Advanced Automation System Loads Analysis and Definition

Workload Analysis
Volume II

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ABSTRACT

The Advanced Automation System (AAS) is a proposed replacement for the hardware and software that function as the current real time air traffic control computer system. For purposes of system performance modeling, capacity management and system performance testing, a system workload is defined. This report, Volume II, describes the rationale for all workload parameter values. The workload parameters have values determined for the years 1985, 1990, 1995, 2000, and 2010. For the AAS time period, 1995 to 2010, the workload includes values for two AAS states, "Prepare for Backup" and "Handle Backup". Facility-specific values are estimated for key workload parameters.

A summary of workload parameter values for the AAS is presented in Volume I, "Workload Definition." In addition, the workload parameters are briefly defined.

Volume III, "NAS Operational Data," describes some of the operational data which are the bases for the workload values described in Volume II and summarized in Volume I.

ACKNOWLEDGEMENT

The generation of workload data for the AAS and the Host/ISSS system involved interaction with innumerable people with a variety of skills and background. From these people, the authors borrowed research, data, ideas and experience. Many hours of their time was spent in explanation of future concepts of air traffic control and the design of the AAS system.

Since this project has been operating for more than two years, it would be impossible to make a list of all those people who gave us valuable assistance. As an alternative, however, we would like to acknowledge the help given to us in the task of revising the last AAS workload document to yield this current report.

Paul Ostwald of MITRE spent hours explaining present and future concepts of aircraft metering. Ellen Cherniavsky helped provide the basis for estimating the Conflict Alert workload. Bill Niedringhaus prepared a model for Trajectories in Conflict which we modified for our use. The experience of these MITRE staff provided us with insight into complex areas.

Much of the programming was performed by Mike Riddle, Keith Golden, and Mark Desrosier who worked on a co-op program at MITRE. Leon Wishert was spread thin in providing programming and clerical assistance whenever needed.

The list of workload parameters identified in Appendix A has been added to and deleted from during the past years. Nevertheless, it still bears a strong resemblance to the original list prepared by Anand Mundra. Dr. Mundra's early work was a firm basis for the results described herein.

Dick Robinson led this project from its inception through some critical times. His expertise in air traffic control provided the team with insight not only on current NAS operations, but also on the future operations where only the experienced dare to tread.

Frank Petroski of MITRE infused ideas and a sense of timeliness into the project. His critique of this report was detailed and included practical recommendations when changes were to be made. Bob Wiseman of FAA was thorough in his reviews and encouraging throughout the project.

Elise Dimmick, Judy Bradley and Jill Stone processed this document, staying with it through innumerable changes and willingly keeping pace with the erratic production of its authors.

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1. INTRODUCTION

The FAA's Advanced Automation Program Office has established the Modeling and Simulation Program Element (MSPE). One of its charters is the creation and maintenance of a set of system workloads to be used throughout the procurement of the Host and Advanced Automation System (AAS), including the Initial Sector Suite System (ISSS). The MITRE Corporation has been tasked under the MSPE with the development of system workload parameters and workload scenarios for use in the design, testing and implementation of the AAS, including the ISSS.

1.1 Background

Volume I[1] of this three-volume MITRE Technical Report, Workload Definition, presented the numerical results of the System Loads Definition and Analysis work effort. Numerical results consist of quantifications of workload parameters, which are used for creating workload scenarios. Volume I also presented an overview of the methodologies used in determining workload parameter values.

This report, Volume II, documents the workload development effort. The methods used to obtain each scenario are described. Modeling efforts are used where minimal data are available. The workload scenarios are subject to refinement and revision as further analyses are conducted.

Volume III,[2] National Airspace System (NAS) Operational Data, presents workload parameter values obtained for the Air Route Traffic Control Centers (ARTCC) for which data was available. Samples of current Air Traffic Control (ATC) field data were reduced and analyzed in order to derive these values. The site-specific workload parameter values were then used to formulate a current workload scenario—a single set of workload parameter values that would represent the computer system loading not expected to be exceeded at an ATC facility today.

1.2 Workload Definition

The MSPE has defined Workload Modeling as a major subprogram of the system capacity planning and management efforts.[3] This subprogram has as its goal the production of "workload parameter" values which are projections over time of air traffic, interfacility messages, and controller activities related to the use of automated ATC aids. A workload parameter characterizes a demand for computer system resources. A "workload scenario" is represented by a complete and consistent set of workload parameters which, taken as a whole, characterize a peak condition ATC environment as handled by a processor. In this report, workload scenarios are time-dependent, i.e., a workload scenario is developed for each of the years: 1985, 1990, 1995, 2000, and 2010.

The approach to parameter evaluation is an attempt to compromise between the requirement to reflect peak system load and to avoid an unrealistically high workload. In the majority of cases the maximum value determined from field data was taken as the scenario value. In those cases where the maximum value was not used, it was felt that there was a compelling reason for not choosing the maximum; this reason is fully described.

1.3 Workload Scenario Valuation Methodology

The methodology used for workload parameter evaluation and scenario construction consisted of a number of steps. These steps are briefly described here: a more complete description of the methodology process appears in Section 2.

1.3.1 Selection of Parameter Set

The selection of the parameters to be used in representing the AAS workload is fully described in the System Loads Development Plan.[3] The process is reviewed here for the reader's convenience.

The AAS workload is characterized by two types of parameters: external load characteristics and system messages. Although the external load characteristics, such as track level, significantly affect the use of system resources, they do not represent specific transactions processed by the system. Therefore, the evaluation of those attributes to be included in the workload definition was, of necessity, qualitative in nature. The system messages, on the other hand, are directly related to a transaction which requires a fixed amount of processing and were evaluated quantitatively.

The selection procedure first involved the compilation of ATC workload characteristics from many disparate sources. This inventory was then divided into two sets: external load characteristics and system messages. The two sets were each ranked with respect to significance of load on the ATC computer. The ranking of set one was based upon MITRE expert opinion, as well as Reference 4. The ranking of set two was also based upon MITRE expert opinion and upon previous studies of NAS message use. A cut-off level, based on system load impact, was established for each set: parameters falling below these levels were discarded from the inventory. Full details are provided in Reference 3.

The parameter set selected for evaluation is described in Appendix A.

1.3.2 Valuation of Parameters

It became clear that a vast amount of operational data is available to evaluate certain key parameters. This is especially true where the parameters in the AAS are also represented in the present NAS Stage A En-Route system. In cases where an AAS function was not implemented in NAS (e.g., Trajectories in Conflict), a model of the AAS function was theorized, and current data was used or extrapolated as a basis for estimating the parameter. In this way, current data was used as building blocks to determine parameter values for which no real data exists. Section 2 of this report provides a detailed valuation of these parameters.

1.3.3 Requirement for a Workload Scenario Parameter Set

The data collection and analysis effort produced parameter values (and sometimes projections) from each of the facilities studied. Once these values were obtained, it was necessary to choose a single value to represent each of these parameters. The choice of this set was based on representing a hypothetical facility with a combined workload as great as any current or future facility. The parameter values for this hypothetical facility are determined for five points in time - 1985, 1990, 1995, 2000 and 2010. Each of these parameter sets is called a workload scenario; the conditions for the scenario are determined by the air traffic environment at each of the specified times.

Parameter values for each scenario are determined by rules which dictate that a compelling reason must be given to choose a value other than the maximum expected value for each parameter. The chief candidate for compelling reason was the incompatibility of one maximum parameter value with another maximum parameter value. Other candidates for compelling reasons are listed in Section 2.1.2.1.

1.3.4 Projection of Parameters

After the workload set was evaluated, it was necessary to project these values to the five time periods of interest: 1985, 1990, 1995, 2000, and 2010. A variety of estimating techniques was used to perform this projection.

1.3.5 ACF-Specific Parameters

Each Area Control Facility (ACF) was analyzed to obtain workload data for the years 1995, 2000, and 2010 (i.e., the Consolidation Period). Information obtained during this analysis pertained to: surveillance sites, TCCCs, control positions and sectors. This information has been added to the list of workload parameter values as numbers 3, 28, 29, and 30. A brief description of each of these parameters is presented in Appendix A.

The current workload scenarios have been determined using the best available data and analysis techniques. Future updates to these scenarios are planned to take advantage of the ongoing program to improve the analysis techniques and expand the data base used to develop workload scenarios.

1.4 Organization of This Document

Because much of the methodology and purpose of the workload project was explained in prior editions (References 1, 5, and 6), this volume contains only one section to explain the analysis. This is Section 2, the first part of which (2.1) provides the background to the analysis. Sections 2.2 and 2.3 provide the rationale for maximum stress and ACF-specific values, respectively. These sections are further divided according to the parameter number for which a rationale is being provided, e.g., Section 2.2.15 presents the analysis for Parameter 15, Sectors Penetrated.

2. WORKLOAD SCENARIO RATIONALE

The methods used to obtain workload parameter values varied considerably. Where the use of NAS data was appropriate, operations data were collected from the 20 ARTCCS throughout the conterminous U.S. The data were analyzed through data processing techniques to extract maximum stress values. Adjustments were made to the maximum stress values to project an ACF value during the Consolidation Period and to augment the values to allow for the additional load required for backup.

Where operational data were not available or were not applicable, other means were used to obtain workload data. In some cases, simple models were prepared to determine the workload scenario. Information on AERA was used in estimating workload values for the consolidation period. Statistics on growth rate of General Aviation and commercial aircraft were used as a basis for projecting current scenario values to the future years.

Certain workload parameters (i.e., Peak Aircraft Track Load, Parameter No. 2.0 and Radar Site Messages, Parameter No. 27.1) were estimated by determining the workload on each facility and by selecting the maximum facility load. These parameters, defined as "ACF-specific" parameters, were obtained through preparation of an analytical model for the Consolidation Period. Much of the data used to build the model was obtained from the results of analyzing many of the other workload scenarios.

This section describes the methodologies used in scenario development, the detailed analysis used in scenario preparation, and the analysis used in determination of ACF-specific scenarios.

2.1 Methodology

For all methods, the objective was to determine workload parameter values associated with peak IFR traffic conditions. For the majority of the parameters, the National Airspace System (NAS) Stage A En Route computer systems were an important source of current data, from which future values could be projected. Most of the remaining parameters represented functions not currently implemented in NAS so those values could not be established from current NAS data. Data sources for the latter parameters were FAA statistics and studies of the particular function.

During this study certain three letter facility designators are used to identify ARTCCs and ACFs. Table 2.1-1 presents two designators; note the practice of using the Z-- code for ARTCCs and a non-Z code for ACFs.

2.1.1 Data Sources

The primary source of data for this effort was the 20 centers controlling en route traffic in the conterminous United States. The Federal Aviation Administration (FAA) and FAA contractors provided technical reports on past performance and forecasts of aircraft activity.

2.1.1.1 The National Airspace System as a Data Source

Since data was obtained for over 60% of the parameters using existing NAS Stage A En Route software, the data collection procedure deserves particular mention. Two NAS data collection programs were used to extract current data (1982-1985) for analysis. With the exception of some 1982 data compiled by Jacques Press, FAA-ACT-130, from the annual computer utilization study, most of the NAS data was obtained by requesting samples from each Air Route Traffic Control Center (ARTCC) during the busiest three hours of the day that was most likely to reflect peak IFR traffic conditions - always a Thursday or Friday. See Table 2.1.1.1-1.

Two programs were operated in conjunction with the normal NAS software to produce 9-track tape files of data. The program called System Analysis Recording (SAR) recorded all NAS message transactions as they occurred and, at specific intervals, recorded the contents of specified tables relating especially to flight plan processing and tracking. The second program, Common Digitizer Record (CD Record), recorded (on 9-track tape files) all radar target reports upon receipt at the NAS common digitizer interface.

MITRE used the FAA's Data Analysis and Reduction Tool (DART)[7] and NOSS Recording Data Processor Subprogram (ULR)[8] to extract flight plan, track, message, and conflict alert processing data from SAR. Further, parameter-specific analysis software was written to determine parameter values for each ARTCC by running the programs using the DART and ULR reports as inputs.

The radar data from CD Record was processed by the FAA's reduction program, COMDIG,[9] to obtain files of time-stamped radar messages stratified by initiating radar site. MITRE

TABLE 2.1-1
ARTCC AND ACF DESIGNATORS

Facility Name	ARTCC ID	ACF ID
Albuquerque	ZAB	ABQ
Anchorage	ZAN	ANC
Atlanta	ZTL	ATL
Boston	ZBW	BOS
Chicago	ZAU	CHI
Cleveland	ZOB	CLE
Denver	ZDV	DEN
Fort Worth	ZFW	FTW
Honolulu	ZHO	HON
Houston	ZHU	HOU
Indianapolis	ZID	IND
Jacksonville	ZJX	JAX
Kansas City	ZKC	MKC
Los Angeles	ZLA	LAX
Memphis	ZME	MEM
Miami	ZMA	MIA
Minneapolis	ZMP	MSP
New York (A)	—	NYA
New York (B)	ZNY	NYB
Oakland	ZOA	OAK
Salt Lake City	ZLC	SLC
Seattle	ZSE	SEA
Washington	ZDC	DCA

TABLE 2.1.1.1-1
STATISTICS OF SAMPLED CENTERS

CENTER	TYPE OF SAMPLE	DATE SAMPLED	TIME (LOCAL) SAMPLED	TYPE OF PROCESSOR	PEAK TRACK LOAD	
					EXPECTED[1]	SAMPLED
ATLANTA	SAR	7/29/82	1541-1650	9020-D	270	246
CLEVELAND	SAR	8/11/82	1301-1408	9020-D	304	197
MINNEAPOLIS	SAR	10/22/82	1254-1354	9020-A	226	156
	CD	11/15/84	1300-1400			
NEW YORK	SAR	12/30/82	1506-1616	9020-D	225	149
SEATTLE	SAR	11/06/82	806-1107	9020-A	235	130 (Est.)
	CD	11/08/84	1000-1100			
ATLANTA	SAR	10/11/83	1611-1747	9020-D	282	259
CLEVELAND	SAR	10/11/83	1713-1846	9020-D	315	261
	CD	11/15/84	1440-1540			
FT WORTH	SAR	8/26/83	952-1110	9020-D	329	204
	CD	11/09/84	1345-1445	9020-D	329	204
KANSAS CITY	SAR	5/26/83	1446-1548	9020-D	314	224
	CD	11/02/84	1457-1557			
WASHINGTON	SAR	10/20/83	1556-1906	9020-D	262	278
	CD	7/20/85	620-720			
	CD	1/24/85	1505-1605			
ALBUQUERQUE	SAR	4/06/84	600-1159	9020-A	298	218
HOUSTON	SAR	4/06/84	1310-1534	9020-A	262	219

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[1] Reference 10

TABLE 2.1.1.1-1
(Concluded)

CENTER	TYPE OF SAMPLE	DATE SAMPLED	TIME (LOCAL) SAMPLED	TYPE OF PROCESSOR	PEAK TRACK LOAD	
					EXPECTED[1]	SAMPLED
INDIANAPOLIS	SAR	4/05/84	1529-1807	9020-D	294	251
	CD	4/05/84	1126-1236			
JACKSONVILLE	SAR	3/30/84	1000-1607	9020-D	224	251
MEMPHIS	SAR	3/30/84	1357-1703	9020-A	298	223
	CD	3/30/84	1400-1500			
BOSTON	SAR	4/16/85	1758-1601	9020-A	191	132
CHICAGO	SAR	6/14/85	1140-1643	9020-D	384	230
DENVER	SAR	2/26/85	845-1214	9020-A	380	213
LOS ANGELES	SAR	2/06/85	914-1008	9020-D	297	186
MIAMI	SAR	5/03/85	1140-1623	9020-A	279	151
NEW YORK	SAR	4/09/85	1453-1801	9020-D	248	245
OAKLAND	SAR	3/21/85	855-1200	9020-A	274	154
SALT LAKE CITY	SAR	3/09/85	850-1205	9020-A	266	165
	CD	11/15/84	1242-1342			

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[1] Reference 10

further organized the data by message and beacon type and wrote software to determine the values of radar-dependent parameters such as Parameter Number 4, Primary Noise.

2.1.1.2 FAA Data Sources

The FAA provided other key data sources, notable among them being the forecast for IFR traffic by ARTCC from the present year to year 2010.[10] This source is notable because the traffic forecast is the single most important workload driver.

The message rates (including radar reports) and the values of many other parameters are a function of controlled traffic level.

Other FAA data sources provided information on VFR traffic forecast[11], and statistics on individual airport activity[12], and terminal area forecasts[13]. The VFR forecasts were used along with IFR forecasts to determine total traffic activity for future years. Terminal area forecasts and individual airport activity statistics were used in determining the contribution to aircraft workload made by approach control traffic during the consolidation years.

Statistics on General Aviation[14] (GA) were used to determine transponder equipage for those aircraft which were not air carrier or military. These statistics are published periodically by the FAA.

2.1.1.3 Other Data Sources

An analysis of Leesburg FSS data by McClinton[15] was used as the basis for determining the airborne characteristics of VFR aircraft. These characteristics include average velocity, travel time, and altitude.

2.1.2 Analysis

The type of analysis used to determine workload depended on the type of data used. For those parameter values determined by examining NAS data, a current scenario was created and these scenario values were projected into the future. Most of the remaining parameters required analysis of new functions or new control configuration (formation of ACFs) and each of the future values was determined directly.

2.1.2.1 Analysis of NAS-derived Parameters

Each SAR data sample yielded estimates of facility-specific parameter values. These estimates are presented in Volume III organized by sample, i.e., the 1984 Albuquerque sample values appear in a separate appendix from the 1983 Atlanta sample values. The codes used throughout this Volume to identify particular ARTCCs by the year in which they were sampled are presented in Table 2.1.2.1-1

When the reduction of all NAS-derived parameters was complete, a workload value existed for each ARTCC. The next step was to evaluate those parameters to determine current scenario values (for this report, current scenario = 1985 scenario). The test for these values is easily stated but implementation is complicated because the "workload scenario concept" includes two kinds of requirements. There is a requirement that the maximum value be chosen for each parameter (unless a compelling reason can be found not to select this value); the other requirement is that the set of parameters must represent a consistent workload scenario. This second requirement became one of the "compelling reasons" to reject a maximum value.

Other "compelling reasons" include the following:

1. The suspicion that data is inaccurate or biased.

2. The sample from which the data was taken represented a traffic load too low to reflect a demanding load. For any sample, this factor may be true for one parameter but not true for another.

3. The key descriptor of the workload scenario is the track load which was chosen to be the highest load forecast for any facility. Analysis of IFR track forecast[10] shows Denver is projected to be the high load facility from 1995 to 2010. An effort to construct an internally consistent workload scenario might use an argument to favor values from facilities that better represent the Denver traffic environment. This was done, for example, to determine values for Message Origin, Parameter 24.

TABLE 2.1.2.1-1
ARTCC CODE USED TO REFERENCE NAS SAMPLE DATA

Sampled ARTCC	Year of Sample	Code	Sampled ARTCC	Year of Sample	Code
Albuquerque	1984	AB4	Jacksonville	1984	DE4
Atlanta	1982	AT2	Kansas City	1983	MK3
Atlanta	1983	AT3	Los Angeles	1985	LA5
Boston	1985	BO5	Memphis	1984	ME4
Chicago	1985	CH5	Miami	1985	MI5
Cleveland	1982	CL2	Minneapolis	1982	MS2
Cleveland	1983	CL3	New York	1985	NY5
Denver	1985	DE5	Oakland	1985	OA5
Ft. Worth	1983	FT3	Salt Lake City	1985	SL5
Houston	1984	HO4	Seattle	1982	SE2
Indianapolis	1984	IN4	Washington	1983	DC3

2.1.2.2 Projection of NAS-derived Parameters

Given that a workload parameter value was derived using NAS data for the current workload scenario, it was necessary to project the current value to the future years of interest, 1985, 1990, 1995, 2000, and 2010. It was originally thought that sufficient data would be reduced and analyzed in order that a relation could be determined whereby future traffic level would predict future workload parameter value:

$$P = f(T)$$

where P is the parameter of interest,
T is the traffic level,
and f(T) is the prediction function.

As it happened, too little data was collected to determine these relationships, so a rather simple projection methodology was used.

First, the workload parameters were categorized as to whether projection of the current value to future years would be appropriate. For example, there is no reason to believe that altitude distribution will change in future years, so the current workload parameter value is probably a good value for all future years of interest. On the other hand, there is good reason to believe that conflict alert rate will change (perhaps increase as traffic increases) and projection to future years is appropriate.

Secondly, for the workload parameters for which projection is appropriate, simple scalar multiplicative factors were developed where possible, (using NAS-derived data) for converting from the current year value to future years. In some cases, projection factors could not be found and so a gradual growth or diminishment of the value was conjectured. Also considered for the projection process were the future impacts on the ATC or aviation environment. For example, conflict alert rate would increase with traffic level, but be mitigated by future AERA functions. Projection methodologies are presented for each parameter in the following sections.

2.1.2.3 Analysis of Parameters Representing Future Functions

Many of the parameters represent functions which are unrelated to those which occur in the current NAS system. Parameters of this type are represented by Trajectories in Conflict (No. 17) and Probability of Flight Trajectory Conflict (No. 21). These parameters were evaluated using current AERA research as a basis. A mathematical model was prepared to evaluate Trajectories in Conflict. The expertise of AERA modellers was the basis for evaluating Probability of Flight Trajectory Conflict.

Other parameters representing future functions are modifications of parameter values used in the current NAS system. As an example, Resynchronization/Flight (No. 18.4) is an AERA extension of the parameter Updates/Flight (No. 18.2).

2.1.3 Facility Back-up

The AAS SLS requires provision for a back-up capability. Essentially, each ACF must be prepared to provide ATC services for adjacent facilities in case of failure.

Two types of factors are needed to reflect the impact that facility back-up will have on performance characteristics. During normal operating conditions, it is assumed that each facility will control traffic within its assigned airspace as well as monitor a portion of airspace equivalent to its airspace (e.g., a facility may be required to monitor 25% of each of four adjacent facilities or 17% of each of six adjacent facilities). This condition is called "Prepare For Back-up" and is represented by an expansion factor of 2.0.

During back-up mode, each facility is assumed to have sufficient capacity to service 30% more airspace. The 30% figure reflects 25% of the airspace of an average adjacent center plus some extra amount to handle unique local situations. The expansion factor for operation during back-up mode ("Handle Back-up") is assumed to be 1.3. These factors were especially helpful to calculate ACF-specific values.

2.2 Determination of the Maximum Stress Scenario

The following is a description of the process by which maximum stress values for each parameter were determined. The order of presentation follows that of the parameter numbering sequence used in Volume I, Workload Definition, e.g., Flight Plan Load is shown as Parameter 1 in Volume 1; in Volume II, it is discussed under 2.2.1.

2.2.1 Flight Plan Load

The parameter is measured in units of flight plans/controlled track. It is an estimate of the number of flight plans in the system at the time that controlled traffic peaks. The data for this parameter is provided by the NAS system, at 1 minute or 5 minute intervals. At the time when the number of controlled tracks is at a peak, the number of active and pending flight plans is counted. Parameter values for each sampled ARTCC are shown in Table 2.2.1-1.

2.2.1.1 Active Flight Plans/Track

The scenario value previously assigned to this parameter was 2.00;[6] Table 2.2.1-2 shows the results of an analysis done to test the applicability of this value compared to new data. The conclusion remains that 2.00 represents a FP/Track storage value unlikely to be exceeded by an ARTCC. This value is assumed not to change significantly over time.

2.2.1.2 Total Flight Plans/Track

This is the sum of active and pending flight plans/controlled track. The scenario value previously assigned to this parameter is 4.00.[6] New data, however, reveals that values as high as 6 have occurred, undoubtedly the effect of oceanic airspace in Miami, New York, and Oakland. To determine a new scenario value, an analysis of the effect of this parameter on storage was done (Table 2.2.1-2) for all ARTCCs with parameter values of 4.00 or higher. The highest storage load occurs at Miami and the scenario value of 4.30 was calculated to provide the Miami level of flight plan storage in 1995. This value is assumed not to change significantly over time.

2.2.2 Peak Track Load

This parameter is the total number of controlled and uncontrolled tracks on a facility vs. sector basis at a peak instant, a basic measure of load on the system.

2.2.2.1 Facility Peak Track Load

The facility peak track load is comprised of the next two parameters.

TABLE 2.2.1-1
DEVELOPMENT OF VALUES FOR PARAMETER 1 USING OPERATIONAL DATA

ARTCC	1.1 ACTIVE FPs/ TRACK	1.2 TOTAL FPs/ TRACK
AT2	1.77	3.60
CL2	1.51	3.18
MS2	1.49	3.24
SE2	*	*
AT3	1.82	4.10
CL3	1.77	3.56
DC3	1.59	3.27
FT3	1.47	2.93
MK3	1.43	2.72
AB4	1.38	3.75
HO4	1.61	3.92
IN4	1.88	3.60
JA4	1.79	3.16
ME4	1.58	2.98
BO5	1.92	4.64
CH5	1.62	3.64
DE5	1.40	2.35
LA5	1.61	4.02
MI5	2.31	6.43
NY5	2.01	5.22
OA5	2.81	3.47
SL5	1.57	2.57
AVERAGE	1.75	3.63
CURRENT SCENARIO	2.00	4.30
1990	2.00	4.30
1995	2.00	4.30
1995	2.00	4.30
2000	2.00	4.30
2010	2.00	4.30

*No data.

TABLE 2.2.1-2
ANALYSIS OF FLIGHT PLAN STORAGE

FACILITY	1995 FORECASTED IFR TRACKS	DATA		CALCULATIONS	
		ACTIVE FPs/ IFR TRACK	TOTAL FPs/ IFR TRACK	STORED FPs	
				ACTIVE	TOTAL
Boston	265	1.92	4.64	509	1230
Miami	424	2.27	6.11	962	2590
New York	330	2.01	5.22	663	1723
Oakland	364	2.81	3.47	1022	1263
Scenario Value	600	2.00	4.30	1200	2590

2.2.2.1.1 Facility Peak Controlled Tracks

This parameter is calculated using an FAA[10] forecast of ARTCC traffic levels (Appendix D), and a methodology to reapportion ARTCCs into ACFs (Appendix L). An adjustment is required that considers the approach control track level (Appendix L). The maximum stress values during the Consolidation Period were taken from Volume I, Table 2-8, Kansas City. These "Prepare for Back-up" values were multiplied by the factor, 1.3, to determine "Handle Back-up".

