROGRAMS

Name	Description	Size (Words)
BBA	Data Base Analyzer	404
BSD	Flight Plan Signoff and Drop Interrogator	1,346
BTQ	Table/Queue Interrogator	762
CRP	Compatibility Reject Processor	922
DAM	Amendment Message Processor	5,700
DDM	Departure Message Processor	2,060
DFA	Planned Shutdown Flight Plan Activator	730
DFP	Flight Plan Message Processor	2,142
DHM	Hold Message Processor	2,900
DMP	Mission Flight Plan Processor	1,548
DPR	Progress Report Processor	1,740
DRF	Request ARTS Transfer Processor	1,072
DRS	Remove Strip Processor	1,776
DSP	Stereo Flight Plan Processor	2,926
DUZ	Flight Data Base Synthesizer	4,128
LNM	Binary Search	42
PAM	Amendment-Merge	702
PAP	Airport Posting	2,456
PAT	ARTS Coordination	1,916
PCA	Posting Combination Addressing	608
PCD	Interfacility-Coordination	3,330
PLF	Advance Flow Control Qualifier	1,178
PLT	Altitude Amendment Merge	3,702
PJJ	Route-Posting Supervisor	3,158
PMC	Interfacility Route Record	1,478
PPD	Posting Modification	856
PPS	Pseudo-Route Record Processor	976
PRT	Route Amendment Merge	1,420
PSB	Sector Bypass	2,508
PTC	Fix-Time Calculation	4,960
PTM	Time Amendment Merge	946
RAA	Adapted Direct Route Processor	798
RAD	Arc Distance Computation	72
RAL	Altitude Transition Processor	1,536
RAM	Route Conversion Amendment Processor	3,598
RAP	Airway Conversion	1,982
RDP	Direct-Route Conversion	5,262
RDX	Fixed Point Arc Distance Computation	34
RFL	Route Conversion Flow Control	444
RGS	Gnomonic Plane to Stereographic Plane	34
RJJ	Route Conversion Supervisor	1,572
RKR	Coded-Route Conversion	4,964
RLI	Line Intercept Calculation	318
RPA	Fix Posting Area Trace	2,638

TABLE 2. FDP PROGRAMS (continued)

Name	Description	Size (Words)
RPF	Airspace Determination	1,428
RPR	Adapted Departure/Arrival Route Processor	2,566
RRD	Preferential Departure/Arrival Route Segment	2,890
RSG	Stereographic Plane to Gnomonic Plane	20
RTD	Transition Determination	5,860
SCA	Field 02 Processor	1,596
SCB	Field 03 Processor	334
SCD	Field 05 Processor	142
SCE	Field 06 Processor	404
SCF	Field 07 Processor	290
SCG	Field 08/09 Processor	570
SCH	Field 10 Format Check	1,980
SCJ	Field 10 Logic Check	5,812
SCK	Field 11 Processor	106
SCM	Field 18 Processor	548
SCN	Field 21 Processor	494
SCP	Field 22 Processor	322
SCR	Route Field Merge	4,062
SCU	Source Eligibility Check	1,194
SCX	Coordinate Conversion	706
SDA	Fix, FRD, and Lat/Long Format Check and Fix Search	966
SDB	CID Conversion	68
SDD	RC-to-RO Converter	1,922
SDE	Fix Compare	188
SDG	Duplicate Flight Plan Search	558
SDU	Amendment Output Initiator	3,094
SHA	Heading Angle Correction	22
STB	Chained-Table Management	278
UAK	Flight Plan Buffer Management	1,782
XFS	FPA Assignment	1,206
	Total	125,052

TABLE 3. FDP PROGRAMS COPIED IN 9020 SYSTEM

Name	Description	Size (Words)
BBA	Data Base Analyzer	404
BSD	Flight Plan Signoff and Drop Interrogator	1,346
BTQ	Table/Queue Interrogator	762
LNM	Binary Search	42
PCA	Posting Combination Addressing	608
PLF	Advance Flow Control Qualifier	1,178
PTC	Fix-Time Calculation	4,960
RAD	Arc Distance Computation	72
RDX	Fixed Point Arc Distance Computation	34
RLI	Line Intercept Calculation	318
RPF	Airspace Determination	1,428
RSG	Stereographic Plane to Gnomonic Plane	20
SCA	Field 02 Processor	1,596
SCB	Field 03 Processor	334
SCD	Field 05 Processor	142
SCE	Field 06 Processor	404
SCH	Field 10 Format Check	1,980
SCJ	Field 10 Logic Check	5,812
SCK	Field 11 Processor	106
SCU	Source Eligibility Check	1,194
SCX	Coordinate Conversion	706
SDA	Fix, FRD, and Lat/Long Format Check and Fix Search	966
SDB	CID Conversion	68
UAK	Flight Plan Buffer Management	1,782
XFS	FPA Assignment	1,206
	Total	27,468

TABLE 4. OTHER SYSTEM PROGRAMS COPIED IN FDP SYSTEM

Name	Description	Size (Words)
RML	Route Match Logic	1,052
SBA	Communication Table Management	218
SBB	Table MW Management	184
SBD	Table FPCR Management	690
SBE	Table FY Management	64
SFA	Flight Plan Data Base Read	596
SFC	Flight Plan Data Base Write	498
SFG	Flight Plan Buffer Management	48
SPF	Flight Plan Position	144
SRT	Response-Message Router	464
XPF	Flight Plan Data Formatter	1,224
XOT	Strip Output Timing	1,854
XPP	Flight Position Determination	968
XRL	Format Computer-Generated Message	1,405
	Total	9,409

3.1.1 Table Allocations for the FDP Functional Split

The following paragraphs present the allocations of the FDP-unique and FDP/9020 system shared tables to the two systems. Also discussed are the special processing or data transmission requirements for each class of tables described in Section 2. The results of these allocations show that 9020 table memory will be reduced by 8,620 words and the FDP system will have a table memory requirement of 135,626 words.

3.1.1.1 FDP-Unique Tables: Table 5 presents the tables unique to the separate FDP computer system. Since they are unique, no copies of the tables are required in the 9020 system and the resultant space savings may be used to increase the flight plan or dynamic buffers there. Both use only and set/use tables are in the list. The tables that are use only must be preset in the FDP system at startup/startover time either from a separate FDP adaptation file or from the existing 9020 adaptation file via the selector channel interface. To minimize the time required for a system restart, the adaptation presets should be separately accomplished in the FDP system.

3.1.1.2 Shared Use Only Tables in the FDP System: The use only tables in the FDP system form two classes. The first is the set of tables which are use only in the original unsplit system (Table 6). These tables are treated in the split the same as the unique use only tables and must be preset from adaptation data during startup/startover. During system operation there is no requirement for transferring any of these tables between the two systems.

The second class of use only tables within the FDP system is presented in Table 7. These are tables which are use only within the FDP system but are set by programs in the 9020 system. Some of the tables are preset from adaptation and would be loaded at startup/startover in the same manner as the use only tables. However, whenever one of these tables is updated in the 9020 system, the update will have to be transmitted to the FDP system via the selector channel interface. The transmissions should be made on an entry-by-entry basis wherever possible to minimize the frequency of transmissions.

TABLE 5. TABLES UNIQUE TO FDP SYSTEM

Name	Usage	Description	Size (Words)
AS	U	Adapted Line Segment Index	24
AX	U	Adapted Fix Stratification	1,050
BB	U	B-Line	5
BQ	U	Bearing Sensitive ARTS Coordination Reference	40
CC	S/U	Chained Table Management	6
CN	U	Coordination Fix	550
EA	U	External Airport	42
GT	S/U	Geographic Trace Communications	7
KK	S/U	Intermediate Route Record	4,950
LI	S/U	Line Segment Trace	18
LV	U	Altitude Stratification Array	8
NA	U	Name Array	1,053
PF	U	Posting FPA Array	176
RD	U	Adapted Direct Route Application	75
RI	S/U	XRF Communications	4
RO	S/U	Route Segment Input	18
RV	U	Arrival Fix/Coordination Fix Array	24
SL	U	S-Line	30
SZ	U	SID/STAR	40
WD	U	Flow Control Fuel Advisory Delay	500
		Total	8,620

TABLE 6. USE ONLY TABLES COPIED IN FDP SYSTEM

Name	Description	Size (Words)
AR	Airway	1,053
AW	Airway Index	44
AZ	Air-Carrier/Air-Taxi Identification	35
CB	Center Boundary Composition	127
CH	Channel Control	4
FF	Fix Stratification	1,539
JU	Junction Identification	145
JV	Junction Pointer	73
LR	System Analysis Recording Control	690
MC	Referred Response and Program-Initiated Message	35
NN	NAS Table Lengths	72
PC	Program Control Information	512
TA	Airport/Fix Off Airway/Coded Route	212
TN	Transition Route Control Fix	86
TP	Transition Route Pointer	43
TS	Stereo Data	3
	Total	4,673

TABLE 7. TABLES USED ONLY IN FDP SYSTEM BUT SET IN 9020 SYSTEM

Name	Description	Size (Words)
AD	Airport Data	379
AN*	Airspace Index	304
FE	FDEP Device	280
FR	FPCR Alphanumeric Chain Index	42
FS*	Flight Strip Status	62
HF	Track Numbered Display	2,100
MY	Message Identification	396
PR	Adapted Arrival and Departure Control	297
SY	System Parameters	320
TT	Teletypewriter Output Device	56
TY	IOT Output Device	20
WA*	Winds Aloft	624
WI*	Center Internal Flow Control Qualifier	210
WO*	Center External Flow Control Qualifier	210
	Total	5,300

*Lockable table

3.1.1.3 Set Only Tables in the FDP System: One table in the FDP system will be set only. This table is TW (Tracking Miscellaneous). Since the table is set only within the FDP system, no copy of the table is required in the system. The items set by the FDP system are assembled into a communication block and transferred to the 9020 system where they are merged into the functional copy of the TW table. If the table were to be placed in both systems, data transfers would have to be made both ways, resulting in higher selector channel utilization.

3.1.1.4 Fully Shared Tables in the FDP System: Several tables will be both set and used by both computer systems. Thus, in general, copies of the tables will be required in both systems. The tables form three groups: communications tables, data base tables, and independent shared tables. Each of these groups is discussed in the following paragraphs.

3.1.1.4.1 Shared Communications Tables in the FDP System - The shared communications tables form two groups, input and output. The input communications tables, presented in Table 8, are used in transmitting work requests from the 9020 system to the FDP system. The tables in this group must reside in both computer systems; however, the table contents may not be the same. When a program in the 9020 system wants to send a message to one of the FDP programs, for example, entries are built in the MG, MP, MT, and MW tables, sent across the selector channel to the FDP system, and stored in the same tables there. However, the table entries in the 9020 system are not retained since there will be no further reference to them by the 9020 system. When the processing of the message is completed in the FDP system, the associated entries for these tables will be deleted. If a 9020 program wants to send a message to another 9020 program, the MG, MP, MT, and MW entries will be built as before but they will be retained. Thus, while the tables will reside in both systems, their contents will be dissimilar.

The output communications tables, presented in Table 9, are treated in the same manner as the input communications tables except that the table entries are built in the FDP system and transmitted to the 9020 system for storage

TABLE 8. FDP INPUT COMMUNICATION TABLES FROM 9020 SYSTEM

Name	Description	Size (Words)
MG	Message Field Control	350
MP	Pending Message Control	360
MT*	Subprogram Message Control	250
MW*	Alphanumeric Message Data	500
TB	Chained Table Management Interface	3
	Total	1,463

*Lockable table

TABLE 9. FDP OUTPUT COMMUNICATION TABLES TO 9020 SYSTEM

Name	Description	To Program	Size (Words)
AQ**	ARTS Output Communication	CNA	380
BI**	SCV Communication	SCV	4
CK**	Conflict Alert Altitude Communication	RCD	54
DQ**	DARC Communication	CDA	120
FK**	SBD Communication	SBD	2
HE**	HTI Communication	HTI	144
HI**	HCI Communication	HCI	172
IP**	CIP Communication	CIP	40
IQ**	HRD Communication	HRD	20
IS**	Strip Printing/CRD Update Initiation	COP	120
JI**	CBC Request	CBC	450
MQ**	NAS Output Communication	CNN	150
PG**	Flight Plan Printout Communication	CSS	75
SF	CSF Communication	CSF	11
XQ**	CRJ Communication	CRJ	50
	Total		1,792

**Lock not required in FDP system

and the resultant execution. The table entries are not retained in the FDP system. In fact, since these tables are not used for any intra-FDP communications, no copy of these tables need exist in the FDP system; only the capability to build the table entries need exist.

3.1.1.4.2 Shared Data Base Tables - Table 10 presents the set/use tables shared between the 9020 system and the FDP system. Whenever either system updates an entry in one of these tables, the entry will have to be transmitted via the selector channel to the other system. The update and data transfer will have to be protected by the setting of a system lock for lockable table entries in both systems. Tables which do not now have locks will have to be examined individually to determine if locks will be required.

3.1.1.4.3 Independent Shared Tables in the FDP System - Table 11 presents the shared tables that may be independently maintained in the two computer systems. These tables may be independently maintained because the programs which set or use them are resident in both systems. The Pool Storage table, GTMAIN area, and all lock tables are also included in this group of tables.

3.1.2 FDP Resource Utilization and Implementation Estimate

This section presents estimates of the resource utilization changes due to the split of the FDP function into a separate computer system. Estimates are determined for the reduction in 9020 CPU usage and the loading of the selector channel used to communicate between the two systems. Also presented is an estimate of the manpower required to implement the functional split.