2.2.2.1.2 Facility Peak Uncontrolled Tracks

At the current time NAS does not track VFR aircraft. In 1990, Conflict Alert will be implemented against IFR and Mode-C (and Mode-S) equipped VFR traffic, necessitating the tracking of Mode-C/Mode-S, VFR aircraft. During the Consolidation Period, all transponder equipped VFR aircraft are required to be tracked. To calculate values for this parameter for all years but 1985, multiply Parameter 2.2.1, Facility Peak Controlled Track by Parameter 7, VFR/IFR Target Ratio and 5.2, Transponder Equipage of uncontrolled aircraft.

2.2.2.1.3 Facility Peak Total Track Load

This parameter is calculated by adding the peak controlled plus peak uncontrolled tracks.

2.2.2.2 Sector Peak Track Load

This parameter is the peak tracks controlled by a single maximum-stress sector, for AAS only, i.e., not applicable to the Host/ISSS period.

2.2.2.2.1 Sector Peak Controlled Tracks

Although the FAA has forecasted peak track load for each en route facility, an equivalent sector peak track projection has not been made. This analysis develops estimates of average sector traffic loading and an estimated peak-to-average sector traffic ratio to estimate the sector peak controlled track count for the Consolidation Period.

Table 2.2.2.2.1-1 is a summary of calculations made throughout the 1985-2010 interval. Although the peak track estimate is not applicable for the Host/ISSS Period (1985-1995) this period is used to establish a trend. In rows D - G, average

TABLE 2.2.2.2.1-1
PEAK SECTOR TRACK COUNT CALCULATIONS

	PARAMETERS	Host/ISSS Period			Consolidation Period		
		1985	1990	1995	1995	2000	2010
	Facility Traffic						
A	Controlled Tracks	380	490	600	910	1060	1310
B	Uncontrolled Tracks	0	230	340	770	900	1130
C	Sectors /Facility (Tracks)	45	50	50	90	92	95
	Sector Traffic						
D	Average Controlled = (A/C)	8.4	9.8	12.0	10.1	11.5	13.8
E	Average En Route Controlled[1,3]	8.4	9.8	12.0	12.0	13.8	16.6
F	Average Uncontrolled[5] = (2xB/C)	0.0	9.2	13.6	17.0	19.6	23.8
G	Average En Route Uncontrolled[2,4]	0.0	9.2	13.6	18.3	21.6	26.2
H	Average En Route Controlled x2 = (2xE)	16.9	19.6	24.0	24.0	27.6	33.2
I	Average En Route Controlled x3 = (3xE)	25.3	29.4	36.0	36.0	41.4	49.8
J	Average En Route Controlled x4 = (4xE)	33.8	39.2	48.0	48.0	55.2	66.4
K	2x Average Controlled + 3x Average Uncontrolled = (H+3xJ)	16.9	47.2	64.8	78.9	92.4	111.8
L	Peak Controlled Tracks/Sector	—	—	—	50	50	50
M	Peak Total Tracks/Sector	—	—	—	120	120	120

Notes:

[1] The 1995 average controlled en route track count for a sector during the Consolidation Period is the same for the 1995 Host/ISSS since it is assumed that sector sizes remain the same.

[2] The 1995 average uncontrolled track count during the Consolidation Period is equal to that for the 1995 Host/ISSS x (94/70). This factor accounts for the tracking of Mode-A-only aircraft during the Consolidation Period.

[3] En route controlled tracks for 2000 & 2010 = Dx(12.0/10.1) = 1.2xD

[4] En route uncontrolled tracks for 2000 & 2010 = Fx(18.3/17.1) = 1.1xF

[5] The factor "2" is included in the calculation because uncontrolled aircraft are detected in approximately half of the sectors (ie - low altitude sectors).

controlled track values are calculated from both the forecasted maximum stress facility traffic loads and the maximum stress sector counts for each year. The values in rows D and F are used just to calculate the values of interest in rows E and G. The average en route controlled tracks/sector (row E) represents average values for the sectors with the most controlled traffic, i.e., the high altitude, en route sectors. The average en route uncontrolled tracks/sector (row G) represents average values for the sectors with the most uncontrolled traffic, i.e., the transitional sectors. These values are multiplied by a peak-to-average ratio (described in the next paragraph) to determine maximum stress sector load.

Rows H through J are multiples of the average en route controlled track level. In order to determine the peak-to-average ratio, air traffic controllers and central flow control personnel were consulted and results from a MITRE (unvalidated) track counting program were evaluated. The conclusion was that a peak-to-average ratio of 3 to 4 was realistic; therefore peak sector track levels of 3 and 4 (and 2) times average were calculated.

This analysis results in sector load estimates as high as 65 controlled tracks for 2010 using a peak-to-average ratio of 4. However, a decrease in peak-to-average behavior is expected as the average track load per sector increases. A sector track load of 50 represents a peak-to-average ratio of 4 in 1995 and decreases to 3 in 2010. This conclusion appears to be consistent with the field controllers' opinion that, from an operational perspective, 50 controlled aircraft is the most a sector controller could handle at any time and still be able to provide back-up assistance should the automation fail.

Considering that the controllers' estimate was made relative to current traffic and was verified by the calculations for 2010, the "safe" estimate of peak track load/sector for all of the Consolidation Period is set at 50.

No addition to the peak track value is anticipated for the handle-back-up case because facility back-up plans are expected to be formulated with busy sectors as a criterion for combining sectors during transition-to-back-up.

2.2.2.2.2 Sector Peak Total Tracks

The peak total number of tracks was determined in a manner similar to peak controlled tracks. This peak is expected to occur in a low altitude or transition enroute sector where a moderate number of controlled and a significant number of uncontrolled aircraft would be present.

Assuming that the peak value for controlled traffic is twice the average value in such a Sector, and that the ratio of peak/average value for uncontrolled traffic is 3, the sector peak total load is calculated as:

2x(average con-tracks) + 3x(average uncon-tracks)

The calculations are shown in Table 2.2.2.2.1-1, row K.

The value for total tracks per sector is rounded upward to 120 for 2010 and is considered as the peak value for the 1995 to 2010 period.

2.2.3 Number of Surveillance Sites

This parameter provides an expected count of long and short range surveillance sites reporting to both the maximum stress ACF and the maximum stress sector. An additional count was made of all the geographical areas including the maximum stress sector and a strip 150 nmi beyond the sector boundary per the AAS System Level Specification[29] requirements (Section 3.2.1.1.2.1.2.1, Response to Local Message Inputs).

There are two sources of values for the facility total: an analysis of the NAS Radar Surveillance Network Plan[33] determined the maximum number of long and short range radars by ARTCC projected for the years 1985-1995; a further analysis of that data source (Appendix C) determined the maximum number of sites for each ACF. The maximum stress values for Parameter 3.1, 1995-2010, were taken from the ACF-specific data presented in Volume I, Section 2.3.

The sector values (Parameters 3.2 and 3.3) were determined by considering two nominal sector sizes, a low-altitude sector sized at 50 x 50 nmi and a high-altitude sector sized at 100 x 100 nmi. Using a map of sensor site locations nationwide, the nominal low-altitude sector was placed within the ACF-B where the most radars, both short and long range, would provide surveillance. Likewise, the nominal high-altitude sector was placed within the ACF-A where the most radars would provide surveillance. Included in the count were short range radars within 50 nmi of the sector, and long range radars within 100 nmi of the sector. The maximum sensor count for both short and long range radars for the above two cases was taken as the parameter value. The above procedure was repeated for nominal sector sizes plus 150 nmi beyond the sector boundaries.

2.2.3.1 Facility Total

Table 2.2.3.1-1 lists the number of long and short range radars by ARTCC and by date of implementation. As can be seen, the Minneapolis-St. Paul ARTCC has the maximum number of long range radar sites during the period 1985-1995. Table 2-4.1, Volume I presents an ACF-specific list of long and short range radar sites. It can be seen that the ACF with the maximum number of long range radars is Seattle with a total of 36. This value reflects an actual count of 14 radar sites located within the facility boundary plus 4 sites outside of the boundary. The outside radars consisted of all those sites within 100 nmi of the boundary but which did not provide duplicate coverage within the facility. This count was doubled to account for "Prepare for Back-up" conditions. Two more long range radars outside the boundary were added to the count because it was conceivable that they may be linked to Seattle.

Minneapolis-St. Paul is the ACF with the maximum number of short range radars with 36. For the ACF consolidation time period, it was assumed that no radar site growth occurs and the maximum stress value for short range radars = 36. For "Handle Back-up" conditions, the maximum values, attributed to Seattle and Minneapolis (Volume I, Table 2-4.2) were used. Like the "Prepare for Back-up" calculation, two more outside long range radars were added to the Seattle total.

2.2.3.2 Sector

It was found that the nominal high-altitude sector, when positioned inside the Cleveland ACF-A, would yield a higher radar count then in any other ACF. The sector would be surveilled by 7 long range radars and 9 short range radars.

2.2.3.3 Sector Plus 150 nmi Beyond Boundary

Extending the boundaries of the nominal high altitude sector by 150 nmi, and positioning it inside the Cleveland ACF-A (again, the maximum over all facilities), a count of 17 long range radars was made. For the short range radars, the problem became one of finding the ACF with the most short range radars, since 400 x 400 nmi (100 x 100 nmi plus 150 nmi extension) will completely cover most any ACF. The Fort Worth ACF was selected, as it has 14 short range radars.

TABLE 2.2.3.1-1
RADAR SUMMARY 1985 - 1995

CENTER	CODE	UP TO 1985			1986 - 1990			1991 - 1995		
		LRR	SRR	TOTAL	LRR	SRR	TOTAL	LRR	SRR	TOTAL
ALBUQUERQUE	ZAB	7	-	7	7	-	7	8	1	9
ATLANTA	ZTL	11	-	11	11	-	11	2	6	8
BOSTON	ZBW	8	-	8	8	-	8	8	-	8
CHICAGO	ZAU	9	-	9	9	-	9	10	-	10
CLEVELAND	ZOB	8	-	8	8	-	8	8	-	8
DENVER	ZDV	11	-	11	13	-	13	14	-	14
FORT WORTH	ZFW	5	-	5	5	-	5	6	1	7
HOUSTON	ZHU	8	-	8	8	1	9	5	-	5
INDIANAPOLIS	ZID	7	-	7	7	-	7	6	-	6
JACKSONVILLE	ZJX	10	-	10	10	-	10	5	4	9
KANSAS CITY	ZKC	9	-	9	10	-	10	9	-	9
LOS ANGELES	ZLA	8	1	9	9	1	10	10	1	11
MEMPHIS	ZME	8	-	8	8	1	9	4	6	10
MIAMI	ZMA	6	-	6	6	-	6	6	-	6
MINNEAPOLIS	ZMP	13	-	13	14	-	14	16	4	20
NEW YORK	ZNY	4	-	4	4	-	4	4	-	4
OAKLAND	ZOA	7	-	7	6	-	6	6	-	6
SALT LAKE CITY	ZLC	12	-	12	12	-	12	16	1	17
SEATTLE	ZSC	6	-	6	7	2	9	7	2	9
WASHINGTON	ZDC	5	-	5	5	-	5	4	2	6

2.2.4 Primary Noise Rate

Primary noise is that set of search target reports that consist of non-aircraft reflections. However, the primary radar cannot distinguish primary noise from the returns of real aircraft so any primary target report not correlated with a beacon target report could be noise. Data has been collected from long range radars (CD-record tapes) and reduction and analysis programs have been constructed to separate these two categories of targets.

The data reduction and analysis programs consist of various extraction and counting programs as well as a primary track-all tracker. A manual step for counting primary tracks is also involved. Four centers were selected for reduction: Los Angeles, Minneapolis, New York, and Washington, DC (ZDC). Two ZDC samples were taken: a weather-intensive sample during summer thunderstorms, and a clear-day sample, referred to below as "non-weather."

The approach to determine primary noise rate was to examine all the radar sites for several centers and to discern which of the primary (search) radar messages were attributable to aircraft, and which were not. The latter category was considered primary noise.

Two techniques were employed. First, the automated primary-only track-all tracker was used against the entire surveillance area of each site. Second, areas of size 20 x 20 nmi were selected at random from the entire surveillance area of the radar site, the primary returns for these areas were plotted, and visual identification of trails was used to discern aircraft from noise. These sampled results were then adjusted to represent the entire population (entire surveillance area of the site). Since the automated tracker was in the validation and verification stage of development, it was decided that the manual results should be used to represent the parameter.

The results for the five samples are presented below.

	Primary Noise/Radar/Radar Scan	
	Average for all Radars	Maximum Site
DCA (non-weather)	61	90
DCA (weather)	117	234
LAX	46	99
MSP	47	96
NYC	27	48

Using the results, a normal or ambient noise level for long range radar is 100, with a maximum value of 200 during "weather". For short range radar, the ambient noise level is taken as 100 and the value of 350 is taken as the maximum noise rate, the Airport Surveillance Radar (ASR)-9 Specification value of 300 plus 50 to compensate for uncertainty.

These maximum values, however, are highly unlikely to affect all radars simultaneously. A scenario is proposed to reflect an unusual weather front activity that affects 75% of the facility area simultaneously. This scenario was used because it was considered feasible by the weather specialist of the ZDC ARTCC. During this storm condition, 75% of all radars will produce maximum noise returns. The remaining 25% will produce noise only at the normal or ambient level.

2.2.5 Transponder Equipage

Data has been analyzed to determine the percentage of both VFR and IFR aircraft which operate transponders*. The data for VFR aircraft came from radar reports and for IFR aircraft from flight plan information.

2.2.5.1 Controlled Aircraft Equipage

The transponder equipage field is examined for all flight plans filed by IFR aircraft during the sample periods enumerated in Table 2.1.1.1-1. The percentage of field flights in 3 equipage categories was then determined for every ARTCC sampled (Table 2.2.5-1). Because the trend from 1982 to 1985 shows decreasing percentages of "Mode-A Only" and "No Transponder", the average of 1985 values was chosen to represent the following current scenario:

1%	Mode A only
98%	Mode C only
1%	No transponder.

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*The data used to determine IFR and VFR transponder equipage was obtained during the analysis of "Primary Noise" in Section 2.2.4. See the section for a description of the data collection and reduction procedures.

TABLE 2.2.5-1
DEVELOPMENT OF VALUES FOR PARAMETER 5.1 USING OPERATIONAL DATA

	% CONTROLLED AIRCRAFT		
ARTCC	5.1.1 ATCRBS MODE A Only	5.1.2 ATCRBS MODE C	5.1.3 NO TRANSPONDER
AT2	4	95	1
CL2	3	97	0
MS2	4	96	0
SE2	7	92	1
AT3	3	97	0
CL3	3	96	1
DC3	1	97	2
FT3	1	99	0
MK3	2	97	1
AB4	1	99	0
HO4	4	95	1
IN4	2	97	1
JA4	4	95	1
ME4	2	97	1
BO5	1	99	0
CH5	1	99	0
DE5	0	100	0
LA5	1	99	0
MI5	1	98	1
NY5	0	98	1
OA5	1	99	0
SL5	0	100	0
AVERAGE	2	97	1
CURRENT SCENARIO	1	98	1

2.2.5.2 Uncontrolled Aircraft Equipage

The data source for VFR flights was radar reports. A count of all radar reports (beacon and primary) at each sampled radar (see Table 2.1.1.1-1) yielded an estimate of total VFR traffic plus the distribution of transponder equipage.

Transponder equipage was calculated for a number of centers. The analysis consisted of examining the beacon codes used by VFR aircraft to determine whether they emanated from either Mode A or Mode A/C transponders. Primary aircraft radar returns which could not be paired with beacon returns were considered to identify VFR aircraft without a transponder. A summary of the results of this effort is shown below.

VFR Transponder Equipage

ARTCC	Mode A	Mode A/C	No Equipage
ZNY	35.6	46.2	18.2
ZMP	1.2	44.7	54.1
ZLA	41.6	49.9	8.5
ZDC	23.9	27.9	48.2
Average:	25.6	42.2	32.2

Consistent with the criterion for selecting data which represents a stressed center, the data for the ZLA (Los Angeles) center was selected as the workload values. ZLA is generally considered a very active VFR area. The stress is shown by the relatively low value of "No Equipage" for that center.

There is no known forecast for the growth rate of Mode-S transponders. Rather, a growth rate of General Aviation and of controlled aircraft has been derived from FAA-published information[16]. Interposed onto these growth rates are assumptions concerning:

1. inauguration of Mode-S operation
2. equipage of new GA aircraft
3. the rate of introduction of Mode-S into commercial and military (i.e., non-GA) aircraft
4. attrition rate of current transponders

These assumptions are used as the bases for determining a scenario for transponder equipage for future years.

In order to estimate the distribution of transponder equipage for later years, the following aircraft growth rates are assumed:

1. an average increase in active GA aircraft of 2.8% per year (calculated from Reference 16, Table 6)

2. an average increase in controlled aircraft other than GA of 1.9% per year (calculated from Reference 16, Table 2)

3. an average increase in controlled GA aircraft of 3.9% per year (calculated from Reference 16, Table 16)

The bases for transponder installation during subsequent years follow:

1. Mode-S transponder ground stations begin operation in 1989. This assumption is interpreted from information presented in the National Airspace Plan.[17]

2. After 1989, all new aircraft will be equipped with Mode-S transponders.

3. All non-GA aircraft will be equipped with Mode-S within ten years after the ground stations begin operation.

4. Both Mode-A and Mode-C transponders will have an annual attrition rate of 5% after 1989. Replacement will be made with Mode-S.

5. A total of 5% of controlled GA aircraft will operate without transponders through 1990 due to malfunctions.

These data were algebraically combined in a spreadsheet program to produce the transponder equipage values shown in Table 2.2.5-2.

2.2.6 Flight Filing Status

The route filed in the flight plan is the source for this parameter. For every flight plan in each sample, the route-of-flight field is examined to determine the following statistics:

1. % of routes that are direct route only
2. % of routes that are adapted route only
3. % of routes that are both direct & adapted
4. number of segments in direct route only flights

TABLE 2.2.5-2
TRANSPONDER EQUIPAGE FORECAST

TRANSPONDER TYPE	Percent Transponder Equipage					
	Host/ISSS Years			Consolidation Years		
	1985	1990	1995	1995	2000	2010
Controlled Aircraft						
ATCRBS Mode A Only	1	1	0	0	0	0
ATCRBS Mode C	98	87	37	37	9	4
Mode S	0	11	62	62	90	95
No Transponder	1	1	1	1	1	1
Uncontrolled Aircraft						
ATCRBS Mode A Only	42	35	24	24	16	8
ATCRBS Mode C	50	51	35	35	24	11
Mode S	0	7	35	35	54	77
No Transponder	8	7	6	6	6	4

5. number of segments in adapted route only flights
6. number of segments in both direct and adapted route flights

Table 2.2.6-1 shows a summary of parameter values for each ARTCC sampled.

2.2.6.1 Route Distribution

Because the processing of direct routes is the most demanding, the maximum value (40) was chosen for the current scenario. In apportioning values to the other two route distribution parameters, relatively more weight was given to the direct and adapted routes for the same reason - greater processing load because of the presence of direct routes.

2.2.6.2 Route Segment Count

There is no compelling reason to use values other than maximum.

2.2.7 VFR/IFR Target Ratio

This parameter is a ratio of VFR to IFR targets. For a given ATC scenario, IFR and VFR aircraft are distributed throughout that airspace volume surveilled by the radars reporting to the ATC facility. At any point in time, some aircraft are detected by multiple radars and some are not detected due to the horizon/line-of-sight phenomenon. This parameter is the ratio of VFR to IFR targets, considering that an aircraft is counted at most once, i.e., multiple redundant observations of a target are not considered.

The values for this parameter are as follows:

HOST/ISSS			CONSOLIDATION		
1985	1990	1995	1995	2000	2010
0.8	0.8	0.8	0.9	0.9	0.9

The values for the consolidation period apply to both "handle back-up" and "prepare for back-up" modes.

The approach for computing this parameter is to determine the VFR/IFR target ratios for single radar sites, and then to compute an average target ratio weighted by number of radars of each type and their respective unique target return rates.

TABLE 2.2.6-1
DEVELOPMENT OF VALUES FOR PARAMETER 6.0 USING OPERATIONAL DATA

ARTCC	6.1.1 DIRECT ROUTE ONLY	6.1.2 ADAPTED ROUTE ONLY	6.1.3 DIRECT RTE AND ADAPTED ROUTE	6.2.1 DIRECT ROUTE SEGMENTS ONLY	6.2.2 ADAPTED ROUTE SEGMENTS ONLY	6.2.3 DIRECT RTE AND ADAPTED ROUTE SEGMENTS
AT2	42	14	44	1.98	1.82	3.44
CL2	19	11	70	2.16	2.09	3.93
MS2	36	15	49	2.28	1.55	3.65
SE2	37	30	33	1.63	1.51	3.42
AT3	38	14	48	1.98	1.92	3.28
CL3	28	8	64	2.15	1.88	3.90
DC3	25	14	61	2.02	2.99	3.83
FT3	24	24	52	2.22	1.68	3.46
MK3	33	14	53	2.46	1.95	3.73
AB4	14	22	64	2.20	2.03	3.04
HO4	29	24	47	2.08	1.90	3.50
IN4	33	11	56	2.16	1.84	3.55
JA4	29	18	53	2.17	2.11	3.94
ME4	40	19	41	2.02	1.89	3.63
BO5	27	18	55	1.97	1.71	3.75
CH5	35	4	61	1.95	1.59	3.75
DE5	19	29	52	2.20	1.81	4.09
LA5	24	20	56	2.25	1.76	3.77
MI5	23	23	54	1.84	1.61	3.81
NY5	16	24	60	2.16	2.26	3.79
OA5	33	16	51	2.17	2.01	3.47
SL5	28	26	43	2.12	1.73	4.40
AVERAGE	29	18	53	2.10	1.89	3.69
CURRENT SCENARIO	40	15	45	2.3	3.0	4.4
1990	40	15	45	2.3	3.0	4.4
1995	40	15	45	2.3	3.0	4.4
1995	40	10	50	2.3	3.0	4.4
2000	40	10	50	2.3	3.0	4.4
2010	40	10	50	2.3	3.0	4.4

The following steps are used to effect this approach:

1. Determine the VFR/IFR ratios for single radar sites, long and short range
2. Assign representative target levels for these ratios
3. Determine radar coverage for IFR and VFR, with LRR and SRR
4. Choose appropriate ACF radar count
5. Multiply number of targets by number of radars
6. Divide by average radar coverage

2.2.7.1 Single Radar Site Ratio

The VFR/IFR target ratios for a single site are presented in Appendix J and are as follows:

$$\text{LRR} \quad \frac{\text{VFR}}{\text{IFR}} = .35$$

$$\text{SRR} \quad \frac{\text{VFR}}{\text{IFR}} = .64$$

2.2.7.2 Target Level

Representative target levels are computed using radar data from field sites. (See Appendix J.) It was found that the LRR site QRW at the LAX ARTCC had a high target level (average number of targets detected per scan), and is therefore considered appropriate for use in developing the maximum stress VFR/IFR target ratio. An estimate of the SRR target level was obtained by counting only the returns at the QRW site that were within a 60 nmi radius. The target levels are the following:

LRR = 198 targets*
SRR = 54 targets*

---

*Primary and beacon targets. Only beacon targets were counted. Primary target counts were estimated using Parameter 5, Equipage Mix.

Given the VFR/IFR ratios above, the total targets are distributed to match these ratios.

For LRR:

VFR targets, as a proportion of total targets = .35/(1.0+.35) = 0.26; total VFR targets = 0.26 x 198 = 51, total IFR targets = 198 - 51 = 147.

Similarly for SRR:

VFR targets, as a proportion of total targets = .64/(1.0+.64) = .39; total VFR targets = 0.39 x 54 = 21, total IFR targets = 54 - 21 = 33.

2.2.7.3 Radar Coverage

Average radar coverages for short vs. long range radar and VFR vs. IFR traffic are the following:

Radar Coverage

	HOST/ISSS			CONSOLIDATION		
	1985	1990	1995	1995	2000	2010
Combined LRR+SRR						
VFR	1.2	1.2	1.4	2.3	2.3	2.3
IFR	2.8	2.9	3.5	5.2	5.2	5.2

NOTE: the values for radar coverage were computed using a variant of Program RADCOV (see Appendix I). Minneapolis is taken as the representative facility.

2.2.7.4 Radar Count

A maximum stress target ratio must be calculated for each year in which the radar count is unique. The following maximum stress radar counts are taken from Parameter 3.1, Table 2.1, Volume 1. For the Consolidation Period, the radar counts are for "ACFs Data Only", i.e., no back-up mode.

Radar Count

	HOST/ISSS			CONSOLIDATION		
	1985	1990	1995	1995	2000	2010
LRR	13	14	16	21	21	21
SRR	1	2	4	18	18	18

2.2.7.5 Final Calculations

The equation form to compute the parameter for the years of interest is:

$$\frac{VFR}{IFR} = \frac{\dfrac{LRR \times VFR_L + SRR \times VFR_S}{COVERAGE_V}}{\dfrac{LRR \times IFR_L + SRR \times IFR_S}{COVERAGE_I}}$$

where

LRR is number of long range radar

SRR is number of short range radar

VFR_L is VFR target level for LRR

VFR_S is VFR target level for SRR

IFR_L is IFR target level for LRR

IFR_S is IFR target level for SRR

$COVERAGE_V$ is the average coverage (combined LRR and SRR) for VFR targets

$COVERAGE_I$ is the average coverage (combined LRR and SRR) for IFR targets

The calculations for each year/period follow:

*CONSOLIDATION PERIOD

$$\frac{VFR}{IFR} = \frac{\dfrac{21 \times 51 + 18 \times 21}{2.3}}{\dfrac{21 \times 147 + 18 \times 33}{5.2}} = \frac{630}{708} = .9$$

For Host/ISSS years:

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*Since the mix of LRR vs. SRR for "Handle Back-up" is not substantially different, the value for Prepare for Back-up, 0.9, is used.

$$1985 \quad \frac{VFR}{IFR} = \frac{\dfrac{13x51 + 1x21}{1.2}}{\dfrac{13x147 + 1x33}{2.8}} = .8$$

$$1990 \quad \frac{VFR}{IFR} = \frac{\dfrac{14x51 + 2x21}{1.3}}{\dfrac{14x147 + 2x38}{2.9}} = .8$$

$$1995 \quad \frac{VFR}{IFR} = \frac{\dfrac{16x51 + 4x21}{1.43}}{\dfrac{16x147 + 4x33}{3.3}} = .8$$

2.2.8 Altitude Distribution

The altitude distribution of controlled flights is determined from the assigned altitude field of each flight plan for every ARTCC sample.

2.2.8.1 IFR Altitude Distribution

The values for each altitude stratum can be seen in Table 2.2.8-1. The average of 21 samples was so close to the previously computed average that the latter was retained. This made it possible to avoid changing other analyses that proceeded at the same time as the 1985 data was being analyzed; these analyses necessarily used the altitude distribution published in February, 1985.

2.2.8.2 VFR Altitude Distribution

Data for VFR Altitude Distribution is taken from McClinton's analysis of flight plans filed at Leesburg FSS[15]. A total of 1628 VFR flight plans were filed. The VFR altitude distribution listed below was taken from this analysis.

VFR Altitude Stratum, ft MSL	Percentage Occurrence
0 - 6,000	78.3
6000 - 8,000	14.5
8000 - 12,000	6.6
over 12,000	0.6

2.2.9 Speed Distribution

The distribution of speed for controlled flights is determined by reading the speed field of each flight plan for every ARTCC

TABLE 2.2.8-1
DEVELOPMENT OF VALUES FOR PARAMETER 8.0 USING OPERATIONAL DATA

	ALTITUDE DISTRIBUTION - % OF IFR AIRCRAFT AT THE FOLLOWING ALTITUDE INTERVALS			
ARTCC	0- 6,000 FT/MSL	6,000- 12,500 FT/MSL	12,500- 18,000 FT/MSL	ABOVE 18,000 FT/MSL
AT2	10	29	8	53
CL2	10	28	11	51
MS2	6	26	8	60
SE2	12	21	13	54
AT3	11	31	9	49
CL3	14	26	8	52
DC3	11	21	8	60
FT3	6	16	14	64
MK3	6	20	8	66
AB4	1	11	21	68
HO4	6	21	10	63
IN4	10	27	11	52
JA4	11	26	13	50
ME4	4	25	9	62
BO5	19	28	13	41
CH5	7	24	9	59
DE5	0	10	8	81
LA5	7	19	4	69
MI5	14	26	6	54
NY5	15	21	12	52
OA5	11	15	9	65
SL5	0	7	14	79
AVERAGE	9	22	10	59
CURRENT SCENARIO	10	24	10	56
1990	10	24	10	56
1995	10	24	10	56
1995	10	24	10	56
2000	10	24	10	56
2010	10	24	10	56

sample. The values for each speed interval can be seen in Table 2.2.9-1. There was no compelling reason to use values other than average for each scenario. This average speed is assumed not to change significantly over time.

2.2.10 Flight Life

This parameter is a grouping of three parameters: IFR track life, VFR flight life within a facility and IFR flight plan life in the computer system.

2.2.10.1 IFR Track Life

The IFR track life was determined from examination of the DART Track Report for each of the sampled facilities. This report gives detailed information on the track status of each flight from track initiate to track terminate. Only track reports from flights proven to be complete by the presence of the appropriate start and stop control messages were examined. (There is one exception: an arrival flight without a terminate message but with a final track message recorded significantly before the end of the sample period is determined to be complete.)

2.2.10.1.1 Host/ISSS Period

The average track life for all samples varies from 22 minutes to 47 minutes. The most demanding value for track life is the one that produces the highest message rate. Message rate is a function of number of messages/flight, flight (track) life, and number of tracks in the system (track load). For any particular value for messages/flight, multiplying by the "R" factor (track load/track life) will result in message rate:

$$\frac{\text{messages}}{\text{track}} \times \frac{\text{track load}}{\text{track life (minutes)}} = \frac{\text{messages}}{\text{minute}}$$

Therefore, the methodology used to determine the most demanding value of flight (track) life requires the "R" value to be calculated for each sample, the highest value identified, and the maximum stress track life calculated that would produce the highest message rate.

A summary of track life can be seen in Table 2.2.10-1. Note the highest "R" values are found in the two Cleveland samples. The average of these values was chosen to calculate the maximum stress track life. The equations that follow illustrate the calculation of "R" for CL2 and the calculation of maximum stress track life using the average of the two Cleveland samples:

TABLE 2.2.9-1
DEVELOPMENT OF VALUES FOR PARAMETER 9.0 USING OPERATIONAL DATA

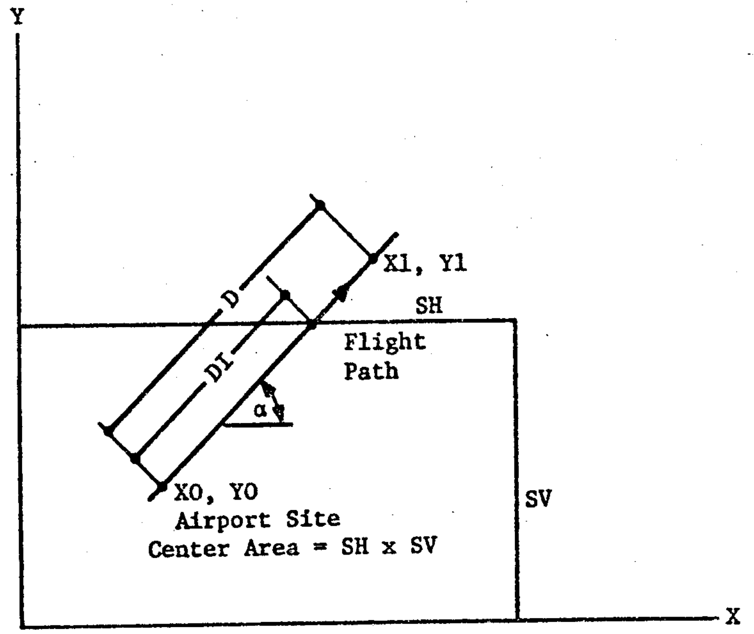
	SPEED DISTRIBUTION – % OF IFR AIRCRAFT AT THE FOLLOWING SPEED INTERVALS:			
ARTCC	UNDER 250 KNOTS	250–400 KNOTS	400–600 KNOTS	OVER 600 KNOTS
AT2	40	15	45	0
CL2	36	18	46	0
MS2	33	18	49	0
SE2	39	17	44	0
AT3	42	18	40	0
CL3	38	21	41	0
DC3	33	18	49	0
FT3	24	19	57	0
MK3	30	21	49	0
AB4	14	23	63	0
HO4	29	25	46	0
IN4	41	17	42	0
JA4	24	19	57	0
ME4	29	18	53	0
BO5	42	21	36	0
CH5	33	17	50	0
DE5	16	12	72	0
LA5	23	15	62	0
MI5	38	12	50	0
NY5	35	19	46	0
OA5	23	19	58	0
SL5	15	16	69	0
AVERAGE	31	18	51	0
CURRENT SCENARIO	30	18	52	0
1990	30	18	52	0
1995	30	18	52	0
1995	30	18	52	0
2000	30	18	52	0
2010	30	18	52	0

TABLE 2.2.10-1
DEVELOPMENT OF VALUES FOR PARAMETER 10.0 USING OPERATIONAL DATA

ARTCC	10.1 CONTROLLED TRACK LIFE	"R"
AT2	30	16.0
CL2	22	21.7
MS2	26	15.8
SE2	39	11.3
AT3	28	17.1
CL3	24	19.9
DC3	33	12.7
FT3	37	14.0
MK3	28	17.7
AB4	43	9.1
HO4	28	15.6
IN4	29	16.0
JA4	42	8.0
ME4	34	13.7
BO5	33	8.0
CH5	31	19.3
DE5	47	12.4
LA5	31	13.6
MI5	36	11.8
NY5	27	12.2
OA5	36	10.1
SL5	47	7.7
STATISTIC	28.8*	21.7**
CURRENT SCENARIO	30	
1990	30	
1995	30	
1995	35	
2000	35	
2010	35	

*Average of CL2 and CL3. (See section 2.2.10.1 for calculation)

**Maximum.



X0, Y0 = Starting Coordinates
X1, Y1 = Ending Coordinates
α = Flight Direction

L = SV/SH

D = Total Distance Flown
DI = Distance Flown In the Center

FIGURE 2.2.10.2-1
VFR FACILITY FLIGHT TIME ANALYSIS

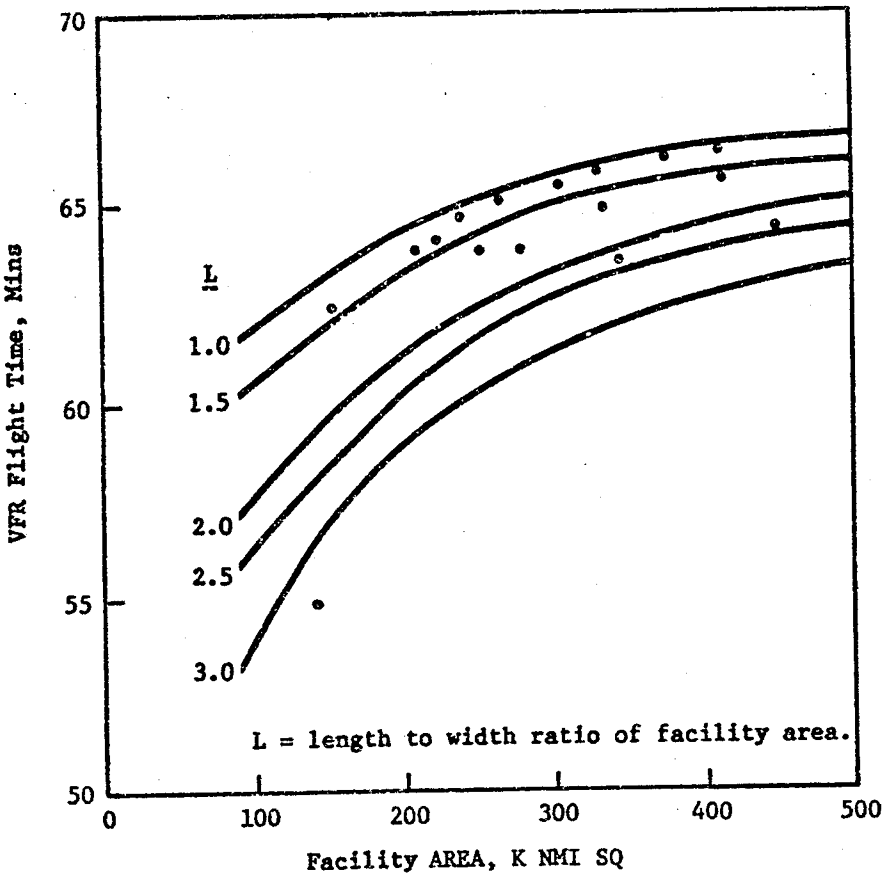


FIGURE 2.2.10.2-2
VFR FACILITY FLIGHT TIME

A value of VFR Facility Time was estimated for each of 15 facilities. A mean VFR Facility Life of 64 minutes was estimated.

For the years 1995 through 2010, it is estimated that an ACF can be approximately 30% greater in area than an average facility.[18] It is estimated that the VFR flight life will increase marginally to 65 minutes.

2.2.10.3 Active Flight Plan Life

The parameter is calculated by multiplying parameter 1.1, Active Flight Plans/Controlled Track, by parameter 10.1, Controlled Track Life. Ex. 2.0 x 30 = 60, 2.0 x 35 = 70.

2.2.10.4 Total Flight Plan Life

This parameter is calculated by multiplying parameter 1.2, Total Flight Plans/Controlled Track, by parameter 10.1, Controlled Track Life. Ex. 4.3 x 30 = 129, 4.3 x 35 = 150.

2.2.11 Flight Type

There are four flight types: arrivals, departures, overflights, and withins. The NAS flight plan data base is examined for each ARTCC to determine the source and destination of each flight listed within the sample period. By comparing a source and/or destination with an adapted internal airport, the flight type can be ascertained.

Table 2.2.11-1 shows the flight type distribution determined for each ARTCC. Also shown are the average and current scenario value for each type. The average of 21 samples was so close (5 to 7%) to the previously computed average[6] that the latter was retained. This made it possible to avoid changing other analyses that proceeded at the same time as the 1985 data was being analyzed; these analyses necessarily used the old altitude distribution.

The value for Handle Back-up was presumed not to change.

2.2.12 Flight Generation Process

Flight Generation is measured by the number of new tracks initiated in a given period of time. Each ARTCC data set was analyzed and the distribution of new track starts was plotted. This plot was compared to a plot of a Poisson Distribution with the same data. The fit was determined by inspection.

TABLE 2.2.11-1
DEVELOPMENT OF VALUES FOR PARAMETER 11.0 USING OPERATIONAL DATA

ARTCC	FLIGHT TYPE DISTRIBUTION ARRIVALS	DEPARTURES	OVERFLIGHTS	WITHINS
AT2	21	28	26	25
CL2	18	30	26	26
MS2	19	21	38	22
SE2	14	20	9	57
AT3	22	29	25	24
CL3	12	28	29	31
DC3	21	28	28	24
FT3	22	26	22	30
MK3	16	20	44	20
AB4	14	19	18	49
HO4	23	30	9	38
IN4	21	30	33	16
JA4	20	22	40	18
ME4	17	24	39	20
BO5	18	28	13	40
CH5	29	35	19	17
DE5	22	22	35	20
LA5	26	30	4	40
MI5	24	26	2	48
NY5	33	37	11	19
OA5	22	31	10	37
SL5	14	17	47	22
AVERAGE	20	26	24	30
CURRENT SCENARIO	21	27	24	28
1990	21	27	24	28
1995	21	27	24	28
1995	20	24	34	22
2000	20	24	34	22
2010	20	24	34	22

2.2.13 Airport Operations

Airport operations refers to two airport-related parameters: the first is an estimate of the percentage of controlled flights that depart, arrive and/or overfly an approach controlled airport; the second is a measure of the distribution of coded routes to all arrivals and departures. Flight plans were examined to estimate both parameters.

2.2.13.1 Distribution of Controlled Flights to Approach Controlled Airports

Table 2.2.13-1 shows three columns labelled ARTS ARRIVAL, ARTS DEPARTURE, and ARTS OVERFLIGHT. ARTS refers to Automatic Radar Terminal System, the computer system used by TRACONs and TRACABs for controlling traffic in the approach area. All arrivals and departures of controlled flights utilizing these approach facilities were counted; the parameter value was calculated by dividing this count by the total number of arrivals and departures, respectively. Note that "within" flights count as both an arrival and a departure. The record of converted route segments was examined to determine the instances of overflight of an ARTS facility. A count of ARTS overflights was made and divided by the total flight count to determine parameter 13.1.3, ARTS overflight.

The current scenario values were determined for % ARTS arrivals and departures by adding the sample values and dividing by two. Both Atlanta samples and the New York sample yielded average values of 80%. There was no compelling reason to use any other than the maximum value for any of these parameters. This value is assumed not to change significantly between 1985 and 1995.

2.2.13.2 Coded Arrival and Departure Routes

Arrivals and departures at busy airports are commonly handled through the use of predetermined routes called coded routes. The NAS table showing converted routes of flights was examined to determine coded route usage. PDRs and SIDs are coded departure routes; PARs and STARs are coded arrival routes. PDARs are coded routes that provide for the departure from one airport to the arrival at another. The use of a PDAR was counted both for the departure and the arrival of the flight to which it was assigned.

TABLE 2.2.13-1
DEVELOPMENT OF VALUES FOR PARAMETER 13.1 USING OPERATIONAL DATA

13.1 DISTRIBUTION OF IFR FLIGHTS TO APPROACH CONTROLLED AIRPORTS

ARTCC	% ARTS ARRIVAL	% ARTS DEPARTURE	% ARTS OVERFLIGHT
AT2	89	72	*
CL2	74	61	*
MS2	*	*	*
SE2	42	37	*
AT3	83	73	*
CL3	74	62	*
DC3	74	76	*
FT3	77	72	*
MK3	*	*	*
AB4	45	75	2
HO4	61	68	5
IN4	65	64	9
JA4	56	60	14
ME4	53	50	6
BO5	68	77	13
CH5	77	78	9
DE5	59	62	2
LA5	67	70	14
MI5	66	65	10
NY5	77	81	9
OA5	69	75	12
SL5	53	54	6
AVERAGE	66	67	9
CURRENT SCENARIO	80	80	14
1990	80	80	14
1995	80	80	14

*No data

Table 2.2.13-2 shows the distribution of coded routes for all arrivals and departures. The approach used to choose the current scenario value was to examine the ARTCCs with the largest number of coded routes in order to determine the maximum number of flights using coded routes. For the candidate ARTCCs, the coded arrival route percentages were summed, as were the coded departure route percentages. These values were multiplied by the number of flights expected to arrive or depart an ARTCC airport. The latter is determined for arrival by multiplying the 1995 flight arrival rate (taken from peak track load, Appendix D) by the percent of all flight types (Table 2.2.11-1) that are arrivals and by the percent of all flights that are ARTS arrivals (Table 2.2.13-1). The same is done to determine total departures using coded routes. (See Table 2.2.13-3.)

2.2.14 Metering Arrival Rate

The peak-hour arrival rate of IFR operations at both metered airports and ACFs is to be determined. Figure 2.2.14-1 depicts the rationale for making an estimate of the peak-IFR arrival workload for metered airports. Daily operations data are provided for airports from the 1978 Tower Airport Statistics Handbook[12]. This data is insufficient for three reasons. First, the data does not separately identify VFR and IFR rates; secondly, it does not provide peak-hour rates; and finally, since peak hour rates are not addressed, no distinction between arrival rates and departure rates at the peak hour are made.

To obtain the IFR operations rate, information is derived from a study of VFR and IFR operational at Los Angeles Airport. The peak-hour activity information on Peak-Hour/Daily operation ratios was gathered from a report on Hourly Airport Activity Profiles for 30 Airports[19]. These data provided an estimate of the peak-hour IFR operations. The peak-hour arrival rate was estimated by analyzing arrival/departure data from seven (7) airports[19-25].

2.2.14.1 Airport Arrival Operations

Sample arrival data were taken from a series of FAA reports (References 20 through 26) describing the detailed operation at specific airports on a busy day (Friday). Table 2.2.14-1 summarizes some of this data for metered airports. The purpose of this table is to show the maximum number of arrival operations experienced during an hour. The time periods selected for evaluation were those hours in which the total number of operations was within 70% of the maximum number of operations

TABLE 2.2.13-2
DEVELOPMENT OF VALUES FOR PARAMETER 13.2 USING OPERATIONAL DATA

13.2 CODED ARRIVAL AND DEPARTURE ROUTES

	-DEPARTURES-			-ARRIVALS-		
ARTCC	PDR	PDAR	SID	PAR	PDAR	STAR
AT2	29	15	0	26	17	11
CL2	37	12	0	58	15	1
MS2	31	3	0	32	3	0
SE2	27	2	0	39	2	0
AT3	24	12	0	18	13	15
CL3	37	7	0	57	9	4
DC3	35	19	4	50	22	0
FT3	43	25	1	32	27	0
MK3	45	10	2	43	11	3
AB4	63	4	10	17	4	5
HO4	40	21	3	40	23	13
IN4	25	5	0	17	6	0
JA4	32	2	4	27	2	0
ME4	42	5	12	36	6	5
BO5	22	16	0	26	18	2
CH5	48	10	0	48	12	0
DE5	54	12	0	58	12	0
LA5	39	17	11	38	18	2
MI5	48	15	0	38	16	7
NY5	25	17	36	54	19	15
OA5	16	16	27	30	19	4
SL5	31	5	4	36	5	0
AVERAGE	36%	11%	5%	37%	13%	4%
CURRENT SCENARIO	44	14	6	47	16	5
1990	44	14	6	47	16	5
1995	44	14	6	47	16	5
1995	44	14	6	47	16	5
2000	44	14	6	47	16	5
2010	44	14	6	47	16	5

TABLE 2.2.13-3
ANALYSIS OF CODED ROUTE USAGE

	A 1995 FORECASTED PEAK TRACK (FLIGHT) LOAD	B TOTAL FLIGHTS/HR (A/30 MIN)[1]	C % CODED ARRIVALS OF TOTAL ARRIVALS	D TOTAL ARRIVALS (.39xB)[2]	E % CODED DEPARTURES OF TOTAL DEPARTURES	F TOTAL DEPARTURES (.44xB)[3]	TOTAL FLIGHTS/HR USING CODED ROUTES (CxD+ExF)
NEW YORK	330	660	78	257	88	290	456
DENVER	581	1162	66	453	70	511	658
HOUSTON	438	876	63	342	76	385	508
FT. WORTH	517	1034	69	403	59	455	546
SCENARIO[4]	600	1200	64	468	68	528	658

(1) Parameter 10.1, Controlled Enroute Track Life

(2) % of total tracks that are arrivals = arrivals (21%) + withins (28%)
* % ARTS arrivals (80%) = 39%

(3) % of total tracks that are departures = departures (27%) + withins (28%)
* % ARTS departures (80%) = 44%

(4) The scenario value is calculated using the Denver value for total flights using coded routes

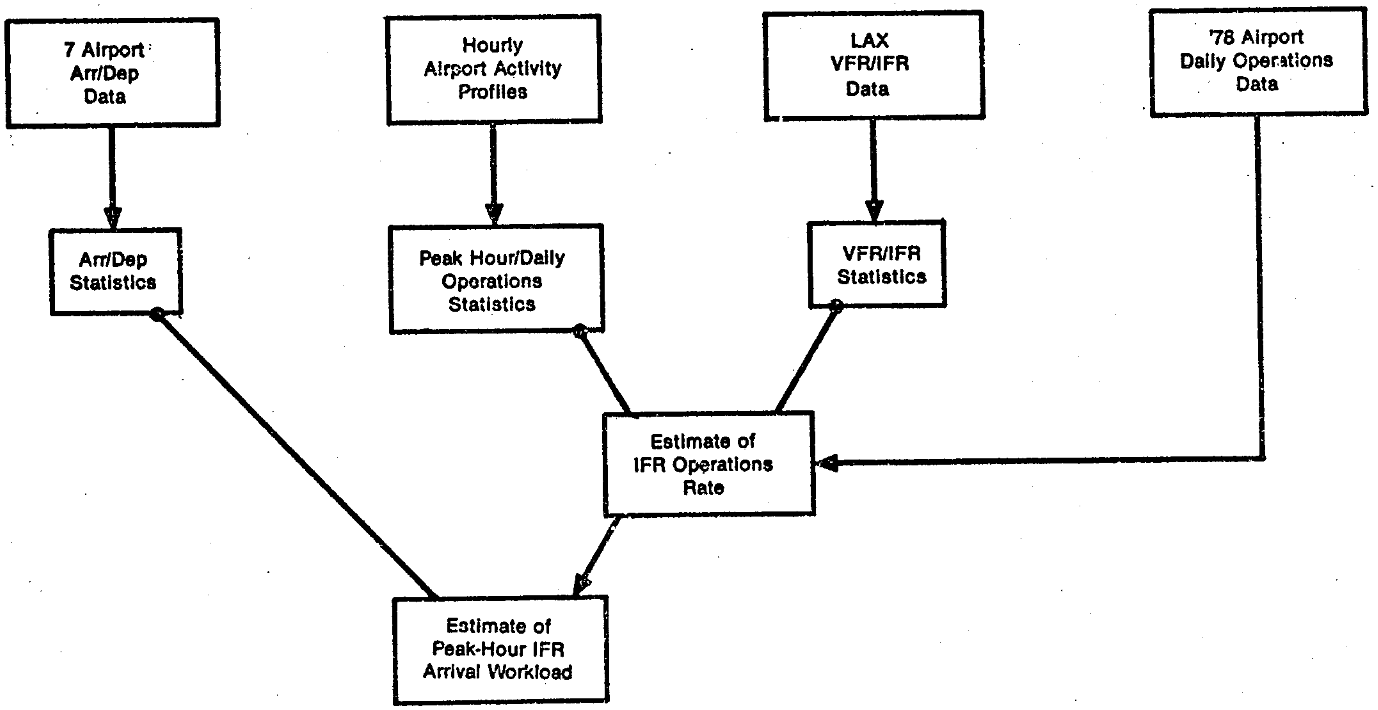


FIGURE 2.2.14-1
ESTIMATION OF ARRIVAL RATE WORKLOAD

TABLE 2.2.14-1
SAMPLE ARRIVAL STATISTICS FOR METERED AIRPORTS

Airport	Max. Opns/Hr.*	Date MM/DD/YY	Hour 00-23	Arr/Dep	% Arr.	Average % Arr.
Atlanta	98[19]	08/06/76	09	53/26	67	71
			11	57/27	68	
			15	54/30	64	
			19	72/15	83	
Chicago-O'Hare	108[20]	08/05/77	09	61/48	56	56
			12	65/49	57	
			13	78/64	55	
			16	71/54	57	
Cleveland	33[21]	08/04/78	11	17/10	63	60
			17	14/11	56	
Houston	33[22]	08/06/76	14	19/12	61	60
			19	18/13	58	
Los Angeles	84[23]	08/05/77	11	35/24	59	59
			14	42/30	58	
			18	49/32	60	
			19	46/35	57	
Philadelphia	62[24]	08/05/77	07	25/18	58	57
			19	26/18	59	
			20	28/24	54	
San Francisco	58[25]	08/77	12	34/22	61	58
			18	30/20	60	
			19	29/25	54	
			20	31/21	60	
Average						60

*Superscripts refer to the reference used.

and the number of arrival operations was greater than the number of departure operations. (The "70%" criterion was selected as a reasonable measure of significant activity.) The "Peak Percentage Arrivals" number represents an hour when the airport is experiencing the highest percentage of arrival operations relative to the total operations. The mean value of these percentages (i.e., 60%) was used to characterize those airports where arrival/departure data were not available.