The CPU load on the 9020 system is reduced considerably due to the movement of the FDP function to another computer. Using the individual program CPU utilization measurements provided in SPAR-64, a total of 67.42% of a 9020A CE is moved to the new system due to the FDP programs and the other programs copied on the FDP system. For this estimate, new programs created since the measurements are not included. These programs are BBA, BSD, BTQ, PLT, PMO, PPS, PRT, PSB, PTM, RDX, SBE, SDG, SDU, SFA, SFC, and SFG. Using the data presented in

TABLE 10. FDP SHARED DATA BASE TABLES

Name	Description	Size (Words)
AP	Airport Index	186
AT*	NAS-to-ARTS Message Control	592
BE	Beacon Code Array	2,048
BF	RFA Flight Plan	12
BW	RFA Converted Route	12
DS	Buffered Flight Plan Data Set Record Availability	1,310
FD	Advance Flow Control Summary	15
FI	Route Processing Communication	19
FQ	FP Availability Entry	9
FPCR*	Core Resident Flight Plan Index	12,000
FPDK*	Disk Resident Flight Plan Index (includes AK, FL, MO)	37†
FY*	Supplemental Flight Plan Index	6,000
FZ*	Flight Strip and CRD Update Identification	1,500
GS	System Saturation Communication	21
HO*	Track Control/Display	13,300
IC	Interface Control Data	63
IR*	Automatic Track Initiation Point	60
IT*	List Display Data	1,920
IZ	Flight Plan Interrogation	30
JJ	Field 10 Processing Communication	6†
ME	Absolute Memory Equate	2†
PH*	System Operational Status	6
RA	Route Alphanumerics	175†
RC	Route Control	153
SC*	Sector Index	147
TC*	Facility Traffic Count	40
TK*	Tracking Data - Part 1	9,100
UC	Old Aircraft ID	153
XC*	CRD Device	208
XR	R-CRD Device	78
XS	XAK Signoff	2†
	Total	49,204

*Lockable table
†Buffered storage

TABLE 11. INDEPENDENT SHARED TABLES IN FDP SYSTEM

Name	Description	Size (Words)
FV	FP Software Lock Array	600
FX	Flight Plan Buffer	43,520
MK	SBB Communication	1
PO	Pool Storage	28,752
SX	MXS Working Area	300
UU	Test and Set Lock	21
	Total	73,194

Table A-1, the CPU usage added back into the 9020 due to intersystem lock usage is 2.1% of a CE. This figure is arrived at by summing the frequencies of the shared tables which are lockable and assuming a 250 usec overhead for the intersystem portion of the lock mechanism. Summing the execution frequencies of the programs which are Monitor-activated within the FDP system and estimating the frequencies of 9020 program activations due to the FDP system provides an estimate of the CPU usage caused by intersystem program activations. Using an estimate of 200 usec per activation, a CPU usage of .25% of a CE is estimated. Thus the total 9020 CPU load should be reduced by approximately 65.07% of a CE.

The expected loading of the selector channel used to tie the two systems together is determined by using the data in Table A-2, which provides transmission frequencies and transmission packet sizes for the shared tables, and by adding the loading due to intersystem locks and program activations. For the FDP functional split, the shared tables cause 5,378 bytes/sec to be transferred between the systems on the average. The associated intersystem locks, estimated from Table A-2 at 42.3 locks per second, cause a channel loading of 2,704 bytes/sec at four words per lock. The intersystem program activations, at two words per activation, cause a channel loading of 85.2 bytes/sec. With a selector channel capacity of 150 Kbytes per second, this results in a channel utilization of 5.4%.

The FDP functional split comprises direct changes to 88 programs which are either moved or copied to the FDP system. These programs contain approximately 134,000 instructions. Using a compiler expansion ratio of 6 to 1, 6 man-months per thousand lines of source code, and 1 man-month additional for each affected program, an estimate of 222 man-months for implementation is determined. This estimate assumes that the programs moved to the new computer system will be redesigned where feasible.

3.2 RDP Functional Split

The definition of the RDP functional split used for the study is the set of programs directly related to the processing of radar data. The following three subsystems make up that group:

o	Radar Processing and Automatic Tracking	26,280 words
o	Track Data Processing	41,170 words
o	Real-Time Quality Control	6,075 words
	Total	73,525 words

The 44 programs making up these three subsystems are presented in Table 12. Note that RIN has been included in the list of programs to be moved to the new system. This means that the I/O required to collect the radar information, less than 2% of each multiplexor channel, will be moved to the new system. A more significant effect of moving RIN to another system is that the IOCE on the 9020 system is then virtually idle with respect to program execution. According to Logicon's Response Time Analysis Study results, RIN uses an average of 17% of an IOCE. Thus IOCE Off-Loading could provide as much as 34% of a CE in processing power over and above the benefit it is now providing.

Examination of the cross calls between the programs in the two systems shows that several RDP programs should be copied in the 9020 system and vice versa. The programs to be copied in the two systems are shown in Tables 13 and 14. Using the sizing data in Tables 12, 13, and 14 the application programs memory size changes for the two systems are as follows:

9020 System decrease	64,344 words
RDP System	101,630 words

TABLE 12. RDP PROGRAMS

Name	Description	Size (Words)
CBC	PVD Beacon Code Selection	4,708
JQB	QAK CODE Organizer	4,480
JQD	CRD (QD) Message Type	1,076
JQN	QAK (QN) Message Processor	4,014
JQP	QAK PVD and QAK AUTO HAND Organizer	2,452
JQR	Reported Altitude, Interim Altitude, and Flight Plan Readout Processor	1,466
JQT	QAK TRACK Organizer	4,070
JQU	QAK QU Processor	4,882
JTA	TA Message Processor	666
JTI	TI Message Processor	2,324
JTU	Track Update Message Processor	514
KSI	Dynamic Simulation Input Processor	3,942
KSM	Start/Modify Simulation Inputs	102
KSS	Dynamic Simulation Startover	1,562
KSU	Dynamic Simulation Update Processor	2,820
RAT	Automatic Tracking	1,942
RBC	Sector Boundary	296
RBR	Buffer Reconstruction	578
RCA	Collimation Analysis	690
RCC	Intercenter Coordinate and Velocity Transformation	88
RCD	Conflict Detection	6,226
RDC	Radar Discrete Correlation	198
RFA	Flight-Plan-Aided Tracking	6,422
RFM	Reconstruction	696
RFR	Failed Radar Site	396
RIN	Radar Input Processor	1,666
RML	Route Match Logic	1,052
RRA	Registration Analysis	2,370
RRC	Radar Slant Range and Time Correction	298
RSL	Idle-Time Radar Data Processor	114
RSO	Scan-Oriented Quality Control	2,036
RTG	Beacon/Primary Radar Message Processor	2,714
RWD	Radar Write Direct Processor	208
RZM	Altitude Maintenance	1,934
SCV	Beacon Code Allocation	1,058
SDW	Flat Tracking Data Set Write	200
SFI	Flight Plan Insertion	380
SFL	Radar Reconstruction Preprocessor	44
SOC	Startup/Startover Processor	1,180
SOU	Restart Utility	583
SPF	Flight Plan Position	144
SRA	Fix or Point Determination	340
SRC	Surveillance Field 02 Processor	376
SRN	Track-Ball Processor	318
	Total	73,525

TABLE 13. RDP PROGRAMS COPIED IN 9020 SYSTEM

Name	Description	Size (Words)
KSI	Dynamic Simulation Input Processor	3,942
RBC	Sector Boundary	296
RCC	Intercenter Coordinate and Velocity Transformation	88
RML	Route Match Logic	1,052
SCV	Beacon Code Allocation	1,058
SDW	Flat Tracking Data Set Write	200
SFL	Radar Reconstruction Preprocessor	44
SOC	Startup/Startover Processor	1,180
SOU	Restart Utility	583
SPF	Flight Plan Position	144
SRC	Surveillance Field 02 Processor	376
SRN	Track-Ball Processor	318
	Total	9,281

TABLE 14. 9020 SYSTEM PROGRAMS COPIED IN RDP SYSTEM

Name	Description	Size (Words)
LNM	Binary Search	42
PTC	Fix-Time Calculation	4,960
RAD	Arc Distance Computation	72
RDX	Fixed Point Arc Distance Computation	34
RLI	Line Intercept Calculation	318
RPF	Airspace Determination	1,428
RSG	Stereographic Plane to Gnomonic Plane	20
SBA	Communication Table Management	218
SBB	Table MW Management	184
SBD	Table FPCR Management	690
SBE	Table FY Management	64
SBF	Table FC Management	244
SCA	Field 02 Processor	1,596
SCE	Field 06 Processor	404
SCG	Field 08/09 Processor	570
SCH	Field 10 Format Check	1,980
SCJ	Field 10 Logic Check	5,812
SCU	Source Eligibility Check	1,194
SCX	Coordinate Conversion	706
SDA	Fix, FRD, and Lat/Long Format Check and Fix Search	966
SFA	Flight Plan Data Base Read	596
SFC	Flight Plan Data Base Write	498
SFG	Flight Plan Buffer Management	48
SHA	Heading Angle Correction	22
SHF	Table TK/HF Manager	494
SPF	Flight Plan Position	144
SRT	Response-Message Router	464
STS	Saturday to Sunday	110
XOT	Strip Output Timing	1,854
XPP	Flight Position Determination	968
XRL	Format Computer-Generated Message	1,405
	Total	28,105

3.2.1 Table Allocations for the RDP Functional Split

The following paragraphs present the allocations of the RDP-unique and RDP/9020 system shared tables in the two systems. Also discussed are the special processing or data transmission requirements for each class of table described in Section 2. The results of these allocations show that 9020 table memory will be reduced by 19,708 words and the RDP system will have a table memory requirement of 184,431 words.

3.2.1.1 RDP-Unique Tables: Table 15 presents the tables that are unique to the RDP computer system. No copies of these tables are required in the 9020 system as no programs in that system reference the tables. The use only tables must be preset from adaptation data at startup/startover either from the 9020 system or independently in the RDP system. Independent loading of the use only tables in the RDP system will minimize the time required for system restart.

3.2.1.2 Shared Use Only Tables in the RDP System: Tables 16 and 17 present the tables which are use only within the RDP system. Both sets of tables require preset from adaptation at system startup/startover time. For the tables presented in Table 16, no further special processing is required since these tables are never altered in the original unsplit 9020 system. The tables presented in Table 17, however, are set by programs in the 9020 system and use only within the RDP system. Thus, whenever a 9020 system program updates one of these tables, the affected table entry or item must be transmitted to the RDP system over the selector channel interface.

3.2.1.3 Set Only Tables in the RDP System: There are no shared set only tables in the RDP system.

3.2.1.4 Fully Shared Tables in the RDP System: Several shared tables will be both set and used by both computer systems, which means that copies of the tables will be required in both systems. The uses of the tables involving one-way and two-way communications between the systems as well as independent table maintenance are discussed in the following paragraphs.

TABLE 15. TABLES UNIQUE TO RDP SYSTEM

Name	Usage	Description	Size (Words)
AH	U	Rho, Theta Modification	1,954
BV	U	VFR/Tower Beacon Code	3
CMD	S/U	Duplicate RTQC Correction Factors	42
ES	U	Expanded Search Area Array	28
FH	S/U	Rho, Theta Work Area	896
FT	U	Rho, Theta Filter	896
FW	S/U	Record Reconstruction Work Area	5,504
HT	U	Hold Pattern	14
JB	S/U	Beacon Test Message	300
JF	S/U	Fixed Search Test Message	200
JP	S/U	Permanent Echo Intermediate Calculation	252
JR	S/U	RIN Beacon Code History Synchronization	60
JS	S/U	Status Message	300
ND	U	VFR Non-Discrete Code	2
PI	U	Partition Index	18
PM	S/U	Processor (MACH) Control	20
RE	S/U	Registration Data Selection	3,034
RGD	S/U	Duplicate Selective Rejection Radar Sort Box	1,517
RH	S/U	Radar Buffers	1,596
RK	S/U	Registration Beacon Code Array	2,048
RL	S/U	Registration Site Pair Mask	44
RN	S/U	Radar Data	14
RTD	S/U	Dynamic Simulation Radar Data	700
SR	U	Approximate Slant Range Correction	8
WF	U	Weather Filter	224
YP	U	MACH Base Area	28
YQ	U	MACH Assignment	6
		Total	19,708

TABLE 16. USE ONLY TABLES COPIED IN RDP SYSTEM

Name	Description	Size (Words)
AC	Aircraft Characteristics	45
AG	Heading Sensitive Departure/Arrival FDEP Reference	28
AR	Airway	1,053
AW	Airway Index	44
AZ	Air Carrier/Air Taxi Identification	35
BA	Boundary Altitude Range	45
BN	Boundary Nodes	484
BP	Sector Number Translation Array	25
CB	Center Boundary Composition	127
CJ	Coded Route	1,268
CR	Coded Route Index	124
CV	Code Conversion Arrays	1,150
DE	Device Control	2,070
DV	Logical Device Number	54
DZ	Disk Extents	1,000
EE	Error Reference Index	2
ET	Airborne Equipment Qualifier	22
FF	Fix Stratification	1,539
HD	CDC/DCC Logical Device Numbers Array	6
IN	Adapted Fix	1,992
JU	Junction Identification	145
JV	Junction Pointer	73
MC	Referred Response and Program-Initiated Message	35
NC	Name Key Array	27
NM	Facility FDEP Routing	38
NN	NAS Table Lengths	72
NX	Name Index	175
PA	Altitude/Route Alphanumeric Array	524
PB	Posting Area/Center Boundary	1,490
PC	Program Control Information	512
PD	Adapted Departure/Arrival Converted Fix	1,908
RJ	Radar Site MACH Resident Data	84
SG	Simulation Radar Sort Box Array	380
SS	Strobe Message Display	400
SW	Substitute Fix	16
SZ	SID/STAR	40
TA	Airport/Fix Off Airway/Coded Route	212
TF	Preferential Route Transition Fix	339
TL	Transition Line	240
TN	Transition Route Control Fix	86
TP	Transition Route Pointer	43
TS	Stereo Data	3
WT	Terminal Flow Control Qualifier	322
XD	Message Type Description Index	178
	Total	18,455

TABLE 17. TABLES USED ONLY IN RDP SYSTEM BUT SET IN 9020 SYSTEM

Name	Description	Size (Words)
AD	Airport Data	379
AL*	Altimeter Data	2,600
AP	Airport Index	186
AT*	NAS-to-ARTS Message Control	592
CM	RTQC Correction Factors	42
FE	FDEP Device	280
FI	Route Processing Communication	19
FR	FP Alphanumeric Chain Index	42
HP	Plan View Display	325
IC	Interface Control Data	63
IT*	List Display Data	1,920
LY	System Analysis Recording Active Category	64
ME	Absolute Memory Equate	2†
MN*	NAS-to-NAS Message Control	266
NU*	Non-U.S. Manual ARTCC Flight Plan Pointer	24
PE	Program Element Control	5,376
PR	Adapted Departure and Arrival Control	297
RA	Route Alphanumerics	175†
RZ*	Track Recording Eligibility	8
SC*	Sector Index	147
SY	System Parameters	320
TT	Teletypewrite Device	56
UT	Test Control Communication	19
WA*	Winds Aloft	624
WB	Adapted Altitudes for Upper Winds Array	6
WR	Radar Formatting Control	28
XC*	CRD Device	208
XS	XAK Signoff	2†
	Total	14,070

*Lockable table
†Buffered Storage

3.2.1.4.1 Shared Communications Tables in the RDP System - Tables 18 and 19 present the input and output communications tables used in the RDP system. Since these are one-way communications, the tables need exist only in the receiving system. The table entries are generated in the sending system and transmitted to the receiving system and stored there. Thus tables IM and JI, for example, would exist only in the RDP system where they are used. Programs in the 9020 system wishing to use the tables to communicate with programs RWD and CBC would construct entries for the tables and transmit them to the RDP system for storage and activation of RWD and CBC there.