Table 2.2.14-2 describes the peak arrival characteristics at 12 airports. The peak operations rate and average daily operation count was calculated for each of the airports. For each of the airports, data showing peak operations per hour were gathered from Reference 19. Measurements were made for the airports on the ratio of:

$$\frac{\text{Peak Operations Per Hour}}{\text{Average Daily Operations}}$$

An average value of 0.094 was calculated for this ratio from these eleven pieces of data. This number will be used as a factor to calculate peak hourly rates from known daily operations rates[12].

Although the statistics on airport arrival data are minimal, the corresponding data on IFR operations (i.e. - IFR arrival operation rates) are very rare. Some data were gathered from tower operations at the Los Angeles (LAX) airport.* The data showed that 55% of the airborne traffic were IFR operations. This data represents a lower limit on percentage of IFR operations, since Los Angeles is known to have a relatively high level of VFR activity.

As a consequence of the paucity of IFR arrival data, estimates of the percentage of operations which were VFR were made for each airport. Low values (i.e. 55%) were considered to be characteristic of the California airports. IFR percentage values for the east coast area were considered to be relatively high (i.e. 70-75%). Most other areas were estimated to be in between the 55 and 75% values. Table 2.2.14-3 includes the estimates made for all of the 50 airports.

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*The data, gathered from the long range radar (QLA) nearest to LAX, were part of a larger data set which was used to determine VFR/IFR ratios. The study is reported in detail in Appendix J.

TABLE 2.2.14-2
PEAK-ARRIVAL CHARACTERISTICS OF BUSY AIRPORTS

AIRPORT	ARTCC LOCATION	PEAK OPNS/HR	AVERAGE OPNS/DAY	PERCENT, PEAK HR/AVG DAY
ATLANTA	ZTL	123	1543	8.0%
CHICAGO O'HARE	ZAU	169	2203	7.7%
CLEVELAND	ZOB	73	624	11.7%
HOUSTON	ZHU	75	766	9.8%
KANSAS CITY	ZKC	65	573	11.3%
LAS VEGAS	ZLA	114	992	11.5%
LOS ANGELES	ZLA	129	1543	8.4%
NEWARK	ZNY	49	402	12.2%
PHILADELPHIA	ZNY	88	942	9.3%
PITTSBURGH	ZOB	99	928	10.7%
SAN FRANCISCO	ZOA	99	1013	9.8%
WASHINGTON-DCA	ZDC	86	887	9.7%
AVERAGE		97	1035	9.4%

TABLE 2.2.14-3
PEAK-ARRIVAL RATES FOR THE 50 BUSIEST AIRPORTS

ACF	Airport	Peak IFR & VFR Arrivals/ Hour	Terminal IFR %[2]	Peak IFR Only Arrivals/ Hour[1]	ACF[3] Total
Albuquerque	PHX	57	60	34	59
	LAS	47	60	28	
Atlanta	ATL	87	65	(59)	59
Boston-Logan	BOS	54	70	38	66
	BDL	23	70	16	
	BUF	23	70	16	
Chicago	ORD	95	70	(67)	84
	MKE	32	70	22	
Cleveland	DTW	42	70	29	89
	CLE	41	70	29	
	PIT	52	70	36	
Denver	DEN	72	65	(56)	56
Fort Worth	FTW	24	60	14	99
	DFW	64	60	38	
	HOU	46	60	28	
	IAH	41	60	25	
Houston	SAT	32	60	19	38
	MSY	27	60	(21)	
Indianapolis	IND	33	70	23	66
	CMH	29	70	20	
	CVG	19	70	13	
	DAY	20	70	14	
Jacksonville	TPA	34	75	26	36
	MCO	17	75	13	

NOTES:

[1] Values without parentheses were calculated from 1978 sample statistics on hourly airport operations (see Ref. #22). Values with parentheses were observed from recent sample data.

[2] Values were on the basis of observing 1429 target reports from the long range radar closest to LAX. The value for other facilities was estimated from this base.

[3] A Reduction Factor (RF) of 0.94 is multiplied by the peak arrival rates for those facilities with more than one metered airport.

$$\text{Where RF} = \frac{\text{Peak Arrival Rate for a Facility}}{\text{Sum of Peak Arrival Rates for Metered Airports}}$$

TABLE 2.2.14-3
(Concluded)

ACF	Airport	Peak IFR & VFR Arrivals/ Hour	Terminal IFR %[2]	Peak IFR Only Arrivals/ Hour[1]	ACF[3] Total
Kansas City	MCI	29	70	20	74
	STL	54	70	38	
	OKC	29	70	20	
Los Angeles	LAX	76	55	(48)	58
	SAN	25	55	14	
Memphis	MEM	54	70	38	38
Miami	MIA	56	60	34	75
	PBI	29	60	17	
	FLL	48	60	29	
Minneapolis	MSP	39	75	29	29
New York	JFK	54	70	(39)	139
	EWR	29	70	(33)	
	LGA	58	70	41	
	PHL	50	70	35	
Oakland	SFO	57	55	(35)	81
	SMK	16	55	9	
	OAK	37	55	20	
	SJC	41	55	23	
Salt Lake City	SLC	35	60	21	21
Seattle	SEA	30	65	20	23
	PDX	8	65	5	
Washington	DCA	52	70	(41)	100
	BWI	33	70	(25)	
	IAD	21	70	(17)	
	CLT	34	70	24	
Anchorage	ANC	31	60	19	19
Honolulu	HNL	52	55	29	32
	LIH	10	55	6	
	OGG	14	55	8	

See notes on previous page.

The peak IFR arrival rate is equal to the peak operations rate multiplied by the Average Percentage Arrivals listed in Table 2.2.14-1 multiplied by the percentage of VFR operations also shown in Table 2.2.14-3. Table 2.2.14-3 lists the peak arrival rate calculated for each of the 50 airports. The maximum value, 67 IFR arrivals/hr., represents a peak arrival rate, which value is used to represent the workload scenario arrival rate for a metered airport.

The peak arrival rate for an individual airport is limited by airport runway capacity. It is assumed that traffic into hub airports will begin using adjacent, smaller airports during busy traffic conditions and metering will expand to integrate servicing a hub airport with adjoining airports. Metering for Chicago O'Hare, for instance, could include metering for Midway Airport.

The determination that Chicago O'Hare represents the workload airport for IFR arrival metering gives some verification of the statistical method used. O'Hare is known to have a very high level of IFR operations. In terms of total arrivals rate (i.e. VFR & IFR) O'Hare was nearly 10% higher than Atlanta. On this basis, there was no compelling reason to select the Atlanta statistics as the workload data.

The growth of metering capabilities is assumed to start coincident with AERA (circa 1992) and a growth rate of towered airport operations is assumed to be 1.9% per year[17]. The workload scenario values for Airport Metered Arrival Rate are:

Year	Rate, Arrivals/Hr.
1985	67
1990	67
1995	71
2000	78
2010	94

2.2.14.2 Facility Arrival Operations

Most facilities currently have an average of two hub airports within their boundaries although one facility (i.e., NY-B) has four such airports. Table 2.2.14-3 also summarizes the peak arrival rate for those facilities in which the airports are located. At facilities that have more than one metered airport, the peak arrival rates for each of the airports do not necessarily occur simultaneously. To compensate for suspected differences in peak arrival time between metered airports in the same facility, information was gathered from arrival data[12] to determine the reduction factor:

$$RF = \frac{\text{Peak Arrival Rate for a Facility}}{\text{Sum of Peak Arrival Rates for Metered Airports}}$$

The reduction factors for each facility with multiple metered airports was calculated and the average value of RF is shown in Table 2.2.14-3. The peak value of the Facility Arrival Rate is estimated to be 139 IFR arrivals per hour.

The growth rate for arrival operations at facilities is considered similar to that for airports. A growth rate of 1.9%/yr[17] is used to adjust arrival rates after 1992.

Back-up for facility arrivals is estimated on the basis that the facility must be capable of handling 30% of a neighboring ACF arrival traffic space. It is assumed that the backed-up facility has the next highest arrival rate, i.e. Washington at 101 arrivals/hr (the workload scenario assumes the highest arrival rate for the facility required to back-up).

The workload scenario values for Facility Metered Arrival values are:

Year	Rate, Arrivals/Hr Without Back-up	With Back-up
1985	139	N/A
1990	139	N/A
1995	147	170
2000	162	188
2010	195	226

2.2.15 Sectors Penetrated/Flight

For the HOST/ISSS time period, a sector was defined as an en route sector and NAS data was analyzed to determine the en route sectors penetrated by flights of each type. This information is available, for each ARTCC sampled, in Volume III of this report. Table 2.2.15-1 shows the average sector penetration for each sampled ARTCC.

During the ACF consolidation period, approach control becomes an ACF function so sectors penetrated reflects the additional approach sectors for arrival, departure, and within types. A typical approach control structure is assumed to consist of one or more "feeder" approach controllers whose sectors begin at about 30 miles from the airport and end at 10 miles from the airport. One or more "final" approach controllers are assumed to control close-in traffic from 10 miles to the outer marker. Departure traffic is handled by one controller providing separation in a sector that covers that airspace from the end of the runway to en route airspace. Traffic at satellite airports is handled by no more than one controller/airport.

2.2.15.1 Determination of Parameter Value for Sectors Penetrated

Parameter values for average number of sectors penetrated per flight at sampled ARTCCs can be seen in Table 2.2.15-1. Note that Denver has the maximum value of 2.87. Although this is—by a large margin—the highest value recorded, Denver currently has a very high traffic load and is the facility with the second highest traffic load in the ACF Consolidation Period. No compelling reason could be found to accept a lower value for this parameter.

The value for the ACF Consolidation Period was determined (Table 2.2.15-2) by using Denver's sector penetration values for each flight type and adding sectors to account for the consolidated approach control function. The following assumptions were made:

1. Parameter 13.1, ARTS Arrivals, Departures, and Overflights identifies the percent of all flights using approach control. Assume that 20 percent of all ARTS arrivals require satellite airport approach control.

2. Parameter 11.0, Flight Type, identifies the distribution of flights in the four control categories - arrival, departure, overflight, within.

3. The values for Flight Type and ARTS (Approach Control) Penetrations are unlikely to change during the ACF consolidation period (1995 - 2010).

2.2.16 Trajectory Length

No value was calculated for this parameter because information about AERA design is not yet detailed enough to permit the analysis needed to determine its impact on workload.

TABLE 2.2.15-1
DEVELOPMENT OF VALUES FOR PARAMETER 15 USING OPERATIONAL DATA

ARTCC	SECTORS PENETRATED/FLIGHT
AT2	2.11
CL2	2.06
MS2	1.82
SE2	2.19
AT3	2.11
CL3	1.49
DC3	1.89
FT3	2.07
MK3	1.89
AB4	2.18
HO4	2.17
IN4	1.97
JA4	2.26
ME4	1.97
BO5	1.95
CH5	2.03
DE5	2.87
LA5	1.80
MI5	1.95
NY5	1.56
OA5	2.38
SL5	1.95
AVERAGE	2.03
CURRENT SCENARIO	2.90
1990	2.90
1995	2.90
1995	4.10
2000	4.10
2010	4.10

TABLE 2.2.15-2
CALCULATIONS FOR SECTORS PENETRATED

FLIGHT TYPE	CALCULATIONS	APPROACH SECTORS	EN ROUTE SECTORS*	TOTAL SECTORS	FLIGHT TYPE DISTRIBUTION	TOTAL
ARRIVALS	[(.65x2) + (.15x1) + 0.14]	1.59	2.84	4.43	.20	0.886
DEPARTURES	[(.80x1) + 0.14]	0.94	2.54	3.48	.24	0.835
OVERFLIGHTS	[0.14]	0.14	3.54	3.68	.34	1.251
WITHINS	[(.65x2) + (.15x1) + (.80x1) +0.14]	2.39	2.26	4.65	.22	1.023
AVERAGE APPROACH SECTORS/FLIGHT						4.096 ≈ 4.1

---

*Taken from 1985 Denver sample.

2.2.17 Trajectories in Conflict

Preliminary studies were recently made on an algorithm for estimating the rate at which conflicts discovered by flight probes are generated in AERA. This method can be used as a means of determining the AAS workload for Trajectories in Conflict.

A subject aircraft is considered to be travelling through cells in an x-y-t coordinate grid, where the basic cell dimension for x-y is equal to SEPH (i.e. - horizontal separation criterion), and the basic dimension for t is SEPT (i.e. - time separation criterion). The cell(s) in which the aircraft is passing through is termed the sparse grid chain, and a contiguous set of cells which includes the sparse grid chain and every orthogonal and diagonal neighboring cell is termed the buffered grid chain. The aircraft is considered to be travelling in level flight, in en route airspace (i.e. - above 18,000 feet) at a flight level between 180 and 450.

An object aircraft is considered to be resident in a sparse cell of the planning region. The model calculates the number of conflicts generated per unit time between a subject and the object aircraft.

The model designed is basically the formula:

$$K,\ \#\ \text{Conflicts/Min} = bzpfLN/C^2I$$

Where:

N = Number of controlled aircraft in a Planning Region (steady state),

I = Interval between successive aircraft entries/exits into/from the planning region,

C = Number of grid cells spanning either the x or the y dimension of the planning region (x, y axes),

L = Number of grid cells spanning the look ahead time (t axis),

b = Ratio of number of cells in buffered grid chain to the number of cells in sparse grid chain,

z = fraction of x-y-t co-occupancies which overlap vertically,

p = fraction of x-y-t-z co-occupancies which represent distinct object aircraft (encounters),

f = fraction of encounters declared conflicts by the fine filter.

Estimates of these variables are calculated in the following description. In some cases the estimates are based on parameter values determined within this report. In other cases, "reasonable" values have been used because no comparable background exists in the present NAS system. The reasonable values are based on the experience and expert judgement of AERA modelers.

Description

The following values are used for the variables in the model.

N - The number of controlled aircraft (tracks) in the planning region is identical to the track level values used in the workload estimate (Parameter 2.1.1 Controlled Tracks). For this analysis the planning region is equivalent to the Area Control Facility (ACF). The values are:

Year	N
1995	910
2000	1060
2010	1310

I - The average interarrival time can be estimated from the controlled track life (Parameter 10.1), which was estimated at 35 minutes and the track level values from above:

$I = \frac{t}{N}$ Where: t = Track Life in the controlled region

C - In a coarse filter, the grid cells are square and have a dimension no larger than SEPH. The number of grid cells in the x - y dimension of a planning region can be taken to be equal to:

$$C = \frac{A}{SEPH}$$

Where: A = Average area of a planning region
SEPH = Horizontal separation criterion

The average area of an En Route Center was determined in the calculation of Parameter 10.2, VFR Facility Flight Life (Section 2.2.10.2), at 300,000 NMI^2. The planning region, in AERA time, is an ACF which has approximately 25% more area than an En Route Center (i.e. - 375,000 NMI^2).

L - The time-dimension of a cell with regard to look-ahead time is equal to at least the time required by an aircraft to traverse it — i.e., SEPH/Vmax. The optimum conflict probe look-ahead time (SEPT) is still under study, but is expected to be between 10 and 20 minutes.

L can be approximated as:

$$SEPT/(SEPH/Vmax)$$

Where SEPT = Time separation criterion
Vmax = Maximum aircraft velocity (Parameter 9.0)

b - A minimum size sparse grid cell (i.e., one) has a buffered grid size = 27 or a Buffered/Sparse ratio of 27/1. As the number of sparse cells increase, the ratio of Buffered/Sparse decreases. The value of b ranges between 27/1 to 12/1; a 15/1 ratio (i.e., b = 15) is reasonable.

z - Except for flights in transition from one altitude to another, an aircraft maintains a prescribed altitude. If the aircraft were uniformly distributed over the 18 useable flight levels* in the en route airspace, the total

---

*In the present en route airspace, there are eleven 1,000 foot flight levels between 180 and 290 and seven 2,000 foot levels between 290 and 450 for a total of 18 levels.

trajectory problem would be reduced by 1/18th. To allow for lack of uniformity in distribution of IAC and for aircraft changing altitude, values of z as high as 1/4 are possible. A reasonable value to use is:

$$z = 1/10$$

p - Object aircraft can co-occupy with the subject aircraft anywhere from 1 to 5 grid cells where their respective flight paths are not nearly parallel or their speeds are significantly different. Most combinations would tend toward the larger value. A reasonable value to assume is 4 cells. The resulting value, therefore, is:

$$p = 1/4$$

f - Given only that a sparse and a buffered grid chain intersect, what is the probability that the two trajectories come within SEPH horizontally at some point in time? A reasonable guess is that 1/3 of all pairs reaching the time filter have predicted separation less than SEPH — that is, conflicts. The estimate is:

$$f = 1/3$$

Summary

As stated, the model for estimating "Trajectories in Conflict" is:

$$K, \#\text{Conflicts/Min} = bzpfLN/C^2I$$

The first four factors, b, z, p, and f, are dimensionless. Substituting values from the "Description":

$$K = 15\left(\frac{1}{10}\right)\left(\frac{1}{4}\right)\left(\frac{1}{3}\right)\left(\text{SEPT} \times \frac{\text{Vmax}}{\text{SEPH}}\right)N\left(\frac{\text{SEPH}^2}{A}\right)\left(\frac{N}{t}\right)$$

$$= 0.125\ \frac{\text{SEPT} \times \text{SEPH} \times \text{Vmax} \times N^2}{\text{Axt}}$$

Assuming the following:

SEPT = 15 min.
SEPH = 10 miles
Vmax = 600 miles/hr.
t = 35 min.

$A \quad = 248{,}000 \text{ nmi}^2$

We get:

$$K = 0.125 \left(\frac{15 \text{ min} \times 10 \text{ mi}}{248{,}000\text{mi} \times 35 \text{ min}}\right)\left(\frac{600 \text{ mi}}{\text{hr}}\right)\left(\frac{\text{hr}}{60 \text{ min}}\right) N^2$$

$$= 2.16 \times 10^{-5} N^2, \text{ conflicts/min}$$

K can be calculated for the following years:

Year	N	K (Prepare for Back-up)	K (Handle Back-up)
1995	910	18	30
2000	1,060	24	41
2010	1,310	37	62

2.2.18 CTA Updates Per Flight

It is currently expected that manual Calculated Time of Arrival (CTA) updates will be very infrequent, almost zero. Newman[18] reports that CTA will be automatically updated two times every hour on the average. An adjustment of +1 is made to allow for above-normal conditions, yielding an expected CTA update of three per hour per flight. This number translates to a CTA update frequency of 3*(30/60) = 1.5, round to 2.

In AERA 1, a resynchronization will accomplish the same function as CTA updates. The following is a very simple derivation of the relationship between the error in the predicted longitudinal velocity of an aircraft and the resynchronization rate of that aircraft. The relationship leads directly to an estimate of the lower bound of the resynchronization rate.

Let S = the predicted, longitudinal ground speed in knots of an aircraft since the aircraft's last resynchronization

d_s = the error in the predicted, longitudinal ground speed, knots

t = the time since the last resynchronization, hours

c = the maximum allowable longitudinal deviation from the predicted position before resynchronization must be performed, nautical miles; the parameter value that has been most often quoted is 2.5 nautical miles

Resynchronization will occur when the actual distance traveled differs from the predicted distance traveled by c, i.e.,

$$(S + d_s)t - St = c$$

or

$$(d_s)t = c = 2.5$$

Solving for t,

$$t = 2.5/d_s$$

The maximum longitudinal velocity error due to wind and pilot error is expected to be about 25 knots. Using the above relationship, an approximate lower bound for the resynchronization frequency of an aircraft is 0.1 hour (i.e., six minutes).

The resynchronization rate is, in turn, 10 per hour per flight. Considering a flight life of 35 minutes (Parameter 10.1), a resynchronization rate of 6 per flight is calculated.

For the "Handle Back-up" scenario, the flight life is increased to 37 minutes yielding a resynchronization rate of 6.2 per flight. The scenario value for "Handle Back-up" is rounded upward to 7 per flight.

2.2.19 Special Use Airspace Blocks

Special use airspaces are areas where aircraft operation is restricted either entirely or during specific times and under specified operating conditions. To determine the likelihood of a requested profile penetrating a Special Use Airspace block, the following methodology was used:

1. Divide up a facility into equi-area squares.

2. Estimate the fraction of the facility area covered by Special Use Airspace.

3. Determine the number of Special Use Airspace blocks in the facility.

4. Assuming a 150 NMI flight probe, use a Poisson distribution to calculate the probability that the probe

will encounter at least one Special Use Airspace block. The probe can be initiated from any block within the facility.

Assuming that a facility is divided up into equi-area blocks, the probability that an aircraft conflict probe will encounter "n" Special Use Airspace blocks is given by the Poisson relationship:

$$p(n) = \exp(-m) \frac{m^n}{n!}$$

When p(n) = the probability that "n" Special Use Airspace blocks will be encountered, and

m = the mean number of encounters expected throughout the facility.

Since we are concerned only with the probability that no Special Use Airspace violations occur (i.e., $n = 0$), the equation reduces to:

$$p(0) = \exp(-m)$$

The probability, in percent, that a violation will occur is:

$$\begin{aligned} P &= [1 - p(0)]\ 100 \\ &= 100\ [1-\exp(-m)] \end{aligned}$$

Treating m further yields:

$$m = F.X$$

Where F = the probability that a given block of airspace is a Special Use Airspace block

$$= \frac{\text{Area of Special Use Airspace}}{\text{Center Area}}$$

X = Number of blocks probed by a conflict probe.

2.2.19.1 Number of Special Use Airspace Blocks

Information for calculating "F" has been published in a paper by Mundra[27] describing problems and solutions with respect to

"User Preferred Routes in the Current ATC System." Some characteristics of Special User Airspace in the conterminous U.S. are included in the table below:

SPECIAL USE AIRSPACES IN CONTERMINOUS U.S. IN 1983

Type of Special Use Airspace	Number of This Type of Airspace in U.S.	Total Square Miles
Prohibited Areas	7	39
Restricted Areas	306	81,316
Warning Areas	94	386,272
Military Operations Areas (MOA)	311	391,427
TOTAL	718	859,054

The fraction of total area represented by these airspaces, assuming 21 ACFs with a mean center area of 176,000 nmi^2 is:

$$F = \frac{859{,}054}{21 \times 176{,}000} = 0.23$$

Also, the number of Special Use Airspace blocks in a facility is calculated to be 718/21 = 34.

2.2.19.2 Probability of Airspace Conflict

During the AAS implementation, when the present centers will be replaced by Area Control Facilities (ACF), which are larger and fewer in number, it is assumed that the total number of Special Use Airspaces in the continental U.S. and the value "F" will not change.

"X" can be calculated by assuming that all of the Special User Airspace is composed of uniformly sized blocks. As shown below, the number of blocks probed by a flight of distance "d" is a minimum when the flight proceeds diagonally through a block; 718 is a maximum when the flight parallels an axis. The average number of blocks probed is approximated as the mean of the maximum and minimum.

$$\text{Maximum \# Blocks encountered} = \frac{2}{\sqrt{2B}}, \frac{\text{Blocks}}{\text{nmi}}$$

$$\text{Minimum \# Blocks encountered} = \frac{1}{B}, \frac{\text{Blocks}}{\text{nmi}}$$

$$\text{Average \# Blocks encountered} = \left(\frac{2}{\sqrt{2B}} + \frac{1}{B}\right)\frac{1}{2}$$

$$= \frac{1.21}{B}, \frac{\text{Blocks}}{\text{nmi}}$$

$$X = d \text{ nmi} \times \frac{1.21}{B}\frac{\text{Blocks}}{\text{nmi}} = \frac{1.21\ d}{B}, \text{ Blocks}$$

The mean block size can be estimated as:

$$B = \sqrt{\frac{859{,}054}{718}} = 35 \text{ nmi}$$

Assuming a flight probe of 150 nmi (i.e., d)

$$X = 1.21 \times \frac{150}{35} = 5.19 \text{ Blocks}$$

$$P = 100\ [1 - \exp(- 5.19 \times 0.14)]$$
$$= 52\%$$

The probability that an airspace probe will intersect a Special Use Airspace block is 52%.

2.2.20 Track Life by Flight Type

The IFR track life was determined from examination of the DART Track Report for each of the sampled facilities. Only track reports from flights proven to be complete by the presence of the appropriate start and stop control messages were examined. (There is one exception: an arrival with a final track message recorded significantly before the end of the sample period).

The values for each flight type can be seen in Table 2.2.20-1. (Note that the average of all types is calculated and presented in Section 2.2.10.1.) The average for the 19 samples was so close to the previously computed average[6] that the latter was retained for the 1985-1995 time period. This made it possible to avoid changing other analyses that proceeded at the same time as the 1985 data was being analyzed; these analyses necessarily used the old track life values.

Parameter values for the ACF Consolidation Period were determined by adding to the current computed track life an estimate of the time required to traverse the approach control airspace to major airports. This analysis can be seen in Section 2.2.10.1.2.

TABLE 2.2.20-1
DEVELOPMENT OF VALUES FOR PARAMETER 20.0 USING OPERATIONAL DATA

Average track life in minutes for the following flight types:

ARTCC	ARRIVALS	DEPARTURES	OVERFLIGHTS	WITHINS
AT2	26	29	38	25
CL2	21	21	24	21
MS2	23	20	33	22
SE2	48	40	52	32
AT3	29	28	31	22
CL3	21	24	28	24
DC3	31	28	39	33
FT3	27	50	37	32
MK3	32	28	27	28
AB4	43	37	65	38
HO4	28	27	41	30
IN4	24	26	37	22
JA4	36	29	48	42
ME4	30	29	38	32
BO5	46	25	—	33
CH5	31	27	42	—
DE5	39	38	65	36
LA5	34	28	—	23
MI5	31	40	—	38
NY5	24	31	34	27
OA5	38	37	41	30
SL5	41	37	59	24
AVERAGE	31	30	40	28
CURRENT SCENARIO	29	29	35	27
1990	29	29	35	27
1995	29	29	35	27
1995	41	29	35	39
2000	41	29	35	39
2010	41	29	35	39

2.2.21 Probability of Flight Trajectory Conflict

An investigation to determine workload for "probability that an event which incurs a flight probe may result in a conflict" has turned up no historical data. In addition, no convenient model can be built in the time frame required. The only alternate available is to obtain some expert judgement on sizing the parameter.

Workload data are listed in order of increased probability values:

Conflict as a Result of:	Probability of Conflict
1. Longitudinal Deviations	0.10
2. Return to Conformance	0.10
3. Filed Plan Activation	0.15
4. Requested Flight Plan Checking	0.15
5. Request for Metering	0.15
6. Controller Request (Trial Plan Probe)	0.15

2.2.22 Conflict Alert Frequency

The conflict alert parameter consists of the following five measures:

1. The number of unique conflict alerts declared/hour/100 tracks. Conflict Alert (CA) messages are examined to determine the highest alert rate for a ten minute period. This rate is then normalized for one hour and for a track load of 100.

2. The number of aircraft pairs that are candidates for conflict alert declaration. The conflict alert algorithm uses successively finer filters to screen potential violators; the number of aircraft pairs that enter the final filter are found in the HC table of the NAS software. The highest count over the sample period yields the value that is normalized for one hour and a 100 track load.

3. The peak number of simultaneous conflict alerts. As CA messages are examined, a count of simultaneous alerts is kept. The value of the maximum count is reported.

4. The average duration of conflict alerts. All conflict alert intervals in the sample period are identified in the file of CA messages and the mean and standard deviation are calculated.

5. The average duration of candidate pairs. All candidate pairs in the sample period are identified in the HC table and the mean and standard deviation are calculated.

The current values for Conflict Alert and Candidate Pairs will be affected by the following future changes:

1. Modifications to enhance effectiveness of the CA algorithm that are currently being implemented

2. Addition of software to detect potential conflicts between controlled flights and Mode-C equipped VFR flights (in design stage)

3. Conflict alerts in the terminal area. Present data is restricted to en route airspace experience.

2.2.22.1 Conflict Alert Rate

Current values for CA rate can be seen in Table 2.2.22.1-1. The maximum CA rate was experienced at Fort Worth; however, the circumstances were sufficiently unusual that this sample was temporarily discounted. The next highest rate (120 CAs/100 tracks/hour) experienced by Oakland and Washington was chosen as the current scenario rate.

The values (CAs/hr/100 tracks) for each sample are plotted by track level to detect a trend (Figure 2.2.22.1-1). As can be seen, no correlation clearly stands out and it is suspected that differences in airspace environment among ARTCCs obscure any trend. The approach taken to predict future values was to use the projected values from the only two ARTCCs with repeated samples, New York and Cleveland.

Obviously, there can be no statistical significance to the result but it is at least intuitively satisfying to report that the rate of CAs/traffic unit appears to increase slightly as traffic increases.

Using the current scenario value (120), the 1985 maximum stress, controlled track load (380), and the slope of the New York and Cleveland data, a linear function ($f(x) = 100 + 0.056X$, $X =$ controlled track load) was created to project the conflict alert

TABLE 2.2.22.1-1
DEVELOPMENT OF VALUES FOR PARAMETER 22 USING OPERATIONAL DATA

ARTCC	22.1 Number of Conflict Alerts/ 100 Tracks/Hour	22.2 Candidate Aircraft Pairs/ 100 Tracks/Hour	22.3 Peak Conflict Alerts/100 Tracks (Instantaneous)
AT2	18	99	2.29
CL2	52	109	2.31
MS2	42	159	2.73
SE2	110	121	6.14
AT3	*	*	*
CL3	76	*	2.52
DC3	120	*	3.47
FT3	212	*	6.07
MK3	83	*	4.59
AB4	25	*	2.96
HO4	55	*	2.84
IN4	44	*	2.12
JA4	76	*	3.28
ME4	34	*	*
BO5	71	*	6.25
CH5	66	*	5.05
DE5	13	*	1.51
LA5	40	*	3.45
MI5	88	*	7.69
NY5	89	*	7.75
OA5	120	*	7.57
SL5	43	*	5.71
AVERAGE	70	*	4.32
CURRENT SCENARIO	120	600	4.00

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*No data

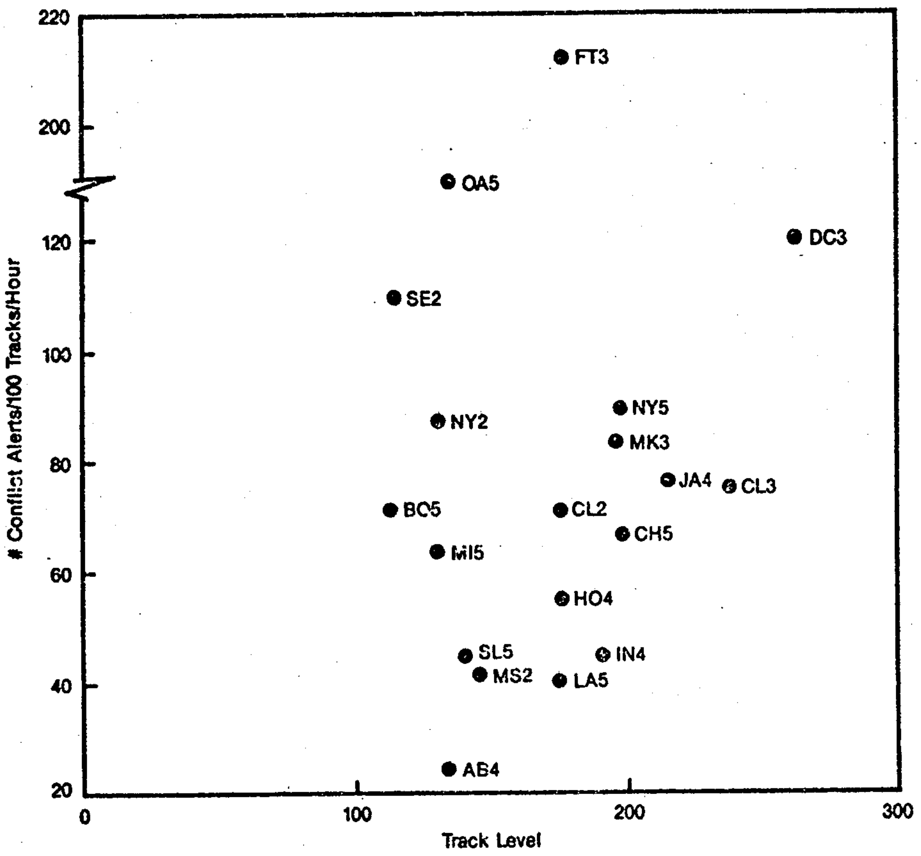

FIGURE 2.2.22.1-1
PEAK CONFLICT ALERT COUNT

rate to the future years. The following table shows the initial projection of conflict alert rates:

1990	1995	1995	2000	2010
127	134	148	156	172

However, this rate will be increased by the addition of the Mode-C Intruder logic which increases the population of affected flights and, ultimately, the number of conflict alerts. Table 2.2.22.1-2 illustrates the calculations done to determine the rate of conflict alerts including VFR Mode-C intruders.

The assessment of conflict alerts was made for aircraft at different altitude strata because the distribution of Mode-C equipped VFR flights revealed that a disproportionate number of these flights were found in altitude strata with a history of high conflict alert rates. Because the parameter is measured in units of CAs/100 tracks/hour, the analysis used 100 IFR tracks as the base.

Table 2.2.22.1-2 is a summary of the VFR Mode-C Intruder (MCI) calculations. The small table at the top of Table 2.2.22.1-2 is a list of conflict alert parameters that vary by year. These are used to calculate the conflict alert rates in the six subsequent tables. Each of these tables is organized to calculate the conflict alert rate for a particular year by altitude stratum.

The values in column A have been calculated by evaluating current operational data (see Table above). The next two columns of data (B & C) are workload parameter values needed to calculate the number of Mode-C/S equipped VFR flights. Values for column B represent Parameter 7; values for column C represent Parameter 5.2.

Column D represents 100 IFR tracks distributed in altitude according to data from two radars: QRW from the Los Angeles ARTCC and QBE from the Minneapolis St. Paul ARTCC. The Mode-C report count forming the basis for the altitude distribution was assumed to be correct. E contains a typical altitude distribution of conflict alerts taken from over 2000 actual conflict alerts recorded from 1983 to 1985, (Table 2.2.22.1-3). There was no "Floor" in force at these times. Using the conflict alert rate for each year and the altitude distribution of conflict alerts, the number of CAs for each altitude strata was determined (Column F).

TABLE 2.2.22.1-2
VFR MODE-C INTRUDER CALCULATIONS

YEAR	(A) CA RATE/100 TRACKS/HOUR	(B) FACILITY VFR/IFR TARGET RATIO	(C) VFR MODE-C/S TRANSPONDER EQUIPAGE
1985	120	0.5	0.50
1990	127	0.8	0.58
1995	134	0.8	0.70
1995	148	0.9	0.70
2000	156	0.9	0.78
2010	172	0.9	0.88

1990 CONFLICT ALERTS	(D) IFR FLIGHTS	(E) CA ALTITUDE DISTRIB.	(F) CONFLICT ALERTS (A*E)	(G) VFR MODE-C ALT. DIST.	(H) VFR MODE-C/S FLIGHTS (B*C*G)	(I) TOTAL MODE-C/S FLIGHTS (D+H)	(J) CALCU-LATED ALERTS (*)
ABOVE 12,000 FEET	59	23	29.21	9	4	63	31
8,000' TO 12,000'	16	19	24.13	23	11	27	34
6,000' TO 8,000'	6	16	20.32	18	8	14	33
0' TO 6000'	19	42	53.34	50	23	42	83
TOTALS							182

1995 CONFLICT ALERTS	(D) IFR FLIGHTS	(E) CA ALTITUDE DISTRIB.	(F) CONFLICT ALERTS (A*E)	(G) VFR MODE-C ALT. DIST.	(H) VFR MODE-C/S FLIGHTS (B*C*G)	(I) TOTAL MODE-C/S FLIGHTS (D+H)	(J) CALCU-LATED ALERTS (*)
ABOVE 12,000 FEET	59	23	30.82	9	5	64	33
8,000' TO 12,000'	16	19	25.46	23	13	29	37
6,000' TO 8,000'	6	16	21.44	18	10	16	36
0' TO 6000'	19	42	56.28	50	28	47	91
TOTALS							197

TABLE 2.2.22.1-2
(Concluded)

1995 CONFLICT ALERTS	(D) IFR FLIGHTS	(E) CA ALTITUDE DISTRIB.	(F) CONFLICT ALERTS (A*E)	(G) VFR MODE-C ALT. DIST.	(H) VFR MODE-C/S FLIGHTS (B*C*G)	(I) TOTAL MODE-C/S FLIGHTS (D+H)	(J) CALCU-LATED ALERTS (*)
ABOVE 12,000 FEET	59	23	34.04	9	6	65	37
8,000' TO 12,000'	16	19	28.12	23	14	30	42
6,000' TO 8,000'	6	16	23.68	18	11	17	40
0' TO 6000'	19	42	62.16	50	32	51	102
TOTALS							221

2000 CONFLICT ALERTS	(D) IFR FLIGHTS	(E) CA ALTITUDE DISTRIB.	(F) CONFLICT ALERTS (A*E)	(G) VFR MODE-C ALT. DIST.	(H) VFR MODE-C/S FLIGHTS (B*C*G)	(I) TOTAL MODE-C/S FLIGHTS (D+H)	(J) CALCU-LATED ALERTS (*)
ABOVE 12,000 FEET	59	23	35.88	9	6	65	39
8,000' TO 12,000'	16	19	29.64	23	16	32	45
6,000' TO 8,000'	6	16	24.96	18	13	19	43
0' TO 6000'	19	42	65.52	50	35	54	109
TOTALS							236

2010 CONFLICT ALERTS	(D) IFR FLIGHTS	(E) CA ALTITUDE DISTRIB.	(F) CONFLICT ALERTS (A*E)	(G) VFR MODE-C ALT. DIST.	(H) VFR MODE-C/S FLIGHTS (B*C*G)	(I) TOTAL MODE-C/S FLIGHTS (D+H)	(J) CALCU-LATED ALERTS (*)
ABOVE 12,000 FEET	59	23	39.56	9	7	66	44
8,000' TO 12,000'	16	19	32.68	23	18	34	51
6,000' TO 8,000'	6	16	27.52	18	14	20	48
0' TO 6000'	19	42	72.24	50	40	59	122
TOTALS							264

* = F[2H + (D - 1)] / (I - 1)

A VFR Mode-C altitude distribution was determined by examining returns from two radars in Los Angeles (QRW) and Minneapolis-St. Paul (QBE). Using parameters B and C in the first table with the VFR Mode-C altitude distribution, the number of VFR flights were located in each altitude stratum (H). Total Mode-C tracks were determined by summing columns D (IFR) and H (VFR).

Total conflict alerts are estimated by using the following relationship:

$$\frac{\text{IFR:IFR conflict alerts}}{\text{IFR:IFR and IFR:VFR conflict alerts}} = \frac{\text{Number of IFR:IFR Pairs}}{\text{Number of IFR:IFR Plus IFR:VFR Pairs}}$$

This relationship is used in calculating the values for Column J.

There are two final modifications to this calculated value of conflict alerts. The reduction in alerts (most of which are called nuisance alerts) by software currently being implemented has not been studied exhaustively. However, it appears likely that 30 percent of the conflict alerts described by MITRE[28] could be eliminated by this software. Accordingly, beginning in 1990, conflict alerts are reduced by this amount.

AERA will contribute toward the reduction in conflict alerts by implementing a flight plan trial probe that will seek to avoid conflicts at the planning stage. An adjustment to the remaining conflict alerts has been made by assuming that all alerts over 18,000 feet in altitude could be avoided by implementation of this function in 1995. This allows another 12 percent of the conflict alerts to be eliminated.

The reductions described above result in the following values for conflict alerts:

	CAs (with Mode-C Intruder from 1990)	New CA Software Reduction	Flight Plan Probe Reduction	Net CA Rate
1985	120	--	--	120
1990	182	55	--	127
1995	197	59	--	138
1995	221	66	27	128
2000	236	71	28	137
2010	264	79	32	153

TABLE 2.2.22.1-3
ALTITUDE DISTRIBUTION OF CONFLICT ALERTS OBSERVED AT 7 ARTCCs

ALTITUDE	FT3	AB4	MI5	LA5	NY5	BO5	OA5	AVERAGE DISTRIBUTION
0-6000	32	21	50	35	40	56	60	42
6000' to 8000'	19	12	17	11	23	15	14	16
8000' to 12,000'	20	20	18	22	24	16	15	19
12,000' to 18,000'	12	19	9	17	9	9	4	11
18,000' ———	17	28	6	15	4	4	7	12
Number of Conflicts	157	174	329	198	870	217	419	

2.2.22.2 Candidate Aircraft Pairs/100 Tracks/Hour

The parameter measures the number of track pairs subjected to the fine lateral filter of the conflict alert algorithm. This information is stored in the HC table of current NAS software which is periodically read by SAR. The ULR software reduces the SAR output to more easily readable form and the MITRE Workload Analysis Software calculates the parameter value.

Analysis of Table 2.2.22.1-1 shows that only four values of this parameter were obtained. ULR does not currently work on the NAS Level 13 or 14 version so no values for 1983-1985 samples were obtained. Ratios of aircraft pairs/conflict alert were calculated in hopes of using a relationship to predict future parameter values. However, these ratios varied from 1.1 to 5.5. A cautious approach was taken and a ratio of 5 was assumed for the current scenario value. Values for future years were also calculated using the ratio value = 5. The following values for parameter 22.2 result:

	Parameter 22.1	Parameter 22.2
1985	120	600
1990	130	650
1995	140	700
1995	140	700
2000	140	700
2010	150	750

2.2.22.3 Peak Conflict Alert Count/100 Tracks

Table 2.2.22.1-1 shows the values of this parameter for each ARTCC. These values are also shown in Figure 2.2.22.3-1 in a more revealing fashion. However, it is hard to discern a trend from this data. The value, 4, was chosen as a logical upper bound for a 1985 track value of 380. The data does not help in projecting this value so it was assumed not to change significantly over time.

2.2.22.4 Conflict Alert Duration

For every unique conflict, the elapsed time was determined and the average was calculated for each of four ARTCCs. No further calculations were done for other ARTCCs because the ULR software would not operate on the HC tables from NAS level 13 or later data sources.

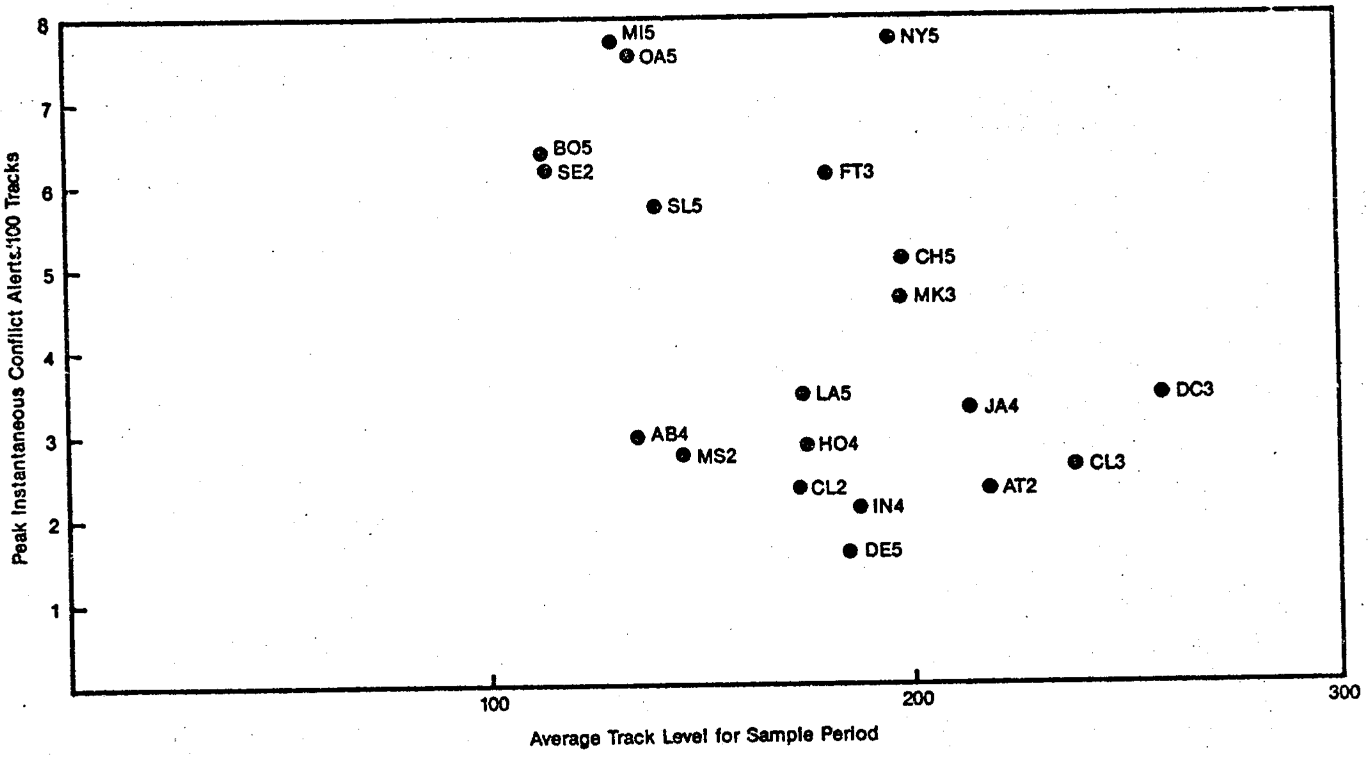

FIGURE 2.2.22.3-1
PEAK INSTANTANEOUS CONFLICT ALERT COUNT

Table 2.2.22.4-1 shows values for this parameter. Note that the scenario value is less than the maximum value. The highest value was not chosen because it was felt that the low traffic level contributed to an unusually high conflict alert duration.

2.2.22.5 Candidate Pair Duration

For every unique candidate conflict, the elapsed time was determined and the average was calculated for each of four ARTCCs. No further calculations were done for other ARTCCs because the ULR software would not operate on the HC tables from NAS level 13 or later data sources.

The current and subsequent scenario value (Table 2.2.22.4-1) approximates the most demanding condition.

2.2.23 MSAW Alert Frequency

This parameter is estimated only for enroute airspace because the data from which the value derives is obtained via SAR. The MSAW message routed to the high speed printer is examined for unique alerts. Messages are produced every 12 seconds; if a series of messages concerning the same aircraft is interrupted for longer than 60 seconds, the continuation of messages is interpreted as another alert.

There was no compelling reason to accept any value other than the maximum (See Table 2.2.22.4-1). Too few samples were obtained to encourage consideration of a less demanding value.

2.2.24 Message Origin

The table of message sources (Table 2.2.24-1) reflects the pattern of a large (traffic and airspace) ARTCC located away from the geographic corners of the U.S. An attempt was made to provide a typical allocation of messages to source.

2.2.25 Converted Route Segments (CRS) Per Flight

An estimate of the maximum number of Converted Route Segments (CRS) for a flight within an ARTCC was made through consultation with MITRE staff. The scenario value chosen was 25 CRS per flight.

The maximum number of CRS per trajectory in a facility during the consolidation period is calculated as follows:

TABLE 2.2.22.4-1
DEVELOPMENT OF VALUES FOR PARAMETER 22 & 23 USING OPERATIONAL DATA

ARTCC	22.4 Conflict Alert Duration	22.5 Candidate Pair Duration	23.1 MSAW Alerts/ 100 Tracks/hr
AT2	1.10	1.50	1
CL2	1.26	1.83	2
MS2	1.55	2.30	
SE2	1.90	2.40	
AT3			
CL3			33
DC3			22
FT3			20
MK3			
AB4			
HO4			24
IN4			7
JA4			
ME4			
BO5			
DE5			
LA5			11
MI5			14
NY5			39
OA5			
SL5			
AVERAGE	1.45	2.01	17
CURRENT SCENARIO	1.50	2.50	39
1990	1.50	2.50	39
1995	1.50	2.50	39
1995	1.50	2.50	
2000	1.50	2.50	
2010	1.50	2.50	

TABLE 2.2.24-1
WORKLOAD SCENARIO VALUES–DISTRIBUTION OF MESSAGES BY TYPE 7 ORIGIN

MESSAGE TYPES	CODE*	MESSAGE ORIGIN (%)						
		BULK STORE	"A" CONTROLLER	"D" CONTROLLER	"R" CONTROLLER	ADJACENT ARTCC	AUTOMATED RADAR APPROACH CONTROL	OTHER
Track Control								
Accept Handoff	QNA,QZA				100			
Initiate Handoff	QNI,QZI				100			
Start Track	QTT				100			
Stop Track	QXT				100			
Initial FP Data								
Flight Plan	FP	15		2		45		38
Flight Data Inputs								
Altitude Modification	QZE, AMA			14	55	29		2
Route Modification	QUO, AMR			27		68		5
Other Amendments				34		33		33
Interim Altitude	QQ			19	81			
Departure Message	DM			12			75	13
Drop Flight Plan	RS, QXF			23	50	13		14
Display								
Force Data Block	QNF,QZF				100			
Data Block Offset	QND,QZD			6	94			
Block Point-Out	QPD			5	95			
Route Display	QUR			12	88			
Flight Data Readout	FR,QF		10	35	37			18
Strip Request	SR		12	38				50
Interfacility								
Accept Transfer	TA					52	48	
Initiate Transfer	TI					47	53	
Track Update	TU					67	33	
Transmission Accepted	DA					47	53	
Terminate Beacon Code	TB						100	
Discrete Code Request	QB			34	66			
Test	TR						100	
% OF TOTAL SOURCES		0.4	0.2	3.9	37.0	28.2	28.3	2.0

*These refer to NAS message designator symbols, and are not intended to apply to AAS message naming convention.

Item	Maximum Number Expected	Converted Route Segments Per Number	Converted Route Segments
Route Converted Fixes	10	1	10
Speed PA's	2	2	4
Altitude PA's	2	8	16
Vector PA's	1	10	10
Hold PA's	1	3	3
		Converted Route Segments/Flight	43

NOTE: PA = Planned Action

The workload scenario value for Converted Route Segments/Flight is thus 43, for the AERA 1 time frame.

Converted Route Segments/Flight	1985 - 1992	1993 - 2010
	25	43

Converted Route Segments including back-up, where back-up area is 30% of an ACF area, is represented by an increase of 14% (i.e., $\sqrt{1+0.30}$), or 49 CRS/Flight.

2.2.26 Target Peaking

This parameter is currently in the state "to be determined." The previous definition of the parameter was target peaking, on a facility-wide basis, but this definition has been found to be inadequate.

The parameter has recently been redefined to be the target peaking characteristics of certain subsets of the set of sensors associated with a facility. The new definition would support modeling and design decisions for a wider range of computer system architectures. Due to this recent redefinition, new analysis was undertaken and is not yet completed.

2.2.27 Message Rates

Radar messages were obtained from CD Record and reduced by COMDIG. ACF-specific target report rates were determined and the most demanding was used to represent maximum stress. Controller and interfacility messages were obtained from SAR and reduced by DART and MITRE workload-specific software to obtain current scenario values.

2.2.27.1 Radar Site Messages

These messages are of two types: aircraft target reports and weather map messages.

Appendices L and M describe the methods used to calculate the ACF facility-specific aircraft target report message rates. These message rates are expressed in target report messages/second for conditions reflecting the most probable radar type mix of Mode-S and ATCRBS. The maximum stress target report rate is derived from these ACF-specific values.