3.2.1.4.2 RDP Shared Data Base Tables - Table 20 presents the set/use tables shared between the 9020 system and the RDP system. Whenever either system updates an entry in one of these tables, the entry must be transmitted over the selector channel to the other system and stored there. For tables which now have defined locks, the update and transfer of table entries will have to be protected by the setting of a system lock for the affected table entry in both systems. Tables which do not now have defined locks will have to be individually examined to determine if locks will be required in the split system.

3.2.1.4.3 Independent Shared Tables in the RDP System - Table 21 presents the shared tables which may be independently maintained in the two computer systems. These include tables that are used for program communications entirely internal to either computer system due to the cross-copying of lower level programs. The Pool Storage table, GTMAIN area, and all lock tables are also included in this group of tables.

3.2.2 RDP Resource Utilization and Implementation Estimate

This section presents estimates of the resource utilization changes due to the split of the RDP function into a separate computer system. Estimates are determined for the reduction in 9020 CPU usage and the loading of the selector channel used to communicate between the two systems. Also presented is an estimate of the manpower required to implement the functional split.

TABLE 18. RDP INPUT COMMUNICATION TABLES FROM 9020 SYSTEM

Name	Description	To Program	Size (Words)
IM	RWD Communication	RWD	3
JI†	CBC Request	CBC	450
	Total		453

†Lock not required in 9020 system

TABLE 19. RDP OUTPUT COMMUNICATION TABLES TO 9020 SYSTEM

Name	Description	To Program	Size (Words)
CQ	Category/Function Communication	CRJ	8
DQ†	DARC Communication	CDA	120
HE†	HTI Communication	HTI	144
HH†	HHM Communication	HHM	22
HI†	HCI Communication	HCI	172
IP†	CIP Communication	CIP	40
IQ†	HRO Communication	HRO	20
IS†	Strip Printing/CRD Update Initiation	COP	120
MG†	Message Field Control	Several	350
MP†	Pending Message Control	Several	360
MT†	Subprogram Message Control	Several	250
MW†	Message Alphanumeric Data	Several	500
PG†	CSS Communication	CSS	75
XQ†	CRJ Communication	CRJ	50
	Total		2,231

†Lock not required in RDP system

TABLE 20. RDP SHARED DATA BASE TABLES

Name	Description	Size (Words)
AA	Radar Adapters	300
AB	RDAM Base Address Control	15
AN*	Airspace Index	304
AQ*	ARTS Output Communication	380
BE	Beacon Code Array	2,048
BX	Weather/Strobe Data Index	168
CK*	Conflict Alert Altitude Communication	54
CS*	RTQC Communication	490
DS	Buffer Flight Plan Data Set Record Availability	1,310
FC	Advance Flow Control Communication	2,400
FD	Advance Flow Control Summary	15
FM*	Automatic Handoff Eligibility	26
FPCR*	Core Resident Flight Plan Index	12,000
FPDK*	Disk Resident Flight Plan Index (includes AK, FL, MO)	37†
FQ	FP Availability Entry	9
FS*	Flight Strip Status	62
FY*	Supplemental Flight Plan Index	6,000
FZ*	Flight Strip and CRD Update Identification	1,500
GS	System Saturation Communication	21
HA	Radar Sort Box FPA Chain Array	356
HC*	Conflict Alert Display	325
HF*	Track-Numbered Display	2,100
HG*	Conflict Alert Group Suppression	440
HO*	Track Control/Display	13,300
IC	Interface Control Data	63
IR*	Automatic Track Initiation	60
IU	Crosstell Track Index Array	50
JJ	Field 10 Processing Communication	6†
JO*	PVD Code List	559
JT	IOCEP Pointer	74
MI	Monitor Miscellaneous	52
MQ*	NAS Output Communication	150
NT	System Status Indicator	2
OH	Subprogram Saved Data	2
PH*	System Operational Status	6
QE	Registration Error and Constants	440
RC	Route Control	153
RG	Radar Sort Box	1,517
RM	Radar Simulation	2,100
RQ	Correction/Tracking Radar Sort Box	1,517
RT	Radar Data	8,470
RU	Radar Site Data	375
RW	Simulation Miscellaneous	8
TC*	Facility Traffic Count	40

†Buffered storage

TABLE 20. RDP SHARED DATA BASE TABLES (continued)

Name	Description	Size (Words)
TE	Track Sort Box Index Array	798
TH*	Tracking Data - Part 2	6,300
TK*	Tracking Data - Part 1	9,100
TW*	Tracking Miscellaneous	22
WS	Weather Data	300
WX	RDAM Radar Index	420
XR	R-CRD Device	78
	Total	76,322

*Lockable table

TABLE 21. INDEPENDENT SHARED TABLES IN RDP SYSTEM

Name	Description	Size (Words)
BI*	SCV Communication	4
FK*	SBD Communication	3
FV	FP Software Lock Array	600
FX	Flight Plan Buffer	43,520
MK	SBB Communication	1
PO	Pool Storage	28,752
UU	Test and Set Lock	21
	Total	72,900

*Lockable table

The CPU load on the 9020 system is reduced considerably due to the movement of the RDP function to another computer. Using the individual program CPU utilization measurements provided in SPAR-64, up to 81% of a 9020A CE is moved to the new system due to the RDP programs and the other programs copied on the RDP system, assuming 15% utilization for the execution of RIN. For this estimate, new programs created since the measurements are not included. These programs are RCD, RFM, RWD, RZM, SDW, SFI, SFL, SOC, RDX, SDE, SBF, SFA, SFC, SFG, and STS. Using the data presented in Table A-1, the CPU usage added back into the 9020 due to intersystem lock usage is 13.9% of a CE. This figure is arrived at by summing the frequencies of the shared tables which are lockable and assuming a 250 usec overhead for the intersystem portion of the lock mechanism. Summing the execution frequencies of the programs which are Monitor-activated within the RDP system and estimating the frequencies of 9020 program activations due to the RDP system provides an estimate of the CPU usage caused by intersystem program activations. Using an estimate of 200 usec per activation, a CPU usage of .21% of a CE is estimated. Thus the total 9020 CPU load should be reduced by approximately 66.89% of a CE.

The expected loading of the selector channel used to tie the two systems together is determined by using the data in Table A-2, which provides transmission frequencies and transmission packet sizes for the shared tables, and by adding the loading due to intersystem locks and program activations. For the RDP functional split, the shared tables cause 43,020 bytes/sec to be transferred between the systems on the average. The associated intersystem locks, estimated from Table A-2 at 55.6 locks per second, cause a channel loading of 1,779 bytes/sec at four words per lock. The intersystem program activations, at two words per activation, cause a channel loading of 100.3 bytes/sec. With a selector channel capacity of 150 Kbytes per second, this results in a channel utilization of 29.9%. The multiplexor channel utilization on the 9020 system will be reduced in the RDP split system due to the movement of RIN to the new system. Logicon's Response Time Analysis Study results indicate, however, that the resultant change will be negligible since total multiplexor utilization is less than 2%.

The RDP functional split comprises direct changes to 75 programs which are either moved or copied to the RDP system. These programs contain approximately 101,630 instructions. Using a compiler expansion ratio of 6 to 1, 6 man-months per thousand lines of source code, and 1 man-month additional for each affected program, an estimate of 177 man-months for implementation is determined.

4. FUNCTIONAL SPLIT OF NEW FUNCTIONS

Two proposed enhancements to the En Route system were examined in the study to determine the impact of implementing them in a separate new computer system attached to the 9020. The selected proposed enhancements are En Route Minimum Safe Altitude Warning (E-MSAW) and Flight Plan Conflict Probe (FPCP). E-MSAW was selected because it is a function with relatively few linkages to the existing software. FPCP, on the other hand, is a function with many linkages to the existing program. This difference in the two functions leads to significantly different implementation approaches as described in the paragraphs below.

4.1 En Route Minimum Safe Altitude Warning (E-MSAW) Function

The E-MSAW capability has been recently implemented in the NAS En Route Computer Program and was selected as a candidate for implementation in a separate computer system for this study. E-MSAW will alert the air traffic controller to actual or potential intrusion of tracks into airspace below minimum vectoring altitudes for the adapted E-MSAW areas under his control. In every other radar system subcycle (12 seconds) a filter is applied to one-third of the eligible tracks in the system. VFR tracks, outbound tracks successfully handed off, tracks without altitude data, and tracks being dropped are not eligible for E-MSAW processing. The filter excludes from further E-MSAW consideration all tracks at or above 25,000 feet and all tracks at or above 14,000 feet that are level or climbing. Tracks that survive this filter are marked as candidates. All candidate tracks are then filtered again to eliminate:

- Tracks in coast mode
- Tracks already on the alert list
- Tracks on hold
- Tracks having zero horizontal velocity

All remaining candidate tracks are checked for E-MSAW violation every other subcycle, and those which are in violation or are predicted to be in violation within 120 seconds are added to the alert list (HS) after a final check for eligibility. This final check eliminates all supposed violations where the track is consistent with arrival or departure from an airport on the flight plan.

Being on the alert list does not automatically mean that the track is displayed, however. Generally, a track must qualify for the list two-out-of-three times it is checked to actually be displayed to the controller as an alert. An exception is the track that is already in violation or is predicted to be in violation within 30 seconds. This track is immediately eligible for display. Any track on the alert list must continue to qualify for the list on the two-out-of-three basis or it is automatically dropped from the list. Tracks are also dropped from the alert list if the altitude data becomes invalid or the aircraft leaves the Radar Sort Box grid.

The operation of the E-MSAW function can be controlled in several ways by EC, EV, ES, and EI messages:

- o The function can be turned ON/OFF for the entire center (EC).
- o The display of alerts can be turned ON/OFF for each adapted PVD (EC).
- o The display of a specific alert on a specific track can be suppressed or restored (ES).
- o The display of any alerts on a specific track can be suppressed or restored (EI).
- o Selected VFR tracks may be specified for E-MSAW processing (EV).

The status of the E-MSAW function can also be observed for the center or any subset of five or fewer PVDs by use of the ER message, which will report either:

- ON/OFF status of E-MSAW and display status of all PVDs
- Display status for one to five PVDs

The following paragraphs discuss the new programs added to the 9020 system for the E-MSAW function, their relationships to the remainder of the 9020 system, and the results of separate implementation of the E-MSAW function.

4.1.1 New Modules Added to NAS

Five new program modules are added to the NAS En Route Computer Program to implement the E-MSAW function. One new table (the alert list HS) and several new entries in existing tables are also to be added. The new modules are:

- IEC: Processes the EC message to turn E-MSAW ON/OFF for the center or to suppress/restore alert displays at selected PVDs. Analysis of the TK table suggests IEC also processes the EV message, which enables/disables VFR tracks for E-MSAW processing.

- IER: Processes the ER message to give the required information about the status of E-MSAW.

- EDG: Determines display eligibility for all alerts and generates the actual display to be channelled to PVDs. EDG also processes the alert and track suppression messages, ES and EI.

- REF: Performs the initial track filtering, eliminating from further consideration by E-MSAW all tracks which:

a) Fail the altitude tests
b) Are inactive
c) Are being dropped
d) Have no valid altitude data
e) Are in hold or coast mode with no alert active
f) Are VFR and not designated for tracking by the controller

- RVD: Updates the alert table and processes eligible candidate tracks. A track is ineligible for RVD if:

a) It is being dropped
b) It is in hold
c) The horizontal velocity is invalid
d) The track is in coast mode and not on the alert list
e) The track has been successfully handed off

RVD processes the remaining candidates by a linear extrapolation of both horizontal and vertical velocity for 120 seconds ahead. If a violation of E-MSAW airspace exists or is predicted, the track is put on the alert list or its alert list entry is updated.

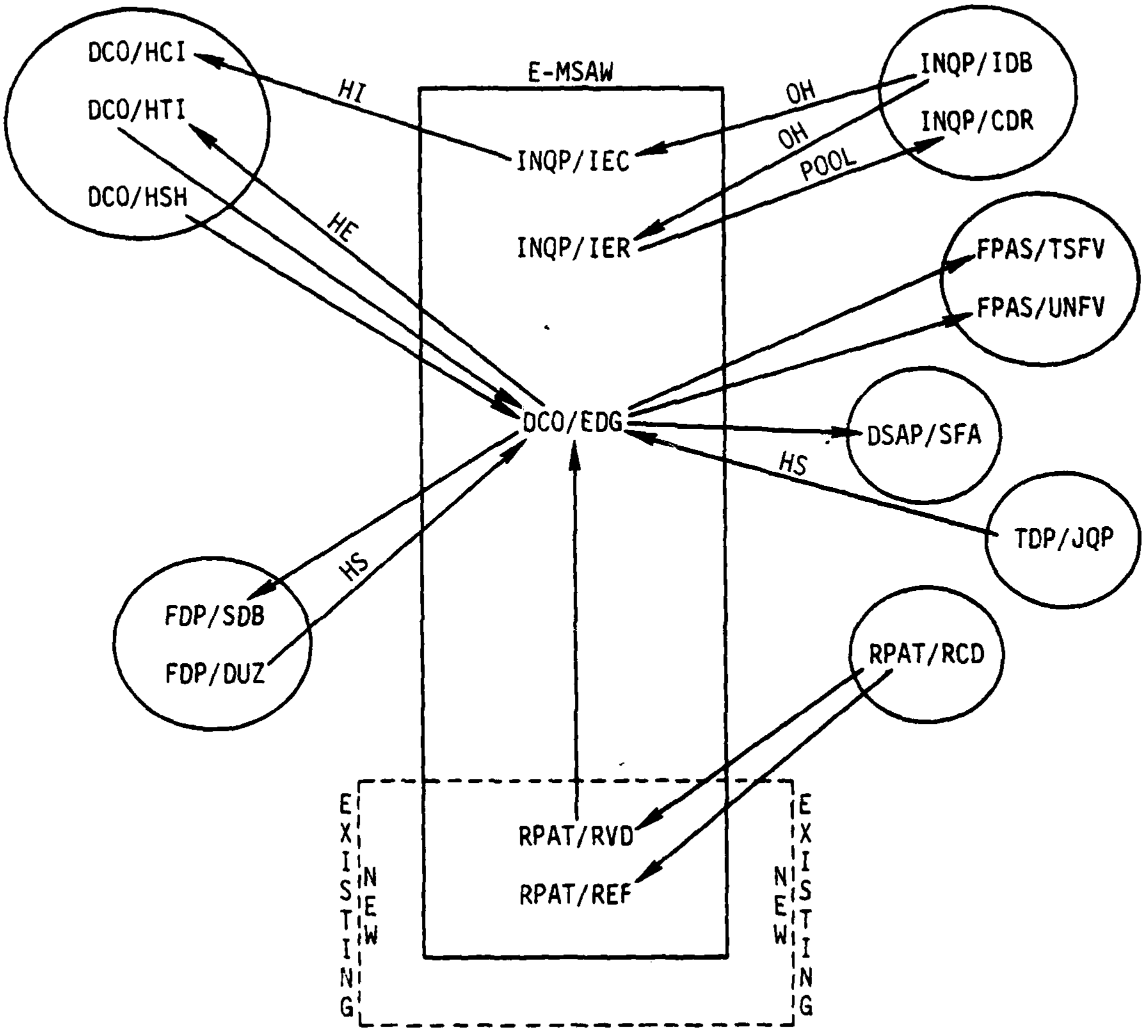
4.1.2 Functional Relationships of New Modules

Referring to Figure 2, the normal sequence of operations for E-MSAW is as follows (E-MSAW is diagrammed as though it were a separate subsystem; actual ownership of the modules is prefixed to each one on the figure):

1) RCD DEMANDs REF every two subcycles.

2) REF processes one-third of the tracks and terminates.

3) RCD DEMANDs RVD every two subcycles.



Legend

—▶: Arrow points to initiated module

-----: Shows proposed split

HS: Table used to pass data, per documentation

DCO/EDG: Subsystem/module identification

FIGURE 2. LINKAGE STRUCTURE OF THE E-MSAW FUNCTION

4) RVD processes the alert table and candidate tracks. If the alert table has any entries, EDG is DEMANDed. RVD then terminates.

5) EDG updates alert displays on all tracks and, through other routines, updates the Flight Data Block and Alert Report on the HSP, then terminates. EDG may also be DEMANDed if ES or EI messages are to be processed.

6) IEC is CALLed when the inquiry processing subsystem (INQP) processes an E-MSAW EC control message, i.e., when the E-MSAW ON/OFF status or display routing status is to be changed. IEC then DEMANDs EDG.

7) IER is called when INQP processes an E-MSAW ER control message, i.e., when there is an inquiry about the status of the E-MSAW function. IER does not activate any of the other E-MSAW modules.

4.1.3 Proposed Separation of E-MSAW Modules

It is proposed to leave the modules IEC, IER, and EDG with the existing system and to move REF and RVD to the new computer system (see Figure 2). No extra copies of any routine will be made so that no module will exist in both computers. This proposal is rationalized in the paragraphs below in terms of minimizing data flow and monitor communications between systems, minimizing memory requirements in each, and still meeting or exceeding system performance requirements.

4.1.3.1 Minimization of Data Flow: This criterion is of primary importance because the duplication of some tables (at least partially) in both systems requires continual intersystem communications to keep the tables updated. Additionally, exclusive access to a table (or entry) may be required by a program in one computer, necessitating the concurrent locking of the duplicate table in the other computer. This double locking process is described in Section 2.3. Thus data in duplicate tables must be updated in one or both directions by monitor-level data communication as well as tables being locked and unlocked by control messages between monitors. Clearly this data flow is a potential source of problems in a system with such a large data base. Table 22 details the structure of items which must be exchanged between the two computer systems for the exercise of the E-MSAW function under this particular proposal for separating modules. Table 23 shows the worst-case estimated volume of intersystem data transfer under this proposal, assuming a track load of 222 (Test Area 602) and an E-MSAW conflict rate of approximately 2%.

4.1.4 Minimization of Monitor Communications

In addition to monitor communications required for data transfer and table locking, some overhead is developed in calling programs on one machine from the other. The proposed split minimizes intersystem calls between E-MSAW modules, while still transferring a considerable computational load to the new computer.

In terms of calling frequency, the DEMAND from RCD to REF is fixed at once every two subcycles (12 seconds) by the parameter SYHGFF. The DEMAND from RCD to RVD is set to once every two subcycles by the parameter SYCRFF when there are any tracks on E-MSAW alert. With no operating history to supply reliable statistics, this second frequency is difficult to estimate, but the rate established by SYCRFF is a maximum. The RVD to EDG DEMAND again depends on whether there are any tracks on E-MSAW alert. At worst, EDG is DEMANDed by every activation of RVD, i.e., as often as every two subcycles. Thus the worst case involves three intersystem activations during one subcycle, together with the associated data transfers.

4.1.5 Minimization of Required Memory

This requirement is met by not maintaining duplicate program modules in the two computers and keeping the minimum of tabular information in the new

TABLE 22. STRUCTURE OF DATA ACCESSED BY BOTH SYSTEMS DURING E-MSAW FUNCTION

Item	Purpose	Frequency	Structure
FYMSG	Status of flt. pln. - TENTative/NORMal	1/ac	1 bit
HOEAI	E-MSAW Alert List entry indicator	1/tk	1 bit
HS	Pointer to head of table HS	1/sys	3-byte addr
HSACTZ	HS entry status	1/tk	2 bits
HSEFI	Empty/Full indicator	1/tk	2 bits
HSEFIZ	Empty/Full indicator duplicate	1/tk	2 bits
HSEWAZ	E-MSAW Warning Altitude	1/tk	8 bits
HSFEC	Full entries count	1/HS	16 bits
HSHSTZ	History bits	1/tk	4 bits
HSHTI	HTI signoff indicator	1/tk	1 bit
HSMIDZ	E-MSAW Area ID	1/tk	8 bits
HSSNT	Subcycle counter	1/HS	16 bits
HSREF	REF execution indicator	1/HS	1 bit
HSTIMZ	Time to violation (seconds)	1/tk	16 bits
HSTKEZ	TK entry number	1/tk	16 bits
HSZDTZ	Altitude velocity	1/tk	16 bits
TK	Pointer to head of table TK	1/sys	3-byte addr
TKECS	Marker set/reset by REF or IEC to identify or cancel a candidate for E-MSAW	1/tk	1 bit
TKEVR	Marker set/reset by IEC to identify a VFR track for E-MSAW processing	1/tk	1 bit
TKHIA	Highest TK entry	1/sys	16-bit signed integer

Note: 1/sys entries are parameters which only need to be transmitted at startup/startover.

TABLE 23. INTERSYSTEM DATA TRANSFER VOLUMES OF E-MSAW

	Information Transferred (Words)/Time (Usec)		
Activation	Tabular Data	Channel Overhead	Lock/Unlock Req
RCD - REF	298/7450	2/300	4/900
RCD - RVD	39/975	2/300	4/900
RVD - EDG	39/975	2/300	4/900
Worst case	376/9400	6/900	12/2700

The following information from previous NAFEC computer performance reports was used to develop the table above:

- o CPU speed = 167K instructions/sec
- o Data channel capacity = 150 bytes/sec
- o Time to lock or unlock table = 150-200 usec
- o Time to set up intersystem transfer = 200-250 usec

Each line of the table consists of three entries, each one given as a volume of data in words and a time to transmit it from one system to the other, as follows:

- o Actual data transferred for the operation of the E-MSAW function (tabular data)
- o Data transferred for interprocessor communication requests (channel overhead)
- o Data transferred and setup time for lock/unlocking tables (lock/unlock req)

Summing the worst-case row and averaging over 12 seconds gives a channel loading of 132 bytes/sec.

machine, i.e., just enough for REF and RVD to do their processing. In more exact terms, the additional memory space required by the E-MSAW function for data and programs in both computers is shown in Tables 24 and 25.

4.1.6 Timing Changes Attributed to E-MSAW Function

Based on CSC's documentation of the E-MSAW function and the assumptions noted in Section 4.1.3.1, timing increases attributable to installation of the E-MSAW function are shown in Tables 26, 27, and 28. An estimated increase in response time is also given for the worst case, described above.

4.2 Flight Plan Conflict Probe

The Flight Plan Conflict Probe (FPCP) is intended to aid the controller in early recognition and resolution of potential conflicts between eligible flights. The FPCP uses stored flight plan data to search for conflicts. Whenever a new flight plan is entered, a search is made for conflicts; if any exist, they are presented to the controller. The controller may elect to either make a permanent flight plan modification, make a trial flight plan modification which can later be made permanent, or leave the conflict unresolved until a later time.

4.2.1 FPCP Subroutine Requirement

The FPCP PDS does not describe which subroutines comprise the FPCP system; the determination of the subroutine requirements for the FPCP comes from examining the changes provided in the PDS. The changes include the addition of nine new routines; these routines were selected to form the nucleus of the FPCP system.

The nine routines directly call a number of routines that already exist in the 9020 system. By duplicating these routines in the FPCP system, the number of control transfers between the two systems can be greatly reduced. Table 29 shows the nine new routines and the routines that they call; all subroutine calls are normal subroutine calls with parameters. Table 30 presents the descriptions and sizes of the programs in the FPCP system.

TABLE 24. ADDITIONAL MEMORY REQUIREMENTS OF E-MSAW FUNCTION DATA

Add to Existing Tables

Existing Computer			New Computer	
BSHSA	HFFRQZ	SYADVM	BSHSA	TKFVCZ
ENAID	HFPVDZ	SYARVM	FYMSG	TKHIA
ENANM	HOEAI	SYFWTI	HOEAI	TKHSIZ
ENAPT	HOEAIZ	TKECS	NNHSA	TKMCTZ
FYMSG	HOEEF	TKEIS	SYHGFA	TKNMTZ
HFBCRZ	HOEEFZ	TKEISZ	SYHGFI	TKNTSZ
HFCAIZ	HPEDS	TKEVR	SYMGFA	TKTMCZ
HFCHNZ	NNHPD	TKFYEZ	SYVLAT	TKUSEZ
HFDISZ	NNHSA	TKXCOZ	TKAAHZ	TKVCOZ
HFFORZ	NNXRB	TKYCOZ	TKAALZ	TKVTPZ
HFFRDZ			TKCORZ	TKZDTZ
			TKECS	TKZXPZ
			TKEVR	

New Tables

Existing Computer	New Computer
EMA (Additional E-MSAW Area Descriptions)	EKIA (E-MSAW Index Array)
EWAA (E-MSAW Airport A/N Array)	ELAA (E-MSAW Areas Array)
HS (E-MSAW Alert List Table)	EL (E-MSAW Segments per Box Tab)
	EM (E-MSAW Area Descriptions)
	EV (E-MSAW Vertex Table)
	HS (E-MSAW Alert Table (partial))

TABLE 25. ADDITIONAL MEMORY REQUIREMENTS OF E-MSAW FUNCTION PROGRAMS

Add to Existing Modules

Existing Computer

Symbol	Name	Size (Words)
BTQ	Table/Queue Interrogator	10
DUZ	Flight Plan Data Base Synthesizer	54
HCD	FSP List Processing	24
HCI	PVD Tabular Processor	266
HHM	PVD Display Time Processor	2
HJM	Reconstitution and Display Availability Processing	2
HTI	PVD Track Data Block Processing	386
JQP	QAK PVD and QAK AUTO HAND Organizer	1,075
PUO	Startup/Startover Processor	24
SHL	Tabular List Formatting	36
SHM	FSP List Formatting	22
SOD	DCO Startup/Startover	60
SOL	Supervisory Startup/Startover	20
	Subtotal	1,981

New Modules

Existing Computer

Symbol	Name	Size (Words)
EDG	E-MSAW Display Generator	2,478
IEC	E-MSAW Control Message	820
IER	E-MSAW Status Request Message	896
	Subtotal	4,194
Total on existing system		6,175