The message rates for each of the kinds of weather map messages are estimated without using field data.

2.2.27.1.1 Target Reports/Radar Scan for IFR (and VFR) Flights

The approach used to calculate this parameter which is expressed in units of messages/radar scan/flight is the following:

1. Assuming 100% ATCRBS radars during the Host/ISSS Period and 100% Mode-S radars during the Consolidation Period, calculate facility-specific radar reports/second for each of the years of interest using the same methods shown in Appendices K and L.

2. Choose the facility with the highest messge rate for each year.

3. From the chosen facility, identify the IFR and VFR target reports/scan.

4. Using maximum stress values for IFR and VFR traffic load (Parameters 2.1.1 and 2.1.2) and the facility-specific values for target reports/scan, calculate the maximum stress number of target reports/radar scan/flight.

5. Develop an equation to calculate the maximum stress message rate for any long range radar mix of Mode-S and ATCRBS.

Tables L.3-4 and K-4 show the facility-specific radar message rate for years 1985 through 2010. It can be seen that Kansas City has the highest radar message rate for all years. Because the previous version of this document reported this parameter in terms of IFR (and VFR) target reports/radar scan, it was decided to translate the Kansas City total target report values into these terms. If the Kansas City values for target reports/radar/flight were used for maximum stress however, one would not be able to multiply them by the <u>maximum stress</u> values of track load to calculate total target report message rate because the Kansas City ACF experiences a smaller VFR track load than does maximum stress. The following calculation uses the Kansas City values for target reports/radar/flight and modifies them to obtain values which assure that the Kansas City value for total target reports can be determined using maximum stress values for track load (see Tables 2.2.27.1-1 and 2.2.27.1-2 for the data used to calculate this parameter). As an example of this procedure, the modification done to 1985 data follows:

1. Calculate the message rate/second using maximum stress traffic loads and Kansas City's parameter values.

$$[(\overset{\text{IFR}}{5.4 \times 380}) + (\overset{\text{VFR}}{1.8 \times 304})]/10 \text{ seconds/scan} = 260 \text{ messages/second}$$

2. Calculate the difference between desired message rate and calculated rate. Reduce the IFR and VFR target report/scan value in a 1 to 2 proportion, i.e., assign a reduction to the VFR rate that is twice that of the IFR rate. This reduction proportion was chosen simply to weight the VFR reduction more heavily than the IFR, reflecting the relative discrepancies in the traffic loads between Kansas City and the maximum stress case.

$$\begin{array}{rl} 260 & \text{messages/second} \\ \underline{-212} & \\ 42 & \text{messages/second} \\ \underline{\times\ 10} & \\ 420 & \text{messages/scan} \end{array} \qquad \left\{ \begin{array}{l} 140 \text{ IFR messages/scan} \\ \\ 280 \text{ VFR messages/scan} \end{array} \right.$$

3. Adjust the equation in step 1 using the two differences.

$$\begin{array}{rrl} 5.4 \times 380 = & 2052 & \text{messages/second} \\ & \underline{-\ 140} & \\ & 1912 & 380 = 5.03 \approx \underline{\underline{\underline{5.0}}} \end{array}$$

TABLE 2.2.27.1-1
SOURCE DATA FOR CALCULATING TARGET REPORT RATE (PREPARE FOR BACK-UP)

			KANSAS CITY				
	Maximum Stress Traffic Load		Traffic Load		Target Report Rate		
					Message/scan/aircraft		Messages/second
Year	IFR	VFR	IFR	VFR	IFR	VFR	Total
1985	380	304	346	147	5.4	1.8	212
1990	490	392	422	188	5.4	1.8	263
1995	600	480	496	221	5.5	1.8	313
1995	910	820	913	557	5.1	1.4	1078
2000	1060	950	1061	648	5.1	1.4	1256
2010	1310	1180	1314	802	5.1	1.4	1564

TABLE 2.2.27.1-2
SOURCE DATA FOR CALCULATING TARGET REPORT RATE
(HANDLE FOR BACK-UP)

Year	Maximum Stress Traffic Load		KANSAS CITY				
			Traffic Load		Target Report Rate		
					Message/scan/aircraft		Messages/second
	IFR	VFR	IFR	VFR	IFR	VFR	Total
1995	1180	1060	1187	725	4.8	1.3	1334
2000	1380	1240	1379	1194	4.8	1.3	1553
2010	1700	1530	1703	1479	4.8	1.3	1932

$$\begin{array}{rl} 1.8 \times 304 = & 547 \\ & \underline{-280} \\ & 267 \quad 304 = 0.88 \approx \underline{\underline{\underline{1.0}}} \end{array}$$

The result is two values that, when used with maximum stress track load values, will allow a maximum stress target report message rate to be calculated that is as high as that experienced at the most demanding facility.

A set of values was calculated for each year. The most demanding value of the 1985-1995 values was chosen to represent the Host/ISSS Period. A most demanding value was similarly chosen for the Consolidation Period.

Message Rate Correction for Scenarios Containing Neither All ATCRBS nor All Mode-S Radars - The scan rate (SR) for Mode-S radar is 5 seconds per scan and for ATCRBS type is 10 seconds per scan. Consequently the message rate for a given target is twice as slow for an ATCRBS as for a Mode-S radar. This is the reason that the workload scenario for radar target message rate specifies that all of the long range radars are of Mode-S type.

To determine the radar target message rate per aircraft for a facility with a mixture of ATCRBS and Mode-S long range radars, the maximum stress radar message rate (Parameter Number 27.1.1 and 27.1.2) can be used in conjunction with a scan rate which is characteristic of the radar mix. For instance, the radar target message rate per IFR aircraft for a scenario with 100% long range Mode-S for the year 1995 is equal to:

$$\frac{\text{Max Stress IFR Target Report Rate/Radar Scan}}{\text{Mode-S Scan Rate}}$$

$$= 5.1C \ \frac{\text{target reports}}{\text{scan/IFR aircraft}} \times \frac{\text{scan}}{\text{5 seconds}}$$

$$= 1.02C \ \frac{\text{target reports}}{\text{IFR aircraft/seconds}}$$

For a facility with a mixture of long range Mode-S and ATCRBS radars the equivalent scan rate used would be greater than five (5) seconds. It is not correct to interpolate between the ATCRBS radar scan rate (i.e., ten (10) seconds per scan) and the Mode-S radar scan rate during the Consolidation Period, since all of the short range radars, irrespective of mode, have a scan rate of five (5) seconds per scan, and are included in the overall calculation of message rate.

To calculate scan rate (SR) as a linear function of the percentage of long range Mode-S radars, data are obtained for Kansas City from Table L.3-3, and are shown on the left side of the table below. Equivalent scan rates are calculated and a linear formula is derived which expresses scan rate as a function of percent long range Mode-S radar. The formula is derived for both IFR and VFR aircraft using the y = mx + b, equation form and the two values of SR and percent of Mode-S.

% Mode S	Aircraft Type	Target Rate, Messages/Sec	Equivalent Scan Rate, Seconds/Scan	Equivalent Scan Rate as a function of % Mode-S
100 13.3	IFR IFR	928 742	5.0 (928/742)5 = 6.25	SR = 6.45-1.45 (% Mode-S)
100 13.3	VFR VFR	151 124	5.0 (151/124)5 = 6.09	SR = 6.26-1.26 (% Mode-S)

To determine the radar target mesage rate per IFR aircraft for a scenario of 50% Mode-S and 50% ATCRBS long range radars, the following scan rate is calculated from the above equations:

SR = 6.4 - 1.4 (0.50) = 5.7 seconds/scan.

Target message rate/IFR aircraft

$$= 5.1C \; \frac{\text{target reports}}{\text{scan/IFR aircraft}} \times \frac{\text{scan}}{\text{5.7 seconds}}$$

$$= 0.89C \; \frac{\text{target reports}}{\text{IFR aircraft/second}}$$

During the Host/ISSS period, the message rate incurred by short range radars is not included in the overall message rate load. For the Host/ISSS years, the scan rate is interpolated between values of five (5) and ten (10) to reflect the mix of Mode-S and ATCRBS long range radars. For instance, where the mix of long range radars is 50% Mode-S and 50% ATCRBS, the scan rate is equal to 7.5.

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2.2.27.1.2 Target Reports/Radar Scan for VFR Flights

The determination of this parameter value was presented in Section 2.2.27.1.1 because the calculation of both parameters was concurrent.

2.2.27.1.3 Weather Map Message Rate

The AAS System Level Specification[29] states that the AAS computer system will process Weather and Fixed Map Unit (WFMU) and ASR-9-generated weather map messages, as well as Central Weather Processor (CWP) weather data. The WFMU weather load on AAS, as a maximum stress:

32 msgs/radar/radar scan (Reference 18)

The ASR-9 weather message load on AAS, as a design limit:

85 msgs/radar/radar scan (per Reference 30 value of 256 msgs/3 scans)

A shortcoming of the above estimate is that using the design limit value for messages per radar per scan will overstate what should be a representative workload parameter value. Hence, this analysis should be considered preliminary.

CWP estimate is determined from conversation with MITRE personnel involved with FAA's CWP project. Empirical measurements shows that a single Radar Remote Weather Display System (RRWDS) sensor experiencing a worst case weather scenario would sense 10,000 vectors in its 72,000 cells (bins). The largest ACF (Seattle) will contain 230,000 4km x 4km cells. (10,000/72,000) x 230,000 = 32,000 vectors. Assuming a CWP refresh rate of 5 minutes for the entire ACF, 32,000 vectors/5 minutes equals approximately 100 vectors per second.

2.2.27.2 Track Control Messages

2.2.27.2.1 Accept Handoff

An Accept Handoff message is entered by a sector controller each time that control of a flight is accepted. Because each sector penetrated by a flight requires this message, the parameter, Sectors Penetrated, is a good estimate of the message rate for Accept Handoff.

2.2.27.2.2 Initiate Handoff

The message rate for Initiate Handoff comprises controller entered messages only. Automatically initiated handoff messages are not counted, therefore the Initiate Handoff message rate can be expected to be less than the Accept Handoff rate. The maximum value (2.5) occurs at Oakland (Table 2.2.27.2-1); the rate for Denver, a high traffic facility, is nearly the same.

There is no compelling reason to choose a different value for the Host/ISSS period. The value for the Consolidation Period is calculated by assuming that the ratio of Accept Handoff values for Host/ISSS and Consolidation Period (2.9:4.1) is also appropriate for Initiate Handoff (2.9/2.5=4.1/x, x=3.5). This same technique applies to the calculation of "Handle Back-up" values.

As explained in 2.2.27.2.1, the values for Initiate Handoff message rate are assumed to vary with Sectors Penetrated. Accordingly, the "Handle Back-up" value is determined by a ratio of Sector Penetrated values for "Handle Back-up" and "Prepare for Back-up" (4.2/4.1). Applying this ratio to 3.5, the "Handle Back-up" value of 3.6 is calculated for Initiate Handoff.

2.2.27.2.3 Track

2.2.27.2.3.1 Track Initiate

The highest rate for this message was observed at Seattle, an ARTCC with a moderate traffic load. The value (0.2 messages/track) will provide a message rate equal to that experienced at Seattle and greater than that observed at any other facility. Tracks for all aircraft with beacon transponders will be initiated automatically in the Consolidation Period.

2.2.27.2.3.2 Track Terminate

The highest rate for this message was observed at Seattle ARTCC with a moderate traffic load. The value 0.2 messages/track will provide a message rate equal to that experienced at Seattle and greater than that observed at any other facility. As traffic density increases over time, the PVD will be displaying more traffic per unit area. This situation will encourage an increased use of this message to eliminate unneeded track information.

TABLE 2.2.27.2-1
DEVELOPMENT OF VALUES FOR PARAMETERS 27.2.2 TO 27.2.3*
USING OPERATIONAL DATA

ARTC	27.2.2 INITIATE HANDOFF	27.2.3.1 TRACK INITIATE	27.2.3.2 TRACK TERMINATE
AT2	1.83	0.06	0.10
CL2	1.60	0.04	0.08
MS2	1.25	0.04	0.23
SE2	1.94	0.31	0.36
AT3	1.72	0.05	0.09
CL3	1.26	0.15	0.09
DC3	1.91	0.08	0.05
FT3	0.98	0.06	0.01
MK3	1.69	0.13	0.12
AB4	2.10	0.22	0.12
HO4	1.46	0.10	0.14
IN4	1.63	0.07	0.10
JA4	1.89	0.09	0.10
ME4	1.49	0.07	0.13
BC5	1.94	0.11	0.14
CH5	1.66	0.05	0.09
DE5	2.40	0.09	0.04
LA5	0.97	0.11	0.02
MI5	2.40	0.43	0.08
NY5	2.01	0.06	0.07
OA5	2.52	0.16	0.09
SL5	1.69	0.14	0.18
AVERAGE	1.74	0.12	0.11
CURRENT SCENARIO	2.5	0.2	0.2
1990	2.5	0.2	0.2
1995	2.5	0.2	0.3
1995	3.5	0.2	0.3
2000	3.5	0.2	0.3
2010	3.5	0.2	0.3

---

*Message rates are expressed in messages/controlled flight.

2.2.27.3 Flight Plan Data Messages

2.2.27.3.1 Flight Plan

Every controlled flight is assumed to require one flight plan.

2.2.27.3.2 Flight Data Modifications

These parameters consist of the sum of the message rates of two messages: the amendment (AM) and the "quick" modification (QN,QZ). See Table 2.2.27.3-1.

No compelling reason was found to choose less demanding current scenario values than the maximum.

There is no reason to change the growth estimate made in 1985 for route and altitude modifications. This estimate was based on the assumption that relatively more route and altitude modifications will be made as traffic becomes more and more dense. No sophisticated traffic analyses were made because of the uncertainty of the effect of AERA functions on controller-issued messages. Due to the uncertainty over how traffic will be routed during the Handle Back-up situation, the Handle Back-up value was based on the assumption that message rate is proportional to flight life.

2.2.27.3.3 Interim Altitude

The maximum recorded value (Table 2.2.27.3-1) was chosen because it was observed at a busy ARTCC (Atlanta). The rationale for message growth rate is the same as that for Flight Data Modifications, parameter 27.3.2.

2.2.27.3.4 Departure

Every departure flight is assumed to generate a departure message. Add the proportion of departures and withins (0.27 + 0.28 for the HOST/ISSS Period, 0.24 + 0.22 for the Consolidation Period) to obtain the proportion of flights that require a departure message. Note that field data show an average of 0.47 messages/flight.

TABLE 2.2.27.3-1
DEVELOPMENT OF VALUES FOR PARAMETER 27.3* USING OPERATIONAL DATA

ARTCC	27.3.2.1 Altitude Modification	27.3.2.2 Route Modification	27.3.2.3 Other Modification	27.3.3 Interim Altitude Message	27.3.4 Departure Message	27.3.5 Drop Flight Plan Message
AT2	0.41	0.24	0.04	1.69	0.50	0.10
CL2	1.09	0.25	0.03	0.80	0.45	0.08
MS2	0.28	0.08	0.07	0.68	0.43	0.23
SE2	0.44	0.18	0.22	1.15	0.72	0.37
AT3	0.43	0.29	0.38	1.97	0.42	0.10
CL3	1.09	0.25	0.13	0.80	0.43	0.00
DC3	0.74	0.33	0.20	1.40	0.43	0.01
FT3	0.30	0.14	0.04	1.05	0.57	0.11
MK3	0.33	0.11	0.18	0.83	0.45	0.00
AB4	0.45	0.18	**	0.90	0.57	0.01
HO4	0.39	0.16	0.11	1.24	0.57	0.00
IN4	0.68	0.45	0.15	1.09	0.34	0.00
JA4	0.98	0.39	0.45	1.02	0.26	0.00
ME4	0.34	0.28	0.09	1.06	0.34	0.00
BO5	1.23	0.42	0.32	0.66	0.70	0.03
CH5	0.52	0.28	0.13	0.89	0.51	0.01
DE5	0.33	0.16	0.10	1.10	0.37	0.03
LA5	0.16	0.18	**	0.61	0.37	0.03
MI5	0.95	0.11	**	1.48	0.70	0.01
NY5	1.18	0.43	0.16	1.28	0.47	0.00
OA5	0.63	0.20	0.14	1.12	0.46	0.06
SL5	0.39	0.35	0.12	0.61	0.29	0.01
AVERAGE	0.61	0.25	0.16	1.07	0.47	0.05
CURRENT SCENARIO	1.2	0.4	0.4	2.0	0.5	0.1
1990	1.6	0.5	0.4	2.4	0.5	0.2
1995	2.1	0.6	0.4	3.0	0.5	0.2
1995	2.8	0.6	0.4	3.4	0.5	0.2
2000	3.3	0.7	0.4	3.9	0.5	0.3
2010	3.7	0.8	0.4	4.2	0.5	0.3

---

*Message rates are expressed in messages/controlled flight.

2.2.27.3.5 Drop Flight Plan

The current scenario value was heavily influenced by what appears to be current practice during heavy traffic of not using this message. Accordingly a nominal value of 0.1 messages/flight was assigned. The rate of change of this value is assumed to be the same as that established earlier[5].

2.2.27.3.6 Traffic Management

Because of the lack of experience with this function, an estimate of 1 message for every overflight and arrival was made. Approximately 50% of all flights are either overflights or arrivals.

2.2.27.4 Metering, Flow Control, and Other Automation Messages

These messages are To Be Determined.

2.2.27.5 Sector Workload Probe

This message is To Be Determined.

2.2.27.6 Display Function Related Messages

2.2.27.6.1 Force Data Block

The largest value for this message (Table 2.2.27.6-1) was observed at one of the busiest ARTCCs so it becomes the current scenario value. No reason is known for the value to change in the future. For "Handle Back-up", the value was increased proportional to the increase in Flight Life (3.6x 37/35 = 3.8).

2.2.27.6.2 Data Block Offset

The highest value for this parameter was observed at Oakland (6.37); the next highest was observed at Denver (5.69). Since the projected 1995 traffic rate for Denver is 1.6 greater than Oakland, it is clear that the Denver message per flight rate results in more messages/minute.

This rate will change when the function is automated. The assumption was made that the message rate/minute would double (5.7/30 min = 0.5x/35 min, x = 13.3). For "Handle Back-up", the rate was increased proportional to the increase in flight life. (13.3 x 37/35 = 14.1).

TABLE 2.2.27.6-1
DEVELOPMENT OF VALUES FOR PARAMETERS 27.6 TO 27.7.2 USING OPERATIONAL DATA*

ARTCC	27.6.1 Force Data Block	27.6.2 Data Block Offset	27.6.3 Data Block Pointout	27.6.4 Route Display Request	27.6.5 Flight Data Readout	27.7.1 Accept Transfer	27.7.2 Initiate Transfer
AT2	2.37	2.20	0.62	0.49	0.36	0.89	0.85
CL2	0.82	2.69	0.31	0.16	0.40	0.88	0.93
MS2	0.76	1.55	0.30	0.29	0.15	0.75	0.74
SE2	1.70	4.29	0.24	0.66	0.55	0.65	0.67
AT3	2.08	2.59	0.38	0.36	0.38	0.85	0.90
CL3	0.80	3.50	0.27	0.09	0.32	0.92	0.92
DC3	1.64	2.36	0.25	0.10	0.40	0.96	1.02
FT3	2.53	2.47	0.41	0.68	0.19	0.88	0.89
MK3	1.61	2.35	0.29	0.37	0.36	0.85	0.84
AB4	2.75	2.96	0.28	0.71	0.51	0.86	0.86
HO4	1.59	2.38	0.49	0.30	0.40	0.86	0.85
IN4	1.77	3.05	0.33	0.22	0.59	0.84	0.91
JA4	1.55	3.07	0.37	0.29	0.48	0.90	0.62
ME4	2.45	2.98	0.47	0.86	0.32	0.89	0.84
BO5	1.88	3.89	0.47	0.14	0.61	0.87	0.95
CH5	2.96	2.18	0.55	0.24	0.53	0.94	0.90
DE5	3.63	5.69	0.41	1.38	0.48	0.93	0.84
LA5	1.95	2.09	0.48	0.09	0.67	0.16	1.11
MI5	3.18	3.56	0.55	0.11	0.46	1.12	0.84
NY5	2.87	2.97	0.03	0.10	.63	0.90	0.90
OA5	2.63	6.37	0.86	0.77	.80	0.89	0.89
SL5	2.65	4.34	0.19	1.48	.39	0.80	0.80
AVERAGE	2.10	3.16	0.39	0.45	.45	0.85	0.87
CURRENT SCENARIO	3.6	5.7	0.6	1.4	0.5	1.0	1.0
1990	3.6	5.7	0.6	1.4	0.5	1.0	1.0
1995	3.6	5.7	0.6	1.4	0.5	1.0	1.0
1995	3.6	13.3	1.2	2.0	0.5	0.5	0.5
2000	3.6	13.3	1.2	2.0	0.5	0.5	0.5
2010	3.6	13.3	1.2	2.0	0.5	0.5	0.5

---

*Message rates are expressed in messages/controlled flight.

2.2.27.6.3 Data Block Pointout

The highest value for this parameter was found in Oakland (0.86) but the value found in Atlanta (0.62) was chosen for current scenario value because the message/minute rate would be just as high in Atlanta.

It is assumed that controller discretion currently prevents about half of the possible pointouts from occurring, therefore, after automation of this function, the message rate will double.

2.2.27.6.4 Route Display Request

Although Salt Lake City experienced the highest message rate/flight (1.48), Denver (1.38) was chosen as maximum stress because it produces the largest flight message rate/minute due to the higher traffic level in Denver. An increase in the use of this message is projected because of the greater use of user-preferred routes. This value was increased proportional to the change in flight life (37/35) to provide "Handle Back-up" values.

2.2.27.6.5 Flight Data Readout

None of the high traffic facilities experienced large values for this parameter. The following table shows that a current scenario value of 0.5 would result in the maximum stress value:

Facility	1995 Traffic Projection	Flight Life	Parameter Value-Msgs/ Flight	Messages/ Minute
Los Angeles	421	31	.67	9
Oakland	364	36	.80	8
Scenario	600	30	.50	10

No change is expected through 2010.

2.2.27.6.6 Data Field Highlight and Mark

This message substitutes for handwritten checkoffs on flight strips. Since the message has not yet been implemented, the value of 3.0 has been chosen based on observation of the control process[31]. Multiply by flight life proportion (37/35) to estimate "Handle Back-up".

2.2.27.6.7 FDE Pointout

This message is used to inform adjoining sectors about characteristics of flights of interest to each sector controller. Since the message has not yet been implemented, the value of 0.5 has been chosen based on observation of the control process[31].

2.2.27.6.8 Request Other FDEs

This message initiates an FDE Pointout. Since the message has not yet been implemented, the value, 0.5, has been chosen based on observation of the ATC process[31].

2.2.27.6.9 Select Logical Display

To be determined.

2.2.27.6.10 Sector Data Modifications

This message substitutes for handwritten notes now made on flight strips. Since the message has not yet been implemented, the value, 2.0, has been chosen based on observation of the ATC process. Multiply by flight proportion (37/35) to estimate "Handle Back-up".

2.2.27.6.11 Acknowledge New Flight Data/Flight Data Updates

This message will be implemented with the ISSS and the intent is to acknowledge the following messages:

	Prepare For Back-up Rate	Handle Back-up Rate
Interim Altitude	4.2	4.5
IP Amendments	4.9	5.2
Departure	0.5	0.5
Automatic Time Update	1.0	1.0
	10.6	11.2

2.2.27.7.1 Accept Transfer

Table 2.2.27.6-1 contains Accept Transfer message rates for each ARTCC sampled. However, to calculate a maximum stress value, one need only assume that each departure to an adjacent NAS facility and arrival to an ARTS facility creates an Accept Transfer message. The following table shows the calculation using maximum stress flight types:

(Param. 11) FLIGHT TYPE	DISTRIBUTION (%)	(Param. 13) % ARTS PENETRATION	MESSAGES/ FLIGHT
Arrival	21	80	0.17
Departure	27		0.27
Overflight	24		0.24
Within	28	80	0.22
All	100	10 (overflights)	0.10
			1.00

During the consolidation period, all ARTS facilities will be integrated into AAS, so the only flights creating Accept Transfer messages will be those departing to another NAS facility - departures (0.27 messages/flight) and overflights (0.24 messages/flight). The sum of these messages rates = 0.5.

2.2.27.7.2 Initiate Track Transfer

The logic used in Section 2.2.27.7.1 is also used to calculate this parameter value.

2.2.27.7.3 Track Update

The largest values for this parameter (Table 2.2.27.7-1) are not experienced by the busiest facilities so a comparison of total messages/minute was made (Table 2.2.27.7-2). The rate at Washington was greatest and a value for messages/flight was calculated for the current scenario. This value is not expected to change until consolidation.

After consolidation, no transfers will be made between ARTS and AAS so this value must be adjusted. The ratio of NAS Track Updates to Total Track Updates (13.31/19.29) for Washington was used to modify the current scenario value (0.69 x 12.3 = 8.45 messages/flight).

TABLE 2.2.27.7-1
DEVELOPMENT OF VALUES FOR PARAMETERS 27.7.3 TO 27.8 USING OPERATIONAL DATA

ARTCC	27.7.3 Track Update	27.7.4 Transmission Accept	27.7.5 Terminate Beacon Code	27.8.1 General Information
AT2	5.17	3.25	0.67	0.10
CL2	10.91	3.86	0.65	0.02
MS2	4.49	2.44	0.30	0.08
SE2	3.40	2.57	0.77	0.28
AT3	7.62	3.11	0.63	0.10
CL3	10.34	3.74	0.89	0.32
DC3	19.29	4.31	0.67	0.07
FT3	5.24	3.07	0.74	0.00
MK3	4.35	3.17	0.51	0.31
AB4	8.68	3.59	0.83	**
HO4	6.14	3.41	0.94	0.50
IN4	8.87	3.48	0.43	0.04
JA4	9.66	3.83	0.42	0.06
ME4	4.97	3.18	0.37	0.00
BO5	14.50	6.25	1.12	**
CH5	7.62	5.04	0.73	0.09
DE5	6.25	2.25	0.54	0.08
LA5	10.84	2.94	0.43	**
MI5	6.98	3.66	**	**
NY5	16.71	3.28	0.69	0.19
OA5	10.97	2.93	1.02	0.16
SL5	11.51	2.70	0.30	0.02
AVERAGE	8.84	3.46	0.69	0.13
CURRENT SCENARIO	12.3	4.0	1.0	0.5
1990	12.3	4.0	1.0	0.5
1995	12.3	4.0	1.0	0.5
1995	8.5	4.0	N/A	0.5
2000	8.5	4.0	N/A	0.5
2010	8.5	4.0	N/A	0.5

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*Message rates are expressed in messages/controlled flight.

TABLE 2.2.27.7-2
ANALYSIS OF MESSAGE RATE FOR TRACK UPDATE

ARTCC	A 1995 FORECASTED TRACK LOAD	B FLIGHT LIFE	C MESSAGES/ FLIGHT FOR TRACK UPDATE	D MESSAGE/ MINUTE (A/BxC)
CLEVELAND	477	23	10.63	220
WASHINGTON	420	33	19.29	245
NEW YORK	330	27	16.71	204
SCENARIO*	600	30	12.25	245

* The scenario value is calculated using the Washington value for total message rate

2.2.27.7.4 Transmission Accept

The largest values for this parameter (Table 2.2.27.7-1) are not experienced by the busiest facilities so a comparison of total messages/minute was made (Table 2.2.27.7-3). The rate at Cleveland was greatest and a value for messages/flight was calculated for the current scenario. This value is not expected to change significantly.

2.2.27.7.5 Terminate Beacon Code

The high value was experienced in Boston, a particularly low traffic facility. A value of 1.0 reflects experiences in Oakland, Houston, and Cleveland. As this message is sent from an ARTS facility upon dropping a track, this function will be unnecessary in the ACF Consolidation Period.

2.2.27.7.6 Initiate Flight Data on Aircraft Entering Back-up Airspace

It is necessary to provide flight data for those flights that will enter back-up airspace. Flight plans for some of those flights will be received because their route will take them through normally controlled airspace. For those flights with routes not penetrating normally controlled airspace, a flight plan message must be received. The following calculation estimates that message rate:

(A) Flight Type %	(B) Assumed Flight Disposition	(A x B)
20	25% of all back-up departures arrive at "our" ACF	0.050
24	20% of all back-up arrivals come from "our" ACF	0.048
34	40% of all overflights go to or come from "our" ACF	0.136
22	0% of all withins affect "our" ACF	0.000
		0.234

23.4% of back-up flights arrive, depart or overfly "our" ACF.

For normal operations, message rate = 1.0 - 0.234 ≈ 0.8; no message during back-up.

TABLE 2.2.27.7-3
ANALYSIS OF MESSAGE RATE FOR TRANSMISSION ACCEPT

ARTCC	A 1995 FORECASTED TRACK LOAD	B FLIGHT LIFE (MIN)	C MESSAGE/FLIGHT FOR TRANSMISSION ACCEPT	D MESSAGES/ MINUTES (A/BxC)
BOSTON	265	33	6.25	50.19
CLEVELAND	477	23	3.80	78.90
WASHINGTON	420	33	4.31	54.85
SCENARIO* (1985 & 1995)	600	30	4.00	78.90

* The maximum message rate (Cleveland) was used to calculate the scenario parameter value.

2.2.27.7.7 Update Flight Data on Aircraft in Back-up Airspace

If the volume of back-up airspace is equal to one ACF, the update message rate is the same as "our" ACF less that percentage (11.8%) of flights that are updated anyway because they will enter "our" airspace after leaving back-up airspace.

*departures from back-up to "our" ACF (20% x 25%)	5.0%
*overflights from back-up to "our" ACF (34% x 60%)	6.8%
	11.8%

The affected messages are FP amendments or modifications of the following types:

Altitude Amendments	3.7 messages/flight
Route Amendments	0.8 messages/flight
Other Amendments	0.4 messages/flight
	4.9 messages/flight

Therefore, 88.2% of 4.9 = 4.3 messages/flight.

2.2.27.7.8 Delete Flight Data on Aircraft Leaving Back-up Airspace

This message applies to the same flights as does Parameter 27.7.6.

2.2.27.8.1 General Information

There was no compelling reason not to choose the highest rate.

2.2.28 Number of TCCCs

The number of TCCCs located in each facility was determined and the procedure is explained in Section 2.3.2; Table 2-5, Volume I, presents the TCCC count for each ACF. The ACF with the greatest number of TCCCs connected (Boston) was chosen as maximum stress.

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*See calculation in Section 2.2.27.7.6.

2.2.29 Number of Control Positions

The number of Control Positions/facility for the consolidation period is explained in 2.3.3. Table 2-6, Volume I, presents the count of control positions for each ACF. The maximum stress number of control positions for the Consolidation Period, both en route and approach, represents conditions in Kansas City.

For the analysis of the Host/ISSS Period, a MITRE[32] projection of en route positions was used. This study used 1982 as the base year and projected to 1995. More recent data was made available for 1985, stimulating a modification of this initial projection. Table 2.2.29-1 presents the MITRE[32] values in columns headed 1982, 1990, 1995. The values for 1985 are taken from an FAA-AT memo of 11-21-85, reproduced in Appendix G, Table G-3. Upon inspecting Table 2.2.29-1, it was seen that Atlanta has the highest sector count in 1985 and this count is about seven sectors higher than the earlier MITRE projection. Accordingly, the expected value for 1995 was increased by seven to 45 and five more sectors were added to account for uncertainty.

2.2.30 Number of Sector Suites

For the Consolidation Period, the number of Sector Suites for each ACF was determined by the procedure explained in Section 2.3.4; Table 2-7, Volume 1, presents the sector suite count for each ACF. Kansas City was projected to be the ACF with the greatest number of sector suites. To compensate for uncertainty, five sector suites were added to the total.

The number of sector suites during the Host period (1990-1995) were calculated in the following way:

Positions	
Airspace Sectors	50
Training	8
Metering/TMU	6
Area Manager	1
En route Automation Specialist	1
CWSU	1
Maintenance Console	1
Special Facilities Use	1
	69 ≃ 70

TABLE 2.2.29-1
EN ROUTE CONTROL POSITIONS FOR ALL ARTCCs

	1982	1985*	1990	1995
ALBUQUERQUE	27	33	31	30
ATLANTA	37	45	41	38
BOSTON	25	24	28	25
CHICAGO	33	42	41	40
CLEVELAND	34	38	36	33
DENVER	33	36	36	33
FORT WORTH	36	37	41	38
HOUSTON	35	37	43	40
INDIANAPOLIS	22	27	27	27
JACKSONVILLE	31	29	33	30
KANSAS CITY	32	35	37	33
LOS ANGELES	30	33	34	32
MEMPHIS	28	28	33	32
MIAMI	21	24	24	23
MINNEAPOLIS	28	29	34	33
NY/BOSTON (A)	29	30	31	28
NEW YORK (B)				
OAKLAND	25	30	28	25
SALT LAKE CITY	19	22	19	17
SEATTLE	22	24	26	24
WASHINGTON	34	38	38	35
ANCHORAGE	12	**	13	12
HONOLULU	8	**	8	7

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*This column contains data recently obtained from FAA-AT. It has not been used to calculate the values shown in 1990 and 1995.

**No data.

2.3 Determination of ACF-Specific Scenarios

During the consolidation years, the present ARTCCs will be reconfigured as ACFs. There will be 23 ACFs (21 in the conterminous United States, one for Alaska, and one for Hawaii and the eastern Pacific Ocean) of two types: Type A and Type B.

It is assumed that Type B ACFs will control aircraft in low altitude strata up to approximately 18,000 ft. The Type A ACFs will be responsible for en route traffic and will handle approach control traffic for airports located outside the boundaries of Type B ACFs.

Because of the eventual necessity to tailor the system to the needs of specific ACFs, an estimate was made of the values of certain key parameters for all CONUS facilities during the ACF consolidation period. The key parameters are the ones that are expected to vary significantly between facilities as well as provide a large workload at any facility. The following key parameters are analyzed:

1. number of surveillance sites
2. number of TCCCs
3. number of control positions
4. number of sector suites
5. number of controlled and uncontrolled aircraft
6. target report message rate

2.3.1 Surveillance Sites

From the March 1985 version of the NAS Radar Surveillance Network Plan (Preliminary Copy)[33], the locations of all radar sites were plotted on a United States map and assigned to ACFs on the following bases:

1. All long range radars located within the boundaries of an ACF were assigned to the ACF. All long range radars located outside the ACF boundary but within 100 miles of the boundary were considered as candidates to be connected to the ACF. Of these radars, all sites that duplicated coverage inside the ACF boundary were not assigned to the ACF.

2. All short range radars located within the boundaries of ACF-Bs were assigned to that Type B ACF.

3. All short range radars located within the boundaries of an ACF-A, in that airspace controlled by the ACF-A from the ground to 60,000 feet, were assigned to the ACF-A. All short range radars located in that ACF-B airspace over which an ACF-A has jurisdiction were not considered to be connected to the ACF-A. Gap filler radars were assumed to be sited to provide coverage below 18,000 ft., therefore, they were treated the same as other short range radars.

4. The determination of Mode-S sites was made by assigning Mode-S capability to those sites indicated in Reference 34.

5. The number of sites under the "Prepare For Back-up" scenario is determined by multiplying by two the number of radar sites within the ACF boundaries (as calculated using Steps 1-3). This is not the same as doubling the number of radars <u>reporting</u> to the Facility because radars reporting to the ACF include radars outside the boundaries. It was thought that doubling the total number of radars reporting to the ACF would introduce a double-counting bias because it is likely that the radars outside the boundary (but reporting to the ACF) are in back-up airspace in any case.

6. The number of sites under the "Handle Back-up" scenario is determined by multiplying the number of radar sites within the ACF boundaries by 1.3.

A list of radar sites by ACF is included as Appendix C.

2.3.2 Number of Tower Computer Control Centers (TCCCs)

The FAA furnished the contractors with a list of 300 towers designated to become Tower Computer Control Centers (TCCCs). A schedule of implementation was also provided. MITRE identified the ACF with which the tower would be associated and tallied the numbers. See Appendix F for the list of towers and the implementation schedule.

2.3.3 Number of Control Positions

The number of control positions appropriate to each of the ACFs was determined by adding the projected number of en route sectors and the projected number of approach control radar positions. The following methodology was used:

1. For en route sectors, the source for current data is FAA's Area Control Facility Implementation Plan (Draft) (Reference 35). This report describes the ACFs according to number of sectors by en route, terminal, oceanic, radar and non-radar.

2. MITRE[32] estimated the number of en route sectors required for each ARTCC through 2010. After Consolidation in 1995, the en route sectors associated with each ACF were projected for the years 1995 and 2010 according to the rates of growth originally projected for the same named ARTCCs.

3. To determine the number of approach positions, MITRE used the ACF Implementation Plan's assignment of approach facilities (to ACFs) to determine the specific towers being provided approach service by each facility. The FAA Terminal Area Forecast (1984)[13] provided values of instrument operations/tower through 1995. Upon instructions from FAA*, we extended the forecast to include 2000 and 2010 by using the average growth rate from 1990-1995. To insure that airport capacity was not exceeded, projected instrument operations were not allowed to exceed an IO (Instrument Operations) ceiling determined in the following way: FAA Tower Airport Statistics Handbook, 1978,[12] contains tower operations statistics, among which is the "peak to average operations ratio" which was used as a surrogate for determining airport capacity. The IOs for 1980 were multiplied by this ratio which provided a ceiling estimate for tower IOs. This process implies that no new runways or procedures will be used to increase airport capacity. In some cases, it was necessary to decrease the FAA projections for 1995 because the ceiling was exceeded.

4. The forecasted instrument operations for the years 1995, 2000, and 2010 were used to determine the Grade Level at each facility. This calculation was made according to current AT criteria (See Appendix G). Hourly Traffic Density Factor was determined by multiplying IOs by 0.6** to adjust for the busiest 183 days of traffic and dividing by 183 days and 16 hours. The resulting factor was applied to traffic ranges for Grade Levels of Radar

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*Gene Mercer, Branch Chief of Aviation Forecasting

**Factor provided by Gary Bryan, MITRE, W44.

Approach (Appendix G). The approach control facility grade level was associated with an average productivity by calculating IOs/control position by Grade Level. This value, tempered by the maximum number of Control Positions/Facility/Grade Level, determined control positions assigned to each Facility. The maximum control positions/level was determined by accepting the current maximum value, excepting the N.Y. TRACON which is an unusual, highly consolidated Facility. Values used for average IOs/Grade Level and Maximum Control Positions/Grade Level follow:

Grade Level	Average IOs/Position	Maximum Positions/Grade Level
2	30	2
3	55	5
4	65	7
5	75	13

The number of control positions for each approach facility was calculated and summed for each ACF. Beginning at consolidation, two reduction factors were applied to reflect efficiencies due to consolidation and use of sector suites. These factors consisted of a 10% reduction to account for efficiencies due to use of sector suites and ACF-specific reductions (see Appendix G) caused by consolidation. These factors were obtained from the analysis done for the AAS Benefit/Cost Study[36]. Tables showing calculations for each ACF are found in Appendix H.

5. The approach and en route control positions were examined by ACF and year. Because of the belief that efficient transition planning will eliminate large variations in sector staffing, the 1995 and 2000 values for control positions were adjusted to alleviate these variations. See Table 2.3.3-1 for the final set of control position values for 1982 (not adjusted), 1995, 2000, and 2010.

The Prepare for Back-up value for each ACF is the sum of the en route and approach values shown in Table 2.2.3-1. It is assumed that conditions under Handle Back-up will not require more than the 24 training positions that each ACF will be alloted.

TABLE 2.3.3-1
NUMBER OF EN ROUTE AND APPROACH CONTROL POSITIONS FOR ALL ACFs

ACF	1982		1995		2000		2010	
	ENROUTE	APPROACH	ENROUTE	APPROACH	ENROUTE	APPROACH	ENROUTE	APPROACH
ABQ	28	22	31	24	26	24	38	24
ATL	21	44	22	45	18	49	24	50
BOS	15	44	15	49	12	51	16	56
CHI	16	27	19	39	16	42	20	45
CLE	27	38	26	48	20	56	28	59
DEN	41	27	41	29	32	33	41	36
FTW	28	40	30	43	23	44	31	48
HOU	37	25	42	26	34	28	48	30
IND	8	36	10	40	9	42	10	43
JAX	41	29	40	37	30	38	37	39
MKC	37	43	38	52	30	55	37	58
LAX	11	33	12	33	10	35	14	36
MEM	40	29	43	33	39	35	50	36
MIA	18	26	20	31	16	30	21	30
MSP	38	35	45	34	37	37	56	39
NYA	30	0	29	0	22	0	27	0
NYB	18	46	17	46	13	47	16	51
OAK	11	27	11	22	9	22	11	24
SLC	30	13	27	15	22	14	28	14
SEA	37	24	40	31	34	32	47	32
DCA	15	59	15	65	12	66	17	67
ANC	12	5	12	7	11	8	16	8
HON	11	8	7	12	5	12	6	13

* Positions include radar control, non-radar control, oceanic, en route and approach

2.3.4 Number of Sector Suites

The values for sector suites were determined by assuming the following:

1. Every control position is assigned a sector suite.

2. Each supervisor is assigned a sector suite [supervisors = (control positions/6) + 1].

3. The following specialist positions are assigned a sector suite:

    a. Flight data specialist: 2 per ACF.

    b. Traffic management specialist: 1 for each airport for which upstream metering is provided plus 1 for each metered airport within the boundaries of the ACF.

4. Metering will apply to the current busiest 50 airports.

5. All ACFs will have 24 training positions and two monitoring and control positions, each of which will have a sector suite.

6. Total sector suites are determined by summing the positions identified in 1-5.

Table 2.3.4-1 shows the distribution of sector suites calculated for every ACF.

2.3.5 Number of Controlled and Uncontrolled Flights

IFR and VFR instantaneous track forecasts were determined in three parts: adjustment of the FAA forecasts for ARTCCs to include additional tracks for aircraft under approach control, reapportionment of the resultant ARTCC en route aircraft count to a comparable count for ACFs, and an apportionment of IFR en route aircraft to both high and low altitudes. The methodology used is described below:

1. Approach Control Aircraft During the Consolidation Period, the ACF will control approach airspace. Estimates of the level of approach control traffic for the Consolidation Period is described in Section L1 of Appendix L.

TABLE 2.3.4-1
SECTOR SUITE COUNT

ACFS	1995				2000				2010			
	A	B	C	D	E	F	G	H	I	J	K	L
	CONTROL POS	SUPERVISOR POSITIONS (A/6 +1)	METERING POSITIONS	TOTAL[1] (A+B+C+29)	CONTROL POSITIONS	SUPERVISOR POSITIONS (E/6 + 1)	METERING POSITIONS	TOTAL[1] (E+F+G+29)	CONTROL POSITIONS	SUPERVISOR POSITIONS (I/6+1)	METERING POSITIONS	TOTAL[1] (I+J+K+29)
Albuquerque	55	10	5	98	59	10	5	102	62	11	5	106
Atlanta	67	12	1	100	70	12	1	111	74	13	1	116
Boston	64	13	4	107	67	12	4	111	72	13	4	117
Chicago	58	10	3	99	60	11	3	102	65	11	3	107
Cleveland	74	13	15	130	80	14	15	137	87	15	15	145
Denver	70	12	11	121	73	13	11	125	77	13	11	129
Fort Worth	73	13	7	121	75	13	7	123	79	14	7	128
Houston	68	12	11	119	73	13	11	125	78	14	11	131
Indianapolis	50	9	7	94	52	9	7	96	53	9	7	97
Jacksonville	77	13	14	132	75	13	14	130	76	13	14	131
Kansas City	90	16	11	143	92	16	11	147	95	16	11	150
Los Angeles	45	8	2	82	48	9	2	87	50	9	2	89
Memphis	76	13	12	129	81	14	12	135	86	15	12	141
Miami	51	9	3	91	51	9	3	91	51	9	3	91
Minneapolis	79	16	8	129	87	15	8	130	95	16	8	147
NY/Boston(A)	29	5	12	74	27	5	12	72	27	5	12	72
New York (B)	63	11	5	107	63	11	5	107	67	12	5	112
Oakland	33	6	4	71	33	6	4	71	35	6	4	73
Salt Lake City	42	8	10	88	42	8	10	88	42	8	10	88
Seattle	71	12	5	116	75	13	5	121	79	14	5	126
Washington	80	24	5	127	82	14	5	129	84	15	5	132
Anchorage[2]	19	4	1	40	21	4	1	42	24	5	1	46
Honolulu[3]	19	4	3	36	19	4	3	36	19	4	3	36

1. Total also includes training (24), monitor and control console (2), CWSU (1), en route automation specialist (1), and special facility use (1) positions
2. Anchorage has only 6 training sectors.
3. Honolulu has only 2 training sectors.

IFR instantaneous track levels for the peak IFR hour of the peak IFR day (i.e., T_1) are forecasted by FAA for the ARTCCs for the year 1995[10]. Values of L_1, L_2 and $T_2 - T_1$ are listed for each ARTCC in the contiguous U.S. in Table L.1-1.

2. Apportionment of ARTCC Air Traffic to ACFs During the consolidation period, ACFs will provide control of aircraft in both en route and approach control sectors. The geographical coverage of the ACFs are shown in Figures 2-2 and 2-3 of the National Airspace System Level II Design[37]. Altitude coverage for the Type B ACFs was considered to range from ground level to 18,000 feet. The higher altitudes are covered by the Type A ACFs. The Type A ACFs cover all altitude levels where there is no Type B coverage.

Table 2.3.5-3 shows how aircraft from major airports in the ARTCCs were apportioned to each ACF. The apportionments were estimated by calculating the total operations rates from all the major airports located within each facility and determining the fraction these represent from each ARTCC. That is:

$$\text{Fractional apportionment of Approach Control Operations in ACF} = \frac{\text{Operations of ARTCC airports in ACF}}{\text{Operations of ARTCC airports}}$$

3. En route Aircraft Tables 2.3.5-1 and 2.3.5-2 show how ARTCC en route aircraft are apportioned to the high and low altitude strata in the ACFs. The apportionment is based both on estimates of area apportioned to each ACF from ARTCCs, and on an estimate of relative density of aircraft in each part of the ARTCC. For instance, in Table 2.3.5-1, the first entry for the Chicago ARTCC is an apportionment of 0.3 x 1.2 to the Cleveland ACF. The first term "0.3" is the fraction of ARTCC area apportioned to the Cleveland ACF. The second term "1.2" is a measure of the aircraft density in that area relative to the other areas in the Chicago ARTCC. A density of 1.0 is considered average.

4. Altitude Apportionment A total of 56% of all IFR en route aircraft and 0% of VFR aircraft operate at the high altitude levels (i.e., at flight levels above the control limits of Type B ACFs).

TABLE 2.3.5-1
APPORTIONMENT OF CENTER TO ACFS HIGH ALTITUDE AIRCRAFT DISTRIBUTION

Center	Code	Fraction	To	Fraction	To	Fraction	To	Fraction	To	Total	
Albuquerque	ZAB	0.5X1.0	ABQ	0.2X1.0	DEN	0.3X1.0	Hou			1.00	
Atlanta	ZTL	0.5X1.0	JAX	0.5x1.0	MEM					1.00	
Boston	ZBW	1.0X1.0	NY-A							1.00	
Chicago	ZAU	0.3X1.2	CLE	0.2X1.2	MKC	0.5X0.8	MSP			1.00	
Cleveland	ZOB	0.65X1.0	CLE	0.05X1.0	JAX	0.05X1.0	MSP	0.25X1.0	NY-A	1.00	
Denver	ZDV	0.1X1.2	ABQ	0.8X1.0	DEN	0.05X1.0	SLC	0.05X0.6	SEA	1.00	
Fort Worth	ZFW	0.85X1.0	HOU	0.15X1.0	MKC					1.00	
Houston	ZHU	0.8X1.0	HOU	0.1X1.0	MEM					1.00	
Indianapolis	ZID	0.8X1.0	CLE	0.1X1.0	JAX	0.1X1.0	MEM			1.00	
Jacksonville	ZJX	0.5X1.1	JAX	0.3X0.75	MEM	0.2X1.2	MIA			1.02	
Kansas City	ZKC	0.2X1.0	DEN	0.8X1.0	MKC					1.00	
Los Angeles	ZLA	0.5X1.0	ABQ	0.5X1.0	SLC					1.00	
Memphis	ZME	0.1X1.0	HOU	0.3X1.0	MKC	0.6X1.0	MEM			1.00	
Miami	ZMA	1.0X1.0	MIA							1.00	
Minneapolis	ZMP	0.1X1.5	MKC	0.9X0.95	MSP					1.01	
New York	ZNY	1.0X1.0	NY-A							1.00	
Oakland	ZOA	0.9X1.05	SLC	0.1X0.6	SEA					1.01	
Salt Lake City	ZLC	0.1X1.2	DEN	0.3X1.2	SLC	0.6X0.85	SEA			0.99	
Seattle	ZSE	1.0X1.0	SEA							1.00	
Washington	ZDC	1.0X1.0	JAX							1.00	

TABLE 2.3.5-2
APPORTIONMENT OF CENTERS TO ACFS
LOW ALTITUDE AIRCRAFT DISTRIBUTION

Center	Code	Fraction	To	Fraction	To	Fraction	To	Fraction	To	Fraction	To	Total
Albuquerque	ZAB	0.5X1.0	ABQ	0.45X1.0	DEN	0.05X1.0	HOU					1.00
Atlanta	ZTL	0.1X1.0	MEM	0.75X1.0	ATL	0.15X1.0	DCA					1.00
Boston	ZBW	1.0X1.0	BOS									1.00
Chicago	ZAU	0.2X1.0	MKC	0.25X0.4	MSP	0.5X1.3	CHI	0.05X1.0	IND			1.00
Cleveland	ZOB	0.65X1.0	CLE	0.05X1.0	MSP	0.1X1.0	BOS	0.15X1.0	NY-B	0.05X1.0	DCA	1.00
Denver	ZDV	0.1X1.2	ABQ	0.8X1.0	DEN	0.05X1.0	SLC	0.05X0.6	SEA			1.00
Fort Worth	ZFW	0.25X1.0	DEN	0.1X1.0	HOU	0.15X1.0	MKC	0.5X1.0	DFW			1.00
Houston	ZHU	0.65X1.0	HOU	0.1X1.0	MEM	0.25X1.0	DFW					1.00
Indianapolis	ZID	0.1X1.0	ATL	0.05X1.0	CHI	0.75X1.0	IND	0.1X1.0	DCA			1.00
Jacksonville	ZJX	0,45X1.1	JAX	0.3X0.7	MEM	0.15X1.2	MIA	0.1X1.2	ATL			1.01
Kansas City	ZKC	0.2X1.0	DEN	0.8X1.0	MKC							1.00
Los Angeles	ZLA	0.3X0.8	ABQ	0.5X0.8	SLC	0.2X1.8	LAX					1.00
Memphis	ZME	03X1.0	MKC	0.5X1.0	MEM	0.1X1.0	ATL	0.1X1.0	DFW			1.00
Miami	ZMA	1.0X1.0	MIA									1.00
Minneapolis	ZMP	0.1X1.5	MKC	0.9X0.95	MSP							1.01
New York	ZNY	1.15X1.0	BOS	0.85X1.0	NY-B							1.00
Oakland	ZOA	0.6X0.8	SLC	0.1X0.6	SEA	0.3X1.5	OAK					0.99
Salt Lake City	ZLC	0.1X1.2	DEN	0.3X1.2	SLC	0.6X0.85	SEA					0.99
Seattle	ZSE	1.0X1.0	SEA									1.00
Washington	ZDC	1.0X1.0	DCA									1.00

TABLE 2.3.5-3
APPORTIONMENT OF CENTERS TO ACFs
APPROACH CONTROL DISTRIBUTION

Center	Code	Fraction	To	Fraction	To	Fraction	To	Fraction	To	Total
Albuquerque	ZAB	0.84	ABQ	0.1.6	DEN					1.00
Atlanta	ZTL	0.85	ATL	0.15	DCA					1.00
Boston	ZBW	1.00	BOS							1.00
Chicago	ZAU	0.15	MSP	0.79	CHI	0.06	IND			1.00
Cleveland	ZOB	0.79	CLE	0.19	BOS	0.02	DCA			1.00
Denver	ZDV	1.00	DEN							1.00
Fort Worth	ZFW	0.12	DEN	0.26	MKC	0.62	DFW			1.00
Houston	ZHU	0.51	HOU	0.097	MEM	0.40	DFW			1.00
Indianapolis	ZID	0.01	CHI	0.90	IND	0.09	DCA			1.00
Jacksonville	ZJX	0.56	JAX	0.35	MEM	0.06	ATL	0.036	DCA	1.00
Kansas City	ZKC	1.00	MKC							1.00
Los Angeles	ZLA	0.15	ABQ	0.08	SLC	0.75	LAX	0.02	OAK	1.00
Memphis	ZME	0.24	MKC	0.67	MEM	0.09	ATL			1.00
Miami	ZMA	0.49	JAX	0.51	MIA					1.00
Minneapolis	ZMP	1.00	MSP							1.00
New York	ZNY	0.15	BOS	0.85	NY-B					1.00
Oakland	ZOA	0.18	SLC	0.82	OAK					1.00
Salt Lake City	ZLC	0.51	SLC	0.49	SEA					1.00
Seattle	ZSE	1.00	SEA							1.00
Washington	ZDC	1.00	DCA							1.00

2.3.6 Target Report Rate

This parameter is expressed in radar target reports/second. No allowance for primary or beacon noise returns has been made. This section describes the calculation process in three steps:

1. Calculate the target report message rate for the ACF controlled airspace only.

2. Calculate the additional target reports received from airspace outside the control airspace.

3. Combine the values and adjust for "Prepare for Back-up" and "Handle Back-up".

These three steps are described in Sections 2.3.6.1, 2.3.6.2, and 2.3.6.3 below.