New Computer

Symbol	Name	Size (Words)
REF	E-MSAW Filter	764
RVD	E-MSAW Violation Detection	4,144
Total on new computer		4,908

TABLE 26. TIMING CHANGES ATTRIBUTED TO E-MSAW FUNCTION

	Existing Computer		New Computer	
Description	Name	Usec	Name	Usec
Add to Existing Modules	DUZ	1,830		
	HCD	120		
	HCI	6,228		
	HHM	12		
	HTI	5,616		
	ICP	300		
	JQP	3,880		
	PUO	1,542		
	RCD	150		
	SHL	234		
	SHM	120		
	SOD	2,988		
	SOL	64		
New NAS Program Modules	EDG	2,616	REF	115,944
	IEC	1,098	RVD	112,116
	IER	1,704		

TABLE 27. WORST-CASE EXECUTION TIME OF THE E-MSAW CYCLE

Event	Time (Usec)
(1) RCD DEMANDs REF	450
(2) REF processes tracks and handles tables	124,294
(3) RCD DEMANDs RVD	450
(4) RVD processes tracks and handles tables	113,991
(5A) RVD DEMANDs EDG	300
(5B) EDG processes and handles tables	4,491
Total worst-case time	243,976 (2.03% of 1 CE)

TABLE 28. FORMULAE FOR E-MSAW TIMING CHANGES

Time Added to Existing NAS Modules (Usec)

DUZ:	40 + 186(H)	ICP:	300	SHL:	234 when EM-OFF
HCD:	120	JQP:	3,880	SHM:	120
HCI:	558 + 162(P)	PUO:	42 + 100(H)	SOD:	48 + 84(P)
HHM:	12	RCD:	150	SOL:	64
HTI:	1,746 + 258(H)				

Timing of New NAS Modules (Usec)

EDG:	2,616
IEC:	1,098
IER:	1,704
REF:	420 + 180(A) + 138(B) + 90(C) + 342(D) + 518(E)
RVD:	186 + 150(H) + 78(T) + 366(CC) + 282(S)

Definition of variables:

- A = Total number of tracks (assumed: 222)
- B = Total number of valid tracks (assumed: 200)
- C = Total number of valid altitude tracks (assumed: 180)
- CC = Total number of candidates (assumed: 120)
- D = Total number of past altitude filter checks (assumed: 2)
- E = Total number of tracks that became candidates (assumed: 60)
- H = Number of HS entries (assumed: 15)
- P = Number of adapted PVD's (assumed: 35)
- S = Number of sort boxes processed (assumed: 200)
- T = Number of tracks processed by RVD (assumed: 120)

TABLE 29. SUBROUTINES IN FPCP SYSTEM

Calling Routine (New)	Called Routine	Routines Called by Called Routine
CFP	SFG	
FFP	SFA	RML,SFG,STS,XPP
	SFG	
IPM	SBA	
	SBB	
	SCA	SCX,RDX
	SCU	
	SFA	RML,SFG,STS,XPP
	SRT	
OPM	-	
PEG	SFA	RML,SFG,STS,XPP
PQD	-	
PQU	-	
PTA	SBA	
	SBB	
	SBE	
	SCA	SCX,RDX
	SCD	
	SCE	
	SCF	
	SCG	SDA,SCX,RDX
	SCH	
	SCJ	RLI,RSG,SCE,SCX,RDX
	SCR	SCE,SCH,SCJ,SDA,RLI,RSG,SCX,RDX
	SCU	
	SDE	
	SDG	SFA,RML,SFG,STS,XPP
	SDU	PLF,PTC,RML,XOT,XPP,XRL,UAK,SFG,SHA,STS,SPF
	SFA	RML,SFG,STS,XPP
	SFC	SFG,SDA,SCX,RDX
	SRT	SBA,SBB
SPK	-	

TABLE 30. MEMORY REQUIREMENTS FOR FPCP SUBROUTINES

Subroutine	Size (words)	Description
CFP	1,534	Coarse Filter Processing
FFP	7,870	Fine Filter Processing
IPM	2,174	Flight Plan Conflict Probe Input Message Processor
OPM	2,138	Conflict Probe Output Message
PEG	1,288	Probe Queue Entry Generator
PLF	1,178	Advance Flow Control Qualifier
PQD	360	Probe Queue Delete
PQU	398	Probe Queue Update
PTA	4,696	Trial Flight Plan Amendment Message Processor
PTC	5,775	Fix-Time Calculation
RDX	34	Fixed Point Arc Distance Computation
RLI	318	Line Intercept Calculation
RML	1,052	Route Match Logic
RSG	20	Stereographic Plane to Gnomonic Plane Transformation
SBA	218	Communications Table Management
SBB	184	Table MW Management
SBE	64	Table FY Management
SCA	1,600	Field 02 Processor
SCD	334	Field 05 Processor
SCE	404	Field 06 Processor
SCF	292	Field 07 Processor
SCG	570	Field 08/09 Processor
SCH	1,978	Field 10 Format Check
SCJ	5,808	Field 10 Logic Check
SCR	4,062	Route Field Merge
SCU	1,194	Source Eligibility Check
SCX	706	Coordinate Conversion
SDA	966	Fix, FRD, and Lat/Long Format Check and Fix Search
SDE	188	Fix Compare
SDG	588	Duplicate Flight Plan Search
SDU	3,326	Amendment Output Initiator
SFA	582	Flight Plan Data Base Read
SFC	498	Flight Plan Data Base Write
SFG	48	Flight Plan Buffer Management
SHA	22	Heading Angle Correction
SPF	144	Flight Plan Position
SPK	358	Table PK Management
SRT	464	Response-Message Router
STS	110	Saturday to Sunday
UAK	1,782	Flight Plan Buffer Management
XOT	1,854	Strip Output Timing
XPP	968	Flight Position Determination
XRL	1,405	Radar Lists and Automatic Track Timing
Total	59,522	

4.2.2 Additional FPCP Requirements

The FPCP system will require a disk for storage of the Flight Plan data set. This data set will have the same FPDK records as the Flight Plan data set in the 9020 system.

In the multisystem environment of the FPCP functional split, it will be necessary for one system to prevent the other system from updating a table entry or disk entry while the first system is updating the entry. This will require a locking mechanism, discussed in Section 2, similar to that currently resident in the 9020 system.

4.2.3 FPCP and 9020 Interface

The program activations that provide the interface between the two systems are listed in Tables 31 and 32. In addition to what is shown in the tables, routines DUZ, JQN, JTA, PTC, and RAT call subroutine SPK to set up the PK table entries prior to making the DEMANDs shown in Table 31. For this reason, subroutine SPK, one of the nine new routines in FPCP, must also be copied on the 9020 side of the interface.

4.2.4 COMPOOL Commmunications

The following paragraphs present the allocations of the FPCP-unique and FPCP/9020 system shared tables to the two systems. Also discussed are the special processing or data transmission requirements for each class of tables described in Section 2. The results of these allocations show that 9020 table memory will be unchanged since no existing tables are unique to FPCP and the FPCP system will have a table memory requirement estimated to be 108,528 words.

4.2.4.1 FPCP-Unique Tables: Table 33 presents the tables that are unique to the separate FPCP computer system. Both use only and set/use tables are in

TABLE 31. INTERFACE TO FPCP FROM 9020 SYSTEM

Calling Routine	Called Routine	COMPOOL Tables Used	Method of Call
DUZ	PEG	PK	DEMAND
JQN	CFP	PK	DEMAND
JTA	PQD	PK	DEMAND
PTC	PQD	PK	DEMAND
RAT	PEG	PK	DEMAND
PUO	PQU		SCHEDL
PCE	IPM	MG,MP,MT,MW	ATTACH
PDE	IPM	MG,MP,MT,MW	ATTACH
PIT	IPM	MG,MP,MT,MW	ATTACH

TABLE 32. INTERFACE FROM FPCP TO 9020 SYSTEM

Calling Routine	Called Routine	COMPOOL Tables Used	Method of Call
OPM	CRJ	XQ,XR,PO	DEMAND
	CRU	FZ,XC,PO	DEMAND
PTA	DUZ		SEND

TABLE 33. FPCP-UNIQUE TABLES

Name	Usage	Description	Estimated Size (Words)
CP	U	Flight Plan Conflict Probe Parameter	40
FPR	S/U	Flight Plan Route	75
IX	S/U	Intruder	30
OF	S/U	Conflict Data Output	10
PJ	S/U	Probe Queue Index	50
PK	S/U	Flight Plan Conflict Probe Communication	20
PT	S/U	Probe Queue	50
SB	U	Segment Bounds	100
SD	S/U	Sector Display	200
		Total	575

the list. The tables that are use only must be preset in the FPCP system at startup/startover time either from a separate FPCP adaptation file or from the existing 9020 adaptation file via the selector channel interface.

4.2.4.2 Shared Use Only Tables in the FPCP System: The use only tables in the FPCP system form two classes. The first is the set of tables that are use only in the 9020 system. These tables are treated the same as the unique use only tables and must be preset from adaptation data during startup/startover. During system operation there is no requirement for transferring any of these tables, presented in Table 34, between the two systems.

The second class of FPCP use only tables is presented in Table 35. These tables are set by programs in the 9020 system. Some of these tables are preset from adaptation and would be loaded at startup/startover in the same manner as the use only tables. However, whenever one of these tables is updated in the 9020 system, the update will have to be transmitted to the FPCP system via the selector channel interface. The transmissions should be made on an entry-by-entry basis wherever possible to minimize the frequency of transmissions.

4.2.4.3 Fully Shared Tables in the FPCP System: These tables will be both set and used by both computer systems. The tables form three groups; communications tables, data base tables, and independent shared tables. Each of these groups is discussed in the following paragraphs.

4.2.4.3.1 Shared Communications Tables in the FPCP System - The shared communications tables form two groups, input and output. The group of input communications tables, presented in Table 36, are used in transmitting work requests from the 9020 system to the FPCP system. The tables in this group must reside in both computer systems; however, the table contents may not be the same. When a program in the 9020 system wants to send a message to one of the FPCP programs, for example, entries are built in the MG, MP, MT, and MW tables, sent across the selector channel to the FPCP system, and stored in the

TABLE 34. SHARED USE ONLY TABLES IN THE FPCP SYSTEM

Name	Description	Size (Words)
AC	Aircraft Characteristics	45
AG	Heading Sensitive Departure/Arrival FDEP Reference	28
AR	Airway	1,053
AW	Airway Index	44
BA	Boundary Altitude Range	45
BN	Boundary Notes	484
BP	Sector Number Translation Array	25
CB	Center Boundary Composition	127
CJ	Coded Route	1,268
CR	Coded Route Index	124
CV	Code Conversion Arrays	1,152
DV	Logical Device Number	54
EE	Error Reference Index	2
ET	Airborne Equipment Qualifier	22
FF	Fix Stratification	1,539
FN	Field Abbreviations	12
IN	Adapted Fix	1,992
JU	Junction Identification	145
JV	Junction Pointer	73
LV	Altitude Stratification Array	8
MC	Referred Response and Program-Initiated Message	35
NC	Name Key Array	27
NM	Facility FDEP Routing	38
NN	NAS Table Length	72
NX	Name Index	175
PA	Altitude/Route Alphanumeric Array	524
PB	Posting Area/Center Boundary	1,490
PD	Adapted Departure/Arrival Converted Fix	1,908
SW	Substitute Fix	16
SZ	SID/STAR	40
TA	Airport/Fix Off Airway/Coded Route	212
TF	Preferential Route Transition Fix	339
TL	Transition Line	240
TN	Transition Route Control Fix	86
TP	Transition Route Pointer	43
TS	Stereo Data	3
WB	Adapted Altitudes for Upper Winds Array	6
WD	Flow Control Fuel Advisory Delay	500
WT	Terminal Flow Control Qualifier	322
XP	Preferential Storage Area	128
	Total	14,446

TABLE 35. USE ONLY TABLES IN FPCP BUT SET IN 9020 SYSTEM

Name	Description	Size (Words)
AD	Airport Data	379
AN	Airspace Index	304
AP	Airport Index	186
AT	NAS-to-ARTS Message Control	592
BE	Beacon Code Array	2,048
BW	RFA Converted Route	12
FE	FDEP Device	280
FI	Route Processing Communication	19
FR	FP Alphanumeric Chain Index	42
FS	Flight Strip Status	62
HF	Track Numbered Display	2,100
IC	Interface Control Data	63
IT	List Display Data	1,920
LY	System Analysis Recording Active Category	64
MI	Monitor Miscellaneous	52
MN	NAS-to-NAS Message Control	266
MY	Message Identification	396
PH	System Operational Status	6
PR	Adapted Departure and Arrival Control	297
SC	Sector Index	147
SY	System Parameters	320
TH	Tracking Data - Part 2	6,300
TT	Teletypewriter	56
TY	IOT Output Device	20
WA	Winds Aloft	624
WI	Center Internal Flow Control Qualifier	210
WO	Center External Flow Control Qualifier	210
	Total	16,975

TABLE 36. FPCP INPUT COMMUNICATION TABLES FROM 9020 SYSTEM

Name	Description	Size (Words)
MG	Message Field Control	350
MP	Pending Message Control	360
MT	Subprogram Message Control	250
MW	Message Alphanumeric Data	500
	Total	1,460

same tables there. However, the table entries in the 9020 system are not retained since there will be no further reference to them by the 9020 system. When the processing of the message is completed in the FPCP system, the associated entries for these tables will be deleted. If a 9020 program wants to send a message to another 9020 program, the MG, MP, MT, and MW entries will be built as before but they will be retained. Thus, while the tables will reside in both systems, their contents will be dissimilar.

The output group of communications tables, presented in Table 37, are treated in the same manner as the input communications tables except that the table entries are built in the FPCP system and transmitted to the 9020 system for storage and the resultant execution. The table entries are not retained in the FPCP system. In fact, since these tables are not used for any intra-FPCP communications, no copy of these tables need exist in the FPCP system; only the capability to build the table entries need exist.

4.2.4.3.2 <u>FPCP Shared Data Base Tables</u> - Table 38 presents the set/use tables shared between the 9020 system and the FPCP system. Whenever either system updates an entry in one of these tables, the entry will have to be transmitted via the selector channel to the other system. The update and data transfer will have to be protected by the setting of a system lock for lockable table entries in both systems. Tables which do not now have locks will have to be examined individually to determine if locks will be required.

4.2.4.3.3 <u>Independent Shared Tables in the FPCP System</u> - Table 39 presents the shared tables that may be independently maintained in the two computer systems. These tables may be independently maintained because the programs which set or use them are resident in both systems. The Pool Storage table, GTMAIN area, and all lock tables are also included in this group of tables.

4.2.5 FPCP Resource Utilization

If the FPCP and 9020 systems are to work together effectively, they must be able to communicate via the selector channel without overloading it. To

TABLE 37. FPCP OUTPUT COMMUNICATION TABLES TO 9020 SYSTEM

Name	Description	Size (Words)
BI	SCV Communication	4
CK	Conflict Alert Altitude Communication	54
DQ	DARC Communication	120
FK	SBD Communication	2
HE	HTI Communication	144
HI	HCI Communication	172
IS	Strip Printing/CRD Update Initiation	120
JI	CBC Request	450
PG	CSS Communication	75
XQ	CRJ Communication	50
	Total	1,191

TABLE 38. FULLY SHARED DATA BASE TABLES

Name	Description	(Size (Words)
BF	RFA Flight Plan	12
BS	Recovery Recording Begin/End	3
DS	Buffered Flight Plan Data Set Record Availability	1,310
FD	Advance Flow Control Summary	15
FPCR	Core Resident Flight Plan Index	12,000
FPDK	Disk Resident Flight Plan Index	37†
FY	Supplemental Flight Plan Index	6,000
FZ	Flight Strip and CRD Update Identification	1,500
GS	System Saturation Communication	21
HO	Track Control/Display	13,300
IR	Automatic Track Initiation Point	60
JJ	Field 10 Processing Communication	6†
ME	Absolute Memory Equate	2†
RA	Route Alphanumerics	175†
RC	Route Control	153
TC	Facility Traffic Count	40
TK	Tracking Data - Part 1	9,100
UC	Old Aircraft ID	153
XC	CRD Device	208
XR	R-CRD Device	78
XS	XAK Signoff	2†
	Total	44,175

†Buffered storage

TABLE 39. INDEPENDENT SHARED TABLES IN FPCP SYSTEM

Name	Description	Size (Words)
FV	FP Software Lock Array	600
MK	SBB Communication	1
PO	Pool Storage	28,752
PQ	Program Element Status Array	32
SX	MSX Working Area	300
UU	Test and Set Lock	21
	Total	29,706

determine the channel load, an estimate has been made of three items: 1) the number of words sent across the channel for table modification, 2) the number of words being sent across to lock and unlock tables, and 3) the number of words being sent to signal program activations between the two systems. The total intersystem channel load is 11,756 bytes per second or 7.8% of the available 150K bytes per second.

4.2.5.1 Channel Loading Due to Table Updates: The amount of data being sent over the channel can be estimated as follows:

1) For each shared table that is set by either system and is not one of the independent storage tables, find all subroutines that set it, using the NAS XREF program. For each of these surroutines, determine the frequency of execution and sum these frequencies for all of the subroutines setting the table.

2) For each table, multiply the resultant frequency of modification by the number of words sent across the channel per modification.

3) Sum the results from step 2 for all tables.

Tables A-1 and A-2 of Appendix A show the results for steps i and 2 for all tables that are set with a frequency of at least .01 per minute. Summing the results from Table A-2 for all shared tables set by either the FPCP or 9020 systems and not one of the independent storage tables gives a channel load of 7,376 bytes per second.

Tables A-1 and A-2 do not include the modifications that comprise the FPCP system as described in the FPCP PDS. These additional table modifications are given in Tables 40 and 41, which are similar to Tables A-1 and A-2. Since there is no specific data available for the frequency of execution of the subroutines in Table 40, it was assumed that IPM and PTA are executed once each time control is transfered to the FPCP system via an IPM ATTACH and that OPM is executed once any time control is transfered to the FPCP system in any way.

TABLE 40. SUBROUTINE FREQUENCY OF EXECUTION

Table	Routines/Frequency Per Minute			
FPCR	PTA	57.04		
FPDK	PTA	57.04		
FY	PTA	57.04		
FZ	OPM	141.91		
JJ	PTA	57.04		
ME	PTA	57.04		
MG	IPM	57.04	PTA	57.04
MP	IPM	57.04	PTA	57.04
RA	PTA	57.04		
XC	OPM	141.91		
XQ	OPM	141.91		
XR	OPM	141.91		

TABLE 41. CHANNEL LOAD FOR TABLE MODIFICATIONS

Table	Calls/Min	Words/Call	Words/Min
FPCR*	57.04	10	570.4
FPDK*	57.04	37	2,110.48
FY*	57.04	8	456.32
FZ*	141.91	3	425.73
JJ	57.04	42	2,395.68
ME	57.04	1	57.04
MG	114.08	14	1,597.12
MP	114.08	9	1,026.72
RA	57.04	15	855.6
XC*	141.91	4	567.64
XQ*	141.91	2	283.82
XR	141.91	6	851.46
Total			11,198.01

*Lockable table

These assumptions are a worst-case estimate. The determination of the subroutine frequency values is given in Section 4.2.5.3. The resulting additional channel load is 774 bytes per second. The total estimated channel load for table modifications is then 8,150 bytes per second.

4.2.5.2 Channel Loading Due to Table Locks: Whenever one of the tables is locked, the signal to lock the table must be sent across the channel. This is estimated to require 4 words per lock and another 4 words per unlock. Summing the frequencies of update tables shared by FPCP and the 9020 system and multiplying the result by 8 words per lock gives an estimate of the channel load of 6,463 locks per minute or 3,446 bytes per second sent across the channel for both locking and unlocking tables.

4.2.5.3 Channel Loading Due to Intersystem Program Activations: Whenever control is transfered from one system to the other, a signal activating the transfer is sent across the channel. This signal is estimated to require 2 words for a DEMAND or SCHEDL and 15 words for a SEND or ATTACH. The control transfer associated with the FPCP system is shown in Table 42. Except for the last three entries of the table, the frequency was determined using the frequency of execution of the calling routine. For the OPM to CRJ and CRU transfers, the frequency of execution was estimated by assuming that for every transfer into FPCP, OPM is executed once; the OPM value is thus obtained by summing the calls/minute for the calling routines DUZ, JQN, JTA, PTC, RAT, PCE, PDE, and PIT. Similarly, PTA is assumed to be executed once for each execution of IPM, which is obtained by adding the calls/minute for PCE, PDE, and PIT. All of these assumptions are worst-cases. The number of bytes sent across the channel to signal control transfers is 160 bytes per second.

TABLE 42. CONTROL TRANSFER CHANNEL REQUIREMENTS

Calling Routine	Called Routine	Method of Call	Calls Per Min	Words Per Call	Words Per Min
DUZ	PEG	DEMAND	10.3	2	20.6
JQN	CFP	DEMAND	34.33	2	68.66
JTA	PQD	DEMAND	1.87	2	3.74
PTC	PQD	DEMAND	28.37	2	56.74
RAT	PEG	DEMAND	10	2	20
PUO	PQU	SCHEDL	--	2	0
PCE	IPM	ATTACH	8.67	15	130.05
PDE	IPM	ATTACH	47.07	15	706.05
PIT	IPM	ATTACH	1.3	15	19.5
OPM	CRJ	DEMAND	141.91	2	283.82
	CRU	DEMAND	141.91	2	283.82
PTA	DUZ	SEND	57.04	15	855.6
Total					2,448.58

5. 9020 COMPATIBLE REPLACEMENT

One possible means of transitioning from the existing 9020 system to a new computer system is to use a modern computer system that is instruction-compatible with the 9020. Approximately 31,000 words of operating system software would be affected by the transition. This would result in an estimated implementation cost of 186 man-months for the required software changes. Such a replacement approach has the advantage that a large portion of the existing 9020 software could be moved to the new computer without change. The approach has the disadvantage that it retains the existing software maintenance problems present with the existing code.

Two currently available computer systems represent the type of system needed to accomplish this means of transition to a higher capacity system. These are the IBM 3033 and the Amdahl 470/V7. The paragraphs below discuss the two systems and how they compare to the existing 9020 system. Additionally, a proposed configuration for the new system is presented together with discussions of the changes needed in the 9020 system to accomplish the transition.

5.1 Comparison of the 9020 and Representative Replacement Systems

The IBM 3033 and the Amdahl 470/V7 represent virtually instruction-compatible replacements for the 9020 system, which is based on the IBM 360/50 and IBM 360/65 models. It should be noted, however, that these systems represent the high end of computer capacity and that smaller systems in the same families could be used on an interim basis. There are minor differences due to new instructions existent in the new machines and 9020 special instructions not present on these machines, but the usage of these special instructions is limited primarily to the Monitor, which will require changes for other reasons. Table 43 shows the relative performance levels of these systems and their major peripherals compared with the IBM 360/50 processor used in the 9020 system. These data were taken from Datapro Reports (Amdahl 9/77, IBM 5/78) and indicate that a single-replacement processor would have approximately 8.6 times the capacity of the existent 9020A triplex system. Logicon's

TABLE 43. RELATIVE PERFORMANCE OF 9020 AND REPLACEMENT SYSTEMS

Performance Area	9020A	IBM 3033 Amdahl 470/V7
Relative Processor Speed (9020A CE = 167,000 inst/sec)	1	28.7
Disk Transfer Rate (MBytes/sec)	.32	1.2
Disk Access Time (msec)	37.5 min	33.4 avg
Tape Transfer Rate (KBytes/sec)	90(800 BPI)	180(1600 BPI)
Channel Bandwidth (MBytes/sec)	1.6	18-26

Response Time Analysis Study results indicate that the duplex 9020D system has approximately 2.2 times CPU capacity of the 9020A. Thus the single-replacement system would provide approximately 3.9 times the capacity of the 9020D system. Such a single-processor replacement system would provide more than adequate system capacity for some time. The development of the AERA concept will, however, reduce the excess capacity somewhat. Preliminary FAA estimates are that AERA will require 5-10 times the current system resource usage to accomplish the control of the same traffic loads. Thus the existing 9020A sites would have the capacity to function well into AERA development using a modern replacement computer, but the existing 9020D sites may not.

5.2 Proposed Replacement Configuration

Figure 3 shows the proposed configuration of the replacement system. The configuration consists of two identical systems with an intersystem link over which "I'm alive" messages are sent so that the backup system may sense and take corrective action if the primary system fails. The primary disk system features two 3330-type disks, which are used in the same manner as they are now in the 9020. This disk system is directly accessible by either processor so that the backup processor can take over control in the event of system failure.

A second identical disk system is manually switchable between processors. This disk system would be used by the backup processor, for example, for testing of modifications to the operational program in parallel with normal system operations on the primary processor. The separate disk system and processor assure that such testing activities would not impact normal operations. A primary and a secondary tape system would be attached to the processors in a similar manner. The primary system would support SAR, REMON, ADR, and any other operational tape usage, while the secondary tape system would perform the same functions for testing activities.

...nfiguration is set up so that no single peripheral failure will necessi- ...tem switchover. These types of failures would be handled as they are

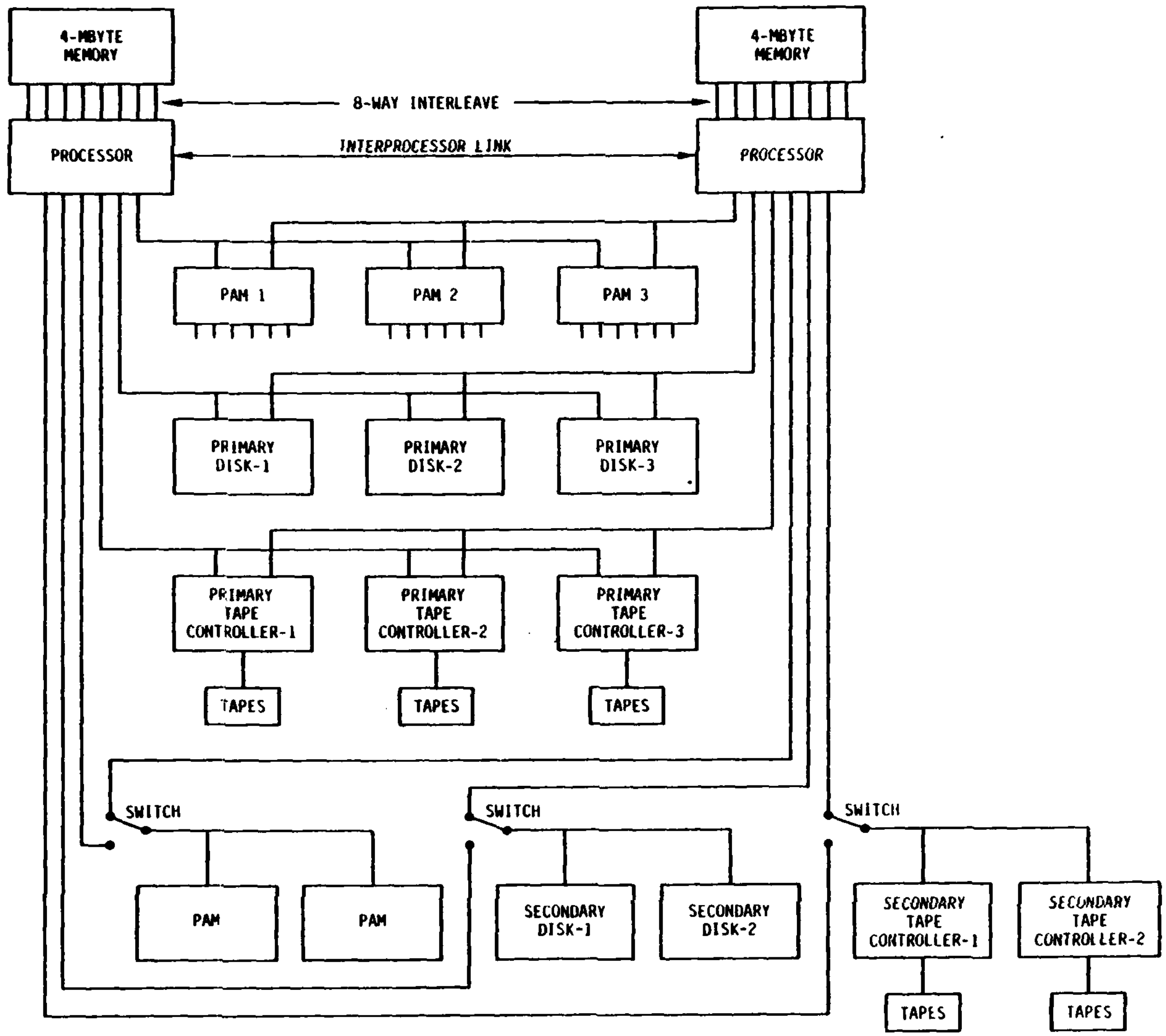


FIGURE 3. PROPOSED REPLACEMENT CONFIGURATION

now, and system restart after peripheral failure should be less than 1 second. Any processor, memory, or channel failure would require startover in the other processor system from the disk-recorded recovery data. Assuming a present startover time of 1 minute for these types of failures, the new system would restart in just under 9 seconds because of the increased speed of the processor and disks.

An examination of the instruction sets of the 9020 and the replacement processor indicates that several instructions have changed and that none of the 9020 special instructions exist on the replacement computer system. However, changing the system assembler will accommodate the changes in operation codes. In addition, with the proposed single-processor configuration, none of the special 9020 instructions is required. One instruction is lost, Set Program Controlled Interrupt (SPCI); however, its need should disappear with necessary I/O software changes to accommodate the 3330-type disks and 1600-BPI tape drives. Table 44 lists the instruction set changes pertinent to the 9020 software. The new instructions provided by the replacement computer are presented in Table 45.

5.3 Software Changes Required in the Replacement System

Software changes to the applications program in the 9020 system should require very little change in the replacement system because the unprotected instruction set of the 9020 is almost completely retained. The two areas of applications program change are in the use of imbedded channel programs and the MVW instruction. The channel programs will change because of the change in disk types. The MVW instruction is used very little and can be replaced by use of the MVC subroutine, which allows moves of very long character strings.

Operating the replacement processor in the Basic Control Mode will allow the existing Monitor, albeit modified somewhat, to be retained. Operating in this mode, however, means that memory paging is disabled. The use of the paging facility would require the use of 370/VS as an operating system. The existing Monitor could also be retained in this mode by operating it under CPM (also

TABLE 44. INSTRUCTION SET DIFFERENCES BETWEEN THE 9020 AND REPLACEMENT COMPUTERS

Instruction	Description	9020 Op Code	Replacement Op Code	Used in 9020	Required in Replacement	Op Code Occupied in Replacement
HIO	Halt I/O	9E	9E00	Yes	Yes	Yes
SPCI	Set Program Controlled Interrupt	9B	None	Yes	No	No
SIO	Start I/O	9C	9C00	Yes	Yes	Yes
TCH	Test Channel	9F	9F00	Yes	Yes	Yes
TIO	Test I/O	9D	9D00	Yes	Yes	Yes
DLY*	Delay	0B	None	No	No	No
IATR*	Insert Address Translator	0E	None	Yes	No	No
LDA*	Load Data Address (IOCE only)	09	None	Yes	No	No
LI*	Load Identity	0C	None	Yes	No	No
LPSB*	Load PSBA	A1	None	Yes	No	No
MVW*	Move Words	D8	None	Yes	No	No
SCON*	Set Configuration	01	None	Yes	No	No
SATR*	Set ATR	0D	None	Yes	No	No
SIOP*	Start I/O Processor	9A	None	Yes	No	No
SPSB*	Store PSBA	A0	None	Yes	No	No

*Special 9020 instruction

TABLE 45. NEW INSTRUCTIONS IN THE REPLACEMENT COMPUTER

Name	Mnemonic	Op Code
Clear Channel		
Clear I/O	CLRIO	9D01
Compare and Swap	CS	BA
Compare Double and Swap	CDS	BB
Compare Logical Character Under Mask	CLM	BD
Compare Logical Long	CLCL	0F
Insert Character Under Mask	ICM	BF
Insert PSW Key	IPK	B20B
Invalidate Page Table Entry	IPTE	B221
Load Control	LCTL	B7
Load Real Address	LRA	B1
Monitor Call	MC	AF
Move Long	MVCL	0E
Purge Translation Lookaside Buffer	PTLB	B20D
Reset Reference Bit	RRB	B213
Set Clock	SCK	B204
Set Clock Comparator	SCKC	B206
Set CPU Timer	SPT	B208
Set PSW Key from Address	SPKA	B20A
Shift and Round Decimal	SRP	F0
Start I/O Fast Release	SIOF	9C01
Store Channel ID	STIDC	B203
Store Character Under Mask	STCM	BE
Store Clock	STCK	B205
Store Clock Comparator	STCKC	B207
Store Control	STCTL	B6
Store CPU ID	STIDP	B202
Store CPU Timer	STPT	B209
Store Then and System Mask	STNSM	AC
Store Then or System Mask	STOSM	AD
Test Protection	TPROT	E501
MVS-Dependent Instructions		
Obtain Local Lock		E504
Release Local Lock		E505
Obtain CMS Lock		E506
Release CMS Lock		E507
Trace SVC Interruption		E508
Trace Program Interruption		E509
Trace Initial SRB Dispatch		E50A
Trace I/O Interruption		E50B
Trace Task Dispatch		E50C
Trace SVC Return		E50D
Fix Page		E502
SVC Assist		E503

known as CP/67 or CMS). The software changes required in the Monitor, which should be transparent to the applications programs, are described below.

All I/O logic will have to be changed in general to accommodate the changes in the instruction set, although this type of change should be nominal. The I/O logic for tape and disk work will have to be changed considerably, however. The 3330-type disk uses Rotational Position Sensing (RPS) and thus requires more complex I/O logic. The 1600 BPI (and faster) tape drives also require new logic to handle error correction. The best source for the I/O logic for these devices would be IBM 370/VS. As the new I/O logic is implemented, all imbedded channel programs should be eliminated from the applications programs and centralized in the Monitor. Approximately 14,700 words of code in the I/O Management and I/O Device Dependent Code subsystems will be affected.

The Monitor will have to be modified to remove all multiprocessor logic. The critical areas in the code may be located by finding uses of the Load Identity, Read Direct, and Write Direct instructions. The overall design of the Monitor and its dispatching and control functions may be retained, however. Approximately 2,800 words of code will be affected, principally in the Program Element Control and Contents Supervisor subsystems.

The system's error processing, startup/startover, and configuration control logic will require extensive change. The basic approach to treating peripheral device failures will remain the same; however, the specific implementation will change due to hardware differences. Memory failure logic will change considerably because independent, translatable, memory boxes will not be used. Likewise, CPU failure logic will change because of the single CPU environment. Approximately 10,500 words of code will be affected.

New logic will have to be developed to provide an intersystem communication link between the primary and backup processors. The logic may be borrowed from the existing Read Direct/Write Direct logic and extended as necessary. The required extensions are to have both systems periodically exchange "I'm alive" messages over the link. If either processor fails, the logic must take appropriate action to ensure continued operations. If the backup processor fails, the primary processor notifies operational personnel so that the problem may be repaired. If the primary processor fails, the backup procesor immediately initiates a startover sequence using the shared primary disk system recovery data. Approximately 3,000 words of code will be required for the intersystem communication function.

Although not a required change, the elimination of buffered programs could be considered while making the transition to the replacement system. With the relatively low cost of memory, a storage size of 4 megabytes could be selected and the need for buffering eliminated. The idea could also be extended to buffered flight plans. The buffering logic need not be removed, just the circumstances set up so that it will not occur. If the logic is retained, it can always be used again if new memory requirements dictate its use.

6. OTHER RECOMMENDATIONS

This section contains discussions of other recommendations and thoughts not necessarily supported by analysis results. The following areas are discussed:

- SAR recordings on a separate computer system
- Slow-speed I/O to a separate system
- Steps aiding staged replacement of the En Route system

6.1 SAR Recordings on a Separate Computer System

The functional splits detailed in Sections 3 and 4 will lead to separate SAR recordings being made on two computer systems. This means that a new program will have to be developed to recombine the recordings so that they can be processed by nonoperational support programs such as DART. Movement of the tape writing activity of the SAR function to the split function system would provide two benefits to the resultant system. First, the recordings made by the two computers could be combined in the split system so that the outputs could be directly processed by support programs. The second, more significant result is that data recording rate seen by the 9020 increases from 90 Kbytes per second to 150 Kbytes per second and the conflict between tape and disk activity on the 9020 is significantly reduced. The result is lower system lock times and improved disk performance, which should translate to improved system response times. Even without the development of a new split function system, the means of achieving the benefits of moving the SAR tape writing activity are available in the ETABS system currently under development. Thus, this change provides a simple means of extending the life of the 9020 if the complete replacement approach is selected for obtaining a new En Route system.

6.2 Slow-Speed I/O on a Separate Computer System

The movement of all slow-speed I/O functions to a separate computer provides benefits similar to the movement of SAR tape writing, although to a lesser extent. Again the ETABS system is a candidate vehicle for doing this. In fact the ETABS system will already accomplish movement of the slow-speed air traffic controller I/O to a separate system. The movement of all slow-speed I/O will eliminate the use of the multiplexor channel in the 9020 and replace it with selector channel activities. Since selector channels operate considerably more efficiently than multiplexor channels with respect to channel and CPU use, the result should be improved 9020 performance.

6.3 Steps Aiding the Staged Replacement of the 9020 System

If the staged replacement of the 9020 system is selected, two steps should be taken to improve the performance of the resultant system before starting the implementation. These steps are described below.

First, a data base of all table set/use information and program linkages should be established. The primary source of the data is the NAS XREF program, but augmentation from other sources will be required. The resultant data base and its supporting software should allow one to determine:

- o What programs set or use a specific table, table item, or array
- o What tables, table items, or arrays are set or used by a specific program or collection of programs
- o What programs are CALLed, DEMANDed, etc., by a specific program or programs
- o Given two specific sets of programs, what tables or items in a table or group of tables are referenced by only one of the sets of programs

Second, the data base should be used to determine what tables should be split to minimize intersystem data transfer between the 14 functional subsystems of the En Route applications programs. These tables should be then split and implemented prior to determining what functional splits will be made.

Regardless of what functional splits are made, assuming splits along subsystem lines, the result will be that system lock usage will decrease and intersystem channel activity will be minimized.

APPENDIX A
TABLE UPDATE FREQUENCIES

Tables A-1 and A-2 contain the frequencies of updates to the tables that may require intersystem transfers for the function program splits treated in this study. Table A-1 was developed from SPAR-64, which contains the execution frequencies of all programs, and the NAS XREF listing, which contains the set/use data for all table items. The information in the table should be regarded as a relatively gross approximation to the present system since the measurements taken for SPAR-64 were taken for the A3d2.1 system in 1975. However, this is the only source of execution frequency data available. The NAS XREF data used are not 100% accurate either because the data do not provide meaningful set/use data for table references from BAL coded programs or from Direct Code in JOVIAL programs. Some modifications were made to the execution frequencies to account for programs which access multiple table entries in a single execution as the table was built assuming that one table entry would be updated per program execution. The frequencies of programs using communications tables, the owners of the tables, were augmented by the frequencies of all other programs putting entries in the communication tables. Thus the frequencies for programs such as CBC and HTI are somewhat higher than indicated in SPAR-64.

Table A-2 summarizes the program access frequency data for each table in Table A-1 and contains the transmission packet size for each update. For tables that are transmitted completely by each program update, Table A-2 shows the estimated size of the table. The update frequencies and the transmission packet sizes are multiplied to provide the average transmission rate for each table. Tables which are lockable are denoted in Table A-2 by an asterisk. Summing the update frequencies for these tables provides an estimate for the intersystem lock frequencies for the shared tables in a split system.

Table A-1. TABLE UPDATE FREQUENCIES BY PROGRAM

Table	Programs/Frequency Per Minute											
AA	RIN	25										
AB	RDA	60.03	RIN	25	RTG	6						
AK	CSF	18	DAM	10	DHM	.2	FTM	10	GCF	31.5	PAM	7.3
	PCA	2.37	PJJ	11.77	PLF	4.57	PLT	7.3	PPS	7.3	PRT	7.3
	PSB	7.3	PTC	28.37	PTM	7.3	SCU	9.97	SDU	7.3	SFA	38.8
	SPX	2.07	SUV	25.63	UAK	11.77	UDP	13.07	XFS	41.73	XPP	69.73
	XUP	2										
AL	IAS	.04	IWX	.04								
AQ	CIP	3	CNA	53.5	DRF	.03	FTM	10	JQN	34.33	JQT	1.67
AT	CNA	4.47	CTU	6.97	FRD	10	IQU	1.23				
BE	DUZ	10.3	FRD	10	SCV	8.53						
BF	RFA	5	RML	17.83	SFI	2.93						
BI	BSD	30	CNA	4.47	CNN	27.17	CSF	18	DRS	2.63	DUZ	10.3
	FTM	10	JQB	3.13	JTI	2.13	SCV	123.66	SDU	7.3		
BW	RFA	5	RML	17.83	SFI	2.93						
BX	RIN	25										
CK	DUZ	10.3	FTM	10	JQN	34.33	JQT	1.67	JTI	2.13	RZM	77.73
	SDU	7.3										
CM	IRD	.2										
CQ	CRJ	34.13										
CS	CSR	4.13	IRD	.2	RCA	.5						
DQ	CDA	26.13	DUZ	10.3	SCV	8.53	SDU	7.3				
DS	SFC	38.8										
FC	SFB	34.83										
FD	PTC	28.37										
FE	IGI	.07	IQU	1.23	PFD	1	XAK	36.77				
FI	DUZ	10.3	PAP	11.77	PAT	2.93	PCD	7.93	PJJ	11.77	PLF	4.57
	PLT	7.3	PMO	7.3	PPS	7.3	PRT	7.3	PSB	7.3	PTC	28.37
	PTM	7.3	RAA	16.6	RAL	5.25	RAM	4.6	RAP	8.35	RDP	7.15
	RJJ	12.2	RKR	.6	RPA	9.6	RPR	9.4	RRD	9.3	RTD	14.95
	SDD	11.73										
FK	BSD	30	DBS	.93	DFP	2.87	DMP	.03	DSP	.03	DUZ	10.3
	JQB	3.13	JQT	1.67	JTI	2.13	SBD	83.39	SDU	7.3	SMN	1
FM	JQP	1.67										
FPCR	CSU	.03	DAM	10	DBS	.93	DDM	1.97	DFP	2.87	DHM	.2
	DMP	.03	DRS	2.63	DSP	.03	DUZ	10.3	FTM	10	JQB	3.13
	JQN	34.33	JQT	1.67	JQU	1.4	JTI	2.13	SCR	.4	SFA	38.8
FPDK	DAM	10	DBS	.93	JQU	1.4	JTI	2.13	SCR	.4	SDU	7.3
FQ	SBD	24										
FR	SBD	24										
FS	CBC	32.73	CRU	9.47	CSF	18	IGI	.07	IQU	1.23	SFB	34.83
	SMP	.03										
FY	BSD	30	CBC	32.73	CNA	4.47	CNN	27.17	COP	21.87	DAM	10
	DDM	1.97	DFP	2.87	DHM	.2	DRS	2.63	DSP	.03	DUZ	10.3
	FTM	10	FWR	10	HCI	8.37	HHM	60	HTI	67.27	JQN	34.33

Table A-1. TABLE UPDATE FREQUENCIES BY PROGRAM (continued)

Table	Programs/Frequency Per Minute											
	JQT	1.67	JTI	2.13	JQB	3.13	PLT	7.3	SBE	2.9	SCV	8.53
	SDU	7.3	SFA	38.8	SFC	38.8	SHF	33.17	XPP	69.73	XRL	13.35
FZ	CBC	32.73	COP	21.87	CRJ	34.13	CRU	9.47	CSF	18	IGI	.07
	IQU	1.23	PCA	3.47	PLF	4.57	PSB	7.3	SFB	34.83	SMP	.03
	SUV	25.63	UDP	13.07	UES	14.67	UFB	39.13	UPH	4.83	VEX	.3
	XAL	1	XRM	2	XRU	16.48	XSP	2	XTM	2		
HC	CAD	5	HCI	8.37	HTI	92.31	JQP	1.67	RCD	10		
HE	BSD	30	CAD	5	CNA	4.47	CNN	27.17	DHM	.2	DRS	2.63
	DUZ	10.3	EDG	5	FTM	10	HCI	8.37	HHM	60	HTI	279.11
	JQN	34.33	JQP	1.67	JQT	1.67	JTA	1.87	JTI	2.13	SDU	7.3
HF	HTI	67.27	SHF	33.17								
HG	COP	21.87	HCI	8.37	XAL	1	XPS	1				
HH	BSD	30										
HI	BSD	30	CAD	5	DRS	2.63	DUZ	10.3	FRD	10	HCI	257.15
	HHM	60	HTI	67.27	JQB	3.13	JQN	34.33	JQP	1.67	JQT	1.67
	JTI	2.13	SDU	7.3	XRL	13.35						
HO	CBC	32.73	CNA	4.47	CNN	27.17	DHM	.2	DUZ	10.3	EDG	5
	FTM	10	HTI	67.27	JQN	34.33	JQP	1.67	JQT	1.67	JTA	1.87
	JTI	2.13	JTU	20.17	SDU	7.3	SHF	33.17				
HP	CRJ	34.13	HCI	47.14	HRD	2.77	IRD	.2	JQP	1.67		
IC	SFC	38.8										
IM	RDA	60.03	RIN	25	RWD	95.03						
IP	CIP	40.36	DHM	.2	DRS	2.63	DUZ	10.3	FTM	10	JQB	3.13
	JQT	1.67	JTI	2.13	SDU	7.3						
IQ	DUZ	10.3	HRD	14.47	JQU	1.4						
IS	COP	84.89	DHM	.2	DMP	.03	DRS	2.63	DUZ	10.3	FTM	10
	JQB	3.13	JQT	1.67	JTI	2.13	SDU	7.3	SUV	25.63		
IT	CSF	18	DUZ	10.3	HCI	8.37	SHL	33.17	SHM	33.17		
IU	CTU	6.97	RAT	50								
IZ	BBA	40.8	BTQ	39.8	FTM	10	RVD	5				
JI	BSD	30	CBC	273.61	DUZ	10.3	FTM	10	HHM	60	HTI	67.27
	JQB	3.13	JQN	34.33	JQP	1.67	JQT	1.67	JTI	2.13	SDU	7.3
	XRL	13.35										
JJ	DAM	10	DDM	1.97	DFP	2.87	DMP	.03	DSP	.03	JQU	1.4
	SCH	11.03	SCJ	10.3	SCR	.4						
JO	CBC	32.73	CRJ	34.13								
JT	RDA	60.03	RIN	25	RSL	135.97	RSO	5.03				
ME	CNA	4.47	CNN	27.17	CRU	9.47	CSF	18	CSR	4.13	CTY	.37
	DAM	10	DDM	1.97	DFP	2.87	DMP	.03	DSP	.03	GMF	34.97
	IGI	.07	JQU	1.4	PAS	1.37	PNA	33.17	PTY	3.67	SCD	4.13
	SHL	33.17	VMG	.3	XCA	7.97	XNF	1.02	XRM	2	XRU	16.48
	XRX	9	XSP	2	XTM	2	XTN	120.31	XUP	2		
MN	CNN	27.17	CTU	6.97								
MO	CIP	3	CNA	4.47	CNN	27.17	CPS	6.41	DRF	.03	FTM	10
	JQB	3.13	JTI	2.13	PJJ	11.77	PMO	7.3	PSB	7.3	PTC	28.37

Table A-1. TABLE UPDATE FREQUENCIES BY PROGRAM (Continued)

Table	Programs/Frequency Per Minute											
	SDU	7.3	SFA	38.8	UAK	11.77						
MQ	CIP	3	CNN	89.1	DRS	2.63	DUZ	10.3	FTM	10	JQN	34.33
	JQT	1.67										
MT	CTY	.37	IGI	.07	PAS	1.37	PCE	8.67	PCR	.1	PDE	47.07
	PIT	1.3	PNA	33.17	PTY	3.67						
NU	FTM	10										
OH	PCR	.1	PDE	47.07	PFD	1	PNA	33.17	PTY	30.67	RCD	10
	RRA	5										
PH	FWR	10	JQB	3.13	JQT	1.67	JTI	2.13	SMN	1		
PG	BSD	30	CDP	16.1	CSS	89.19	DRS	2.63	DUZ	10.3	JQB	3.13
	JTI	2.13	SDU	7.3								
QE	IRD	.2										
RA	DSP	.03	SCJ	10.3								
RC	DBS	.93	JQU	1.4	SCE	10.23	SCH	11.03	SCJ	10.3	SCR	.4
RU	RCA	.5										
RZ	HTI	67.27	IRD	.2								
SC	HCI	8.37	SHL	33.17								
SF	CPS	6.41	CSF	63.67	GCS	31.3	GFS	3.47	PCA	3.47	XNF	1.02
TB	PAP	11.77	PAT	2.93	PCD	7.93	PJJ	11.77	PPD	11.77	RAA	16.6
	RAL	5.25	RAM	4.6	RAP	8.35	RDP	7.15	RJJ	12.2	RKR	.6
	RPA	9.6	RPR	9.4	RRD	9.3	RTD	14.95	SDD	11.73		
TC	BSD	30	DUZ	10.3	SCV	8.53	XAK	36.77	XPP	69.73		
TH	HTI	67.27	SHF	33.17								
TK	BSD	30	CBC	32.73	CNA	4.47	CNN	27.17	DHM	.2	DUZ	10.3
	HTI	67.27	IRD	.2	JQN	34.33	JQP	1.67	JQT	1.67	JTA	1.87
	JTI	2.13	JTU	20.17	PJJ	11.77	REF	5	RZM	12	SDU	7.3
	SFA	38.8	SHF	33.17	XRL	13.35						
TT	PTY	3.67	SAC	3.67								
TW	HTI	67.27	IAS	.04	IRD	.2	RCA	.5	RCD	10	SHF	33.17
TY	CDR	7.0	IQU	1.23	PIT	1.3	XAK	36.77				
UC	CNA	4.47	CNN	27.17	COP	21.87	CSF	18	PSB	7.3	SDU	7.3
	SUV	25.63	UFB	39.13	XRU	16.48						
UT	TSR	40.1										
WA	IUW	.04										
WS	RIN	25										
WX	RTG	6										
XC	COP	21.87	CRJ	34.13	CRU	9.47	CSF	18	UFB	39.13	VEX	.3
	XAK	36.77	XAL	1	XRU	16.48						
XQ	CRJ	63.04	DUZ	10.3	JQB	3.13	JTI	2.13	XRL	13.35		
XR	CRJ	34.13	IRD	.2	JQP	1.67						
XS	CNA	4.47	CNN	21.87	CSF	18	DAM	10	DUZ	10.3	PJJ	11.77
	PLT	7.3	PMO	7.3	PPS	7.3	PRT	7.3	PSB	7.3	PTM	7.3
	UAK	11.77	XAK	36.77								

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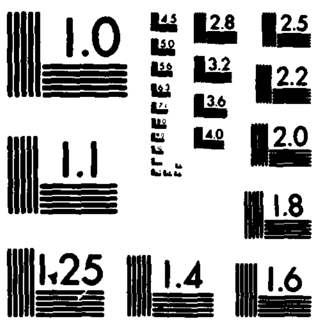

MICROCOPY RESOLUTION TEST CHART

TABLE A-2. TABLE UPDATE RATES

Table	Calls/Min	Words/Call	Words/Min
AA	25	6	150
AB	91.03	15	1.365.45
AK*	382.65	63	24,106.95
AL*	.08	26	2.08
AQ*	102.53	2	205.06
AT*	22.67	74	1,677.58
BE	28.83	1	28.83
BF*	25.76	6	154.56
BI*	238.79	4	955.16
BW*	25.76	6	154.56
BX	25	1	25
CK*	143.46	3	430.38
CM	.2	3	.6
CQ	34.13	8	273.04
CS*	4.83	35	169.05
DQ*	52.26	3	156.78
DS	38.8	1	38.8
FC	34.83	1	34.83
FD	28.37	1	28.37
FE	39.07	10	390.7
FI	231.17	133	30,745.61
FK*	142.78	2	285.56
FM*	1.67	1	1.67
FPCR*	120.85	10	1,208.5
FPDK*	22.16	37	819.92
FQ	24	9	216
FR	24	1	24
FS*	96.36	2	192.72
FY*	561.42	8	4,491.36
FZ*	288.81	3	866.43
HC*	117.35	5	586.75
HE*	490.95	2	981.9
HF*	100.44	2	200.88
HG*	32.24	11	354.64
HH	30	1	30
HI*	505.93	2	1,011.86
HO*	254.45	19	4,834.55
HP	85.91	25	2,147.75
IC	38.8	21	814.8
IM	180.06	3	540.18
IP*	77.72	1	77.72
IQ*	26.17	1	26.17
IR*	75	1	75
IS*	147.91	2	295.82
IT*	103.01	6	618.06

TABLE A-2. TABLE UPDATE RATES (continued)

Table	Calls/Min	Words/Call	Words/Min
IU	66.97	1	66.97
IZ	95.6	1	95.6
JI*	514.49	9	4,630.41
JJ	38.03	42	1,597.26
JO*	66.86	43	2,874.98
JT	226.03	37	8,363.11
ME	353.54	1	353.54
MG	150	14	2,100
MN*	34.14	38	1,297.32
MO*	168.95	35	5,913.25
MP	150	9	1,350
MQ*	151.03	2	302.06
MT*	95.79	2	191.58
MW*	150	15	2,250
NU*	10	12	120
OH	127.01	1	127.01
PH*	17.93	6	107.58
PG*	160.78	3	482.34
QE	.2	1	.2
RA	10.33	15	154.95
RC	34.29	21	720.09
RU	.5	25	12.5
RZ*	67.47	1	67.47
SC*	41.54	7	290.78
SF	109.34	11	1,202.74
TB	155.9	3	467.7
TC*	155.33	40	6,213.2
TH*	100.44	9	903.96
TK*	355.57	13	4,622.41
TT	7.34	2	14.68
TW*	111.18	4,884	543,003.12
TY	46.3	2	92.6
UC	167.35	3	502.05
UT	40.1	19	761.9
WA*	.04	26	1.04
WS	25	200	5,000
WX	6	1	6
XC	177.15	4	708.6
XQ*	91.95	2	183.9
XR	36	6	216
XS	168.48	1	168.48

*Lockable table

APPENDIX B
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