2.3.6.1 ACF Controlled Airspace

The target report message rate comprises the following five components:

A_i	Instantaneous Flight Count

A_1	Controlled (IFR)
A_2	Uncontrolled (VFR)

B_j	Flight Life Distribution

B_1	Proportion in en route airspace
B_2	Proportion in terminal airspace

C_{km}	Radar Scan Rate

$C_{1,1}$	ATCRBS long range
$C_{2,1}$	Mode-S long range
$C_{1,2}$	ATCRBS short range
$C_{2,2}$	Mode-S short range

D_{km}	Radar Distribution

$D_{1,1}$	ATCRBS long range/total long range
$D_{2,1}$	Mode-S long range/total long range
$D_{1,2}$	ATCRBS short range/total short range
$D_{2,2}$	Mode-S short range/total short range

E_{ijm} Radar Coverage

$E_{1,1,1}$ IFR traffic, en route airspace, long range radars
$E_{1,1,2}$ IFR traffic, en route airspace, short range radars
$E_{2,1,1}$ VFR traffic, en route airspace, long range radars
$E_{2,1,2}$ VFR traffic, en route airspace, short range radars
$E_{1,2,1}$ IFR traffic, terminal airspace, long range radars

$E_{1,2,2}$ IFR traffic, terminal airspace, short range radars
$E_{2,2,2}$ VFR traffic, terminal airspace, long range radars
$E_{2,2,2}$ VFR traffic, terminal airspace, short range radars

The equation,

$$A_i \; B_j \; C_{km} \; D_{km} \; E_{ijm},$$

$i=1,2$
$j=1,2$
$k=1,2$
$m=1,2$

where:

- i indexes flight count for IFR(1) and VFR(2)
- j indexes airspace for en route(1) and terminal(2)
- k indexes radar type for ATCRBS(1) and terminal(2)
- m indexes radar range for long range(1) and short range(2),

is summed to produce the target report arrival rate for the airspace controlled by each ACF.

A description of the components (A,B,C,D,E) with respect to units and values follows:

A - This is a measure of the number of flights within controlled airspace (not in back-up airspace) expressed as an instantaneous count. Values for controlled and uncontrolled flights for the years 1995, 2000, and 2010 are found in Volume I, Table 2-8.

B - Radar coverage for flights in terminal airspace is different from that for flights in en route airspace. The factor, 0.7, is used to modify radar target report rate to reflect the average time (70%) that a flight spends in en route airspace. An average of 30% of flight life is spent in terminal airspace.

C – The scan rate of radars varies with two variables. One of the variables is type of radar. Scan rate (in seconds/scan) is 5 for all Mode-S radars and for short range ATCRBS radars. The scan rate is 10 seconds/scan for long range ATCRBS radars and all primary radars.

D – The distribution of radars among ATCRBS and Mode-S, long and short range, is a device to weight radar scan rate. It is calculated for every ACF from the list of radars (located both inside and outside of the ACF) reporting to the ACF (Table 2.3.6-1).

E – Radar coverage is a parameter measured in target reports/flight/scan. It has been determined for en route and terminal airspace, long and short range radars and IFR and VFR flights. See Table 2.3.6-2. This parameter is the source of target report information; all other variables and factors serve to modify it. An explanation of the computational approach for radar coverage may be found in Appendix I.

The equation used to determine target report message rate requires the calculation and summation of 16 values. The calculation for one such value is illustrated in Figure 2.3.6-1.

2.3.6.2 Target Reports from Non-Controlled Airspace

Because many radars must report to more than one ACF, target reports are received from non-controlled airspace. The following three situations require the initial value for target report arrival rate to be increased:

1. For ACF Type A facilities with airspace above ACF Type B facilities, additional target reports come from radars sensing traffic in the Type B airspace and sending reports to the Type A.

2. For those Type B facilities, all of which are located below Type A's, additional target reports come from radars sensing traffic in the Type A airspace located directly above the Type B.

3. Because there are radar sites located in close proximity and on both sides of the ACF (horizontal) boundaries, reports are sent to the ACF of interest from targets outside the boundaries.

TABLE 2.3.6-1
DISTRIBUTION OF BEACON RADAR TYPES (ATCRBS & MODE-S) FOR THOSE RADARS COVERING CONTROLLED AIRSPACE DURING "PREPARE FOR BACK-UP"

ACF	LONG RANGE		SHORT RANGE	
	% ATCRBS	% MODE-S	% ATCRBS	% MODE-S
Albuquerque	45	55	33	67
Atlanta	100	0	53	47
Boston	50	50	47	53
Chicago	83	17	50	50
Cleveland	91	9	67	33
Denver	45	55	60	40
Fort Worth	90	10	35	65
Houston	78	22	50	50
Indianapolis	100	0	20	80
Jacksonville	93	7	56	44
Kansas City	87	13	29	71
Los Angeles	25	75	11	89
Memphis	89	11	54	46
Miami	83	17	63	37
Minneapolis	42	58	44	56
New York (A)	54	46	0	0
New York (B)	63	37	45	55
Oakland	0	100	25	75
Salt Lake City	13	87	50	50
Seattle	39	61	50	50
Washington	88	12	19	81

TABLE 2.3.6-2
RADAR COVERAGE

ACF *	EN ROUTE AIRSPACE				TERMINAL AIRSPACE	
	IFR AIRCRAFT		VFR AIRCRAFT		ALL AIRCRAFT	
	LONG RANGE	SHORT RANGE	LONG RANGE	SHORT RANGE	LONG RANGE	SHORT RANGE
Albuquerque	2.95	0.38	1.03	0.16	1.12	1.00
Atlanta	0.95	1.69	0.54	0.82	0.54	1.34
Boston	2.13	1.81	1.02	0.79	1.07	1.72
Chicago	2.07	2.03	0.94	0.82	1.18	2.00
Cleveland	5.11	1.40	1.49	1.04	1.63	1.98
Denver	3.16	0.27	1.05	0.14	1.11	1.26
Fort Worth	1.27	1.41	0.77	0.64	0.51	1.46
Houston	3.18	0.37	0.89	0.32	0.51	1.25
Indianapolis	1.64	1.93	0.81	0.81	0.79	1.35
Jacksonville	3.24	0.44	0.91	0.76	0.95	1.33
Kansas City	3.73	1.40	1.09	0.54	0.91	1.25
Los Angeles	1.58	4.08	0.86	1.71	1.13	3.74
Memphis	2.53	1.11	0.90	0.59	0.66	1.36
Miami	2.72	2.05	1.01	0.71	0.82	1.59
Minneapolis	2.93	0.84	0.87	0.36	0.85	1.22
New York (A)	5.43	0.00	0.00	0.00	0.00	0.00
New York (B)	2.84	2.42	1.33	0.97	1.30	2.87
Oakland	1.19	2.25	0.61	0.92	0.63	1.95
Salt Lake City	3.04	0.21	0.99	0.08	1.29	1.00
Seattle	3.27	0.58	1.07	0.30	0.85	1.38
Washington	1.82	2.29	0.92	1.01	0.84	1.99

*Because traffic forecasts for Anchorage and Honolulu were not available, radar coverage was not calculated.

CONDITIONS

$A_1 = 1000$

$B_1 = 0.7$

$C_{11} = 0.1$ scans/second (10 seconds/scan)

$D_{11} = 0.6$

$E_{111} = 4.0$

CALCULATION

1000	Instantaneous IFR flights
x 0.6	Proportion of ATCRBS long range radars to all long range radars
600	IFR flights sensed by ATCRBS long range radars
x .7	Proportion of en route flight life to total flight life
420	En route portions of IFR flights sensed by ATCRBS long range radars
x 4.0	Target reports/scan/IFR flight in en route airspace sensed by long range radars
1680	Number of long range radar target reports/scan for IFR flights in en route airspace
x 0.1	ATCRBS long range radar scan rate in scans/second
168	Number of long range ATCRBS radar target reports/sec for IFR flights in en route airspace

FIGURE 2.3.6-1
SAMPLE CALCULATION OF TARGET REPORT MESSAGE RATE
FOR ONE CONDITION – I, J, K, M = 1

2.3.6.2.1 Type A Facilities

The target report message rate of an ACF-A is increased by a fraction of the message rate from those long range radars reporting to the vertically adjacent ACF-B. This fraction has been estimated (Table 2.3.6-3) and should be applied to the ACF-B target report rate represented by the following equation:

$$\sum_{\substack{i=1,2\\ j=1,2\\ k=1,2\\ m=1,2}} A_i \, B_j \, C_{km} \, D_{km} \, E_{ijm},$$

2.3.6.2.2 Type B Facilities

The target report arrival rate of an ACF-B is increased by a fraction of the message rate from those long range radars reporting to the altitudinally adjacent ACF-A. This fraction has been estimated (Table 2.3.6-4)

This fraction has been estimated (Table 2.3.6-4) by considering the area of the ACF A that overlaps the ACF B and the probable distribution of aircraft in the ACF A airspace.

2.3.6.2.3 Radar Coverage Outside ACF Boundaries

It has been assumed that all radars reporting to an ACF will have no masking applied at the site to eliminate coverage of airspace not controlled by the ACF. Accordingly, a source of radar target reports from outside the ACF boundaries has been determined.

The basis for evaluating the radar coverage outside an ACF attributable to a single radar is a formula which evaluates the average radar coverage at a given (x,y) point, by considering the aircraft altitude distribution (per Volume I), the horizon/line-of-sight phenomenon, and the distance from the radar. The formula is as follows:

$$^{*}\text{Coverage} = 1.4231077 - 0.2184681 \sqrt{\text{alt}}$$

where alt is the minimum altitude at which an aircraft can be surveilled, in thousands of feet.

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*Taken from Appendix I.

TABLE 2.3.6-3
FRACTION OF RADAR MESSAGES FOR AIRCRAFT IN TYPE B FACILITY AIRSPACE WHICH ARE SENT TO THE TYPE A FACILITIES ABOVE

Type A Facilities	Facilities Adjacent in Altitude									
	Atlanta	Boston	Chicago	Denver	Fort Worth	Ind.	Los Angeles	New York(B)	Oakland	Wash.
Albuquerque							100%			
Cleveland			50%			100%				
Houston				35%	100%					
Jacksonville	50%									100%
Memphis	50%									
Minneapolis			50%							
New York(A)		100%						100%		
Salt Lake City									100%	

TABLE 2.3.6-4
FRACTION OF RADAR MESSAGES FOR AIRCRAFT IN TYPE A FACILITY AIRSPACE WHICH ARE SENT TO THE TYPE B FACILITIES BELOW

Type B Facilities	Facilites Adjacent in Altitude							
	Albuqu.	Cleveland	Houston	Jackson	Memphis	Minn.	New York(A)	Salt Lake City
Atlanta				26%	35%			
Boston							60%	
Chicago		25%				15%		
*Denver			25%					
Fort Worth			50%					
Indianapolis		35%						
Los Angeles	20%							
New York(B)							40%	
Oakland								25%
Washington				50%				

*Denver is not a "B" facility, but handles the low altitude aircraft in airspace vertically-adjacent to Houston ACF airspace.

The relation for converting the above to a distance formula is the familiar relation[38] between height and distance for surveillance:

$$D = 1.23 \sqrt{(h)}$$

where: D = ground distance in nmi
h = lowest altitude (in feet) at which an aircraft can be seen

To convert the coverage equation to be a function of distance from the radar rather than minimum altitude for surveillance, it is necessary to state alt in terms of D. The relation of h and alt is:

$$alt = h/1000.$$

Substitution and algebra yield:

$$alt = h/1000; \quad h = (D/1.23)^2$$

$$\begin{aligned} alt &= (D/1.23)^2/1000 \\ &= D^2/(1.23^2 \times 1000) \\ &= D^2/1512.9 \end{aligned}$$

$$\begin{aligned} \therefore \quad \text{Radar coverage} &= 1.4231077 - 0.2184682 \times \sqrt{D^2/1512.9} \\ &= 1.4231077 - 0.2184682 \times D/38.9 \\ &= 1.4231077 - 0.0056161 \times D \end{aligned}$$

Using this equation, the radar coverage for an area outside an ACF could be assessed in several ways. For example, a random sampling scheme could select points in the outside area, evaluate the coverage at each point, and then calculate an average coverage for the points. Another method would be to assess the coverage at all points using calculus. That is, the coverage for a contour with constant coverage could be assessed, and the coverage for the set of all contours could be summed using integration. The latter technique is used for this analysis and is further explained below.

The contours with constant coverage are arcs centered at the radar for the case of the radar located within the ACF boundary, and either arcs or circles for the case of the radar located outside the ACF boundary. These two cases of radar location inside or outside the ACF boundary represent two distinct cases for this mathematical approach to coverage assessment.

Given a distance from the radar, a contour with constant coverage is generated as the set of points equi-distant to the radar. (These contours are arcs or circles.) The length of the contour is evaluated using geometry and multiplied by the appropriate coverage. This product is evaluated for the set of all contours using integration. The horizontal area is then divided out to find the average coverage for the area. Equations for the two cases are given below.

For a radar located within ACF boundaries (see Figure 2.3.6.2.3-1), outside coverage is as follows:

Average Coverage of Outside
Area with Radar Located
Within ACF Boundary $= ({}_d\int^{200} g(x)dx)/\text{horizontal Area}$

where: d = distance from radar site to facility boundary in nmi.

$g(x) = f(x)s(x)$

$f(x) =$ radar coverage, i.e., proportion aircraft seen (0.0 to 1.0) at a distance of x nmi from the radar

$= \max(0., \min(1., 1.4231077 - 0.0056161x))$

(the max and min operations simply bound the result between 0. and 1.0)

$s(x) =$ length of arc S subtended by chord b, given radius x and distance d to boundary (see Figure 2.3.6.2.3-1)

$$= \pi x \sin^{-1} \frac{b}{2x} /90$$

where,

$$b = 2\sqrt{(x^2 - d^2)}$$

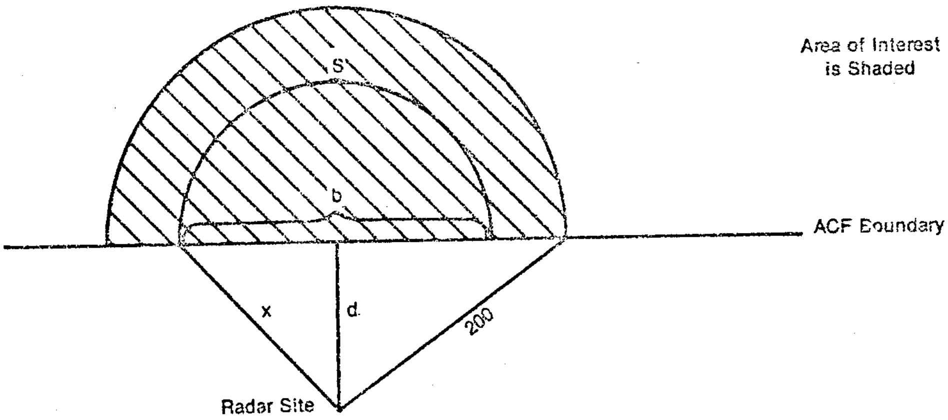

FIGURE 2.3.6.2.3-1
OUTSIDE-ACF COVERAGE FOR RADAR SITE INSIDE ACF BOUNDARY

For the case of a radar located outside the ACF boundaries (see Figure 2.3.6.2.3-2), outside coverage is:

$$\text{Average Coverage of Outside Area with Radar Located Outside ACF Boundary} = \Big(\big({}_0\!\int^{d} g(x)dx/\text{area\_1}\big) * \text{volume\_1}\big) + \big({}_d\!\int^{200} g(x)dx/\text{area\_2}\big) * \text{volume\_2}\big)\Big) / (\text{volume\_1} + \text{volume\_2})$$

where f(x) is function definition as before

$$\text{and } s(x) = \begin{cases} d < x < 200\text{:}\ 2\pi x - x\pi \sin^{-1}\left(\frac{b}{2x}\right)/90 \\ \quad \text{where b is the chord length } 2 * \sqrt{(x^2 - d^2)} \\ x < d\text{:}\ 2\pi x \text{ (entire circumference)} \end{cases}$$

In this case, two areas had to be evaluated separately, since the standard arc length equation:

$$s(x) = \pi x \sin^{-1}\left(\frac{b}{2x}\right)/90$$

only holds for arcs equal to less than half a circle. For $x = 0$ to d (see Figure 2.3.6.2.3-2) the iso-coverage contours are circles centered at the radar site. For $x = d$ to 200, the iso-coverage contours are arcs greater than one half a circle.

2.3.6.3 Final Calculation and Adjustment

The target report message rate for "prepare for back-up" and "handle back-up" is calculated by adding the message rate for controlled airspace (2.3.6.1) plus the additional message rate for radars reporting traffic in non-controlled airspace immediately above or below the ACF (2.3.6.2.1 or 2.3.6.2.2). This sum is doubled for "prepare for back-up" and added to the message rate from coverage outside the boundaries (2.3.6.2.3). For "Handle Back-up," the same procedures are followed with one exception: multiply by 1.3 instead of doubling.

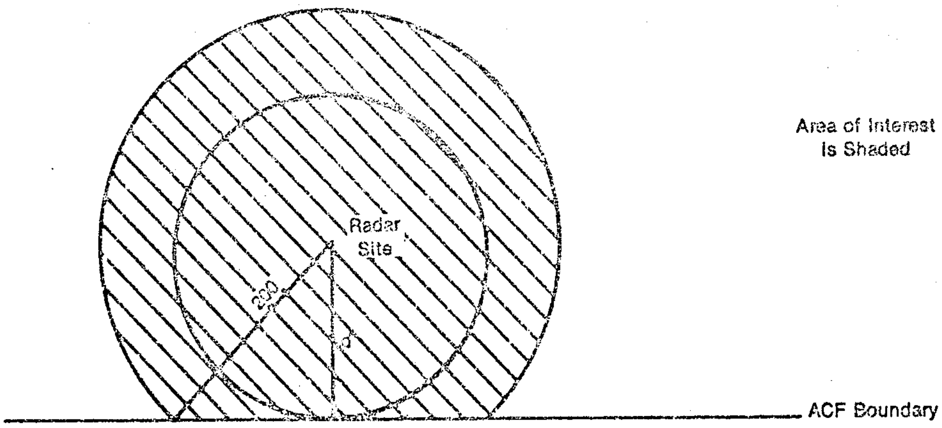

FIGURE 2.3.6.2.3-2
OUTSIDE-ACF COVERAGE FOR RADAR SITE OUTSIDE ACF BOUNDARY

2.4 Facility Back-up Calculation

In order to explain the implications of facility back-up to flight life, flight type, and sectors penetrated, a simple analytical model was constructed. The model assumes that adjacent ACF airspace equal to 30% of the maximum stress ACF in size and traffic load must also be controlled during back-up mode.

To simplify analysis, the disposition of 1000 flights controlled by ACF 1 was evaluated as well as the number of flights entering and/or leaving the back-up airspace within ACF 2. Assumptions made about flight life and sectors penetrated in the back-up airspace allowed conclusions to be drawn about total average flight life and average sectors penetrated during back-up.

2.4.1 Flight Distribution During Back-up

Since there are four potential back-up areas, the common boundary between ACF 1 and the back-up airspace (30% of ACF 2) is assumed to represent 25% of ACF 1's perimeter. It was assumed that 25% of all ACF 1 departures leave one side of the facility and enter the back-up area (formerly ACF 2). It is also assumed that 25% of ACF 1's arrivals crossed the former boundary from ACF 2. Because Overflights can move in both directions, 50% of all Overflights cross the boundary. It was assumed that 100% of all Withins stay within ACF 1.

Using the flight type and life parameter values for the 1995-2010 period, the distribution of ACF 1's 1000 flights was determined. Table 2.4.1-1 identifies those flights that crossed the boundary of ACF 2 (the back-up airspace). Also identified is the flight type of all boundary crossing flights, from the perspective of ACF 1 (Column F) and ACF 2 (Column G).

Using a similar calculation, the number and distribution of flights in the back-up airspace was determined (Table 2.4.1-2). The flight type distribution was altered by assuming that 30% of normal airspace would contain only 10% of the "within" flights, not the maximum stress value of 22%. Accordingly, the values for the other three types were increased.

TABLE 2.4.1-1
ACF 1 FLIGHT DISTRIBUTION

	A	B	C	D	E	F	G		
FLIGHT TYPE	%	INSTAN- TANEOUS FLIGHTS (IAC* x A)	FLIGHT LIFE (MINUTES)	FLIGHTS/ HOUR (B x 60/C)	% OF FLIGHTS CROSSING BACKUP BOUNDARY	BOUNDARY CROSSING FLIGHTS (D x E)	ORIGIN TYPE	%	NON-BOUNDARY CROSSING FLIGHTS (D – F)
ARRIVAL	20	118.1	39	181.6	25%	45	departure overflight	23 23	136
DEPARTURE	24	141.7	31	274.2	25%	69	arrival overflight	34 34	206
OVERFLIGHT	34	200.7	35	344.1	50%	172	arrival departure overflight	15 18 139	172
WITHIN	22	129.9	39	199.8	0%	0			200
		590.3		1000		286			714

* A FLIGHT RATE OF 1000/HOUR = 1000 x 35 MINUTES(/FLIGHT) / 60 MINUTES = 590 INSTANTANEOUS FLIGHTS

TABLE 2.4.1-2
FLIGHT DISTRIBUTION IN BACK-UP AIRSPACE

	A	B	C	D	E	F
FLIGHT TYPE	%*	INSTAN-TANEOUS FLIGHTS (IAC** x A)	FLIGHT LIFE (MINUTES) (***)	FLIGHTS/ HOUR (B x 60/C)	BOUNDARY CROSSING FLIGHTS	NON-BOUNDARY CROSSING FLIGHTS (D - E)
ARRIVAL	23	40.7	19.5	125.3	49	76
DEPARTURE	27	47.8	15.5	185.0	41	144
OVERFLIGHT	40	70.8	17.5	242.7	196	47
WITHIN	10	17.7	19.5	54.5	0	54
		177		607	236	321

* ASSUME 10% WITHINS; DISTRIBUTE REMAINING 12% TO OVERFLIGHTS (50%), ARRIVALS (25%), DEPARTURES (25%).

** ASSUME BACKUP AREA WITH 30% OF 590 INSTANTANEOUS CONTROLLED FLIGHTS

***ASSUME 50% OF MAXIMUM STRESS FLIGHT LIFE

The number of flights/hour was calculated by assuming that the instantaneous flight count was 30% of 590, the ACF 1 value, and flight life in the back-up airspace was 50% of maximum stress value. Subtracting boundary crossing flights (Column E) identified in Table 2.4.1-1, the number and type of non-boundary crossing flights were calculated (Column F).

2.4.2 Calculate "Handle Back-up" Values for Flight Life and Sectors Penetrated

Table 2.4.2-1 is composed of three sections: section 1 comprises Columns A-D and presents information about those flights using ACF 1 airspace; included are the number, type, life (within ACF 1), and sectors penetrated (within ACF 1) of all those flights using ACF 1 airspace. Section 2 (Columns E-J) presents similar information for those flights using the back-up airspace. The last columns, K-P, represent combined airspaces and calculate the combined values to represent the "Handle Back-up" situation.

In lieu of information about back-up and because of the need to "typify", many assumptions were made to build this table. Typical values were assumed for sectors penetrated, Column D; the average, weighted by flight type, is equal to the maximum stress value (Parameter 15). "Flight Life in Back-up Airspace" (Column H) was estimated by drawing candidate airspace boundaries and assuming uniform distribution of arrivals, departures, and overflights. "Sectors Penetrated" was similarly estimated in Column J. Shown below is the final distribution for flight type during "Handle Back-up":

TYPE	%
Arrival	19
Departure	30
Overflight	27
Within	24

Note that the calculated values for the parameters, Flight Life, Sectors Penetrated, and Flight Type are, by various degrees, different than those reported in the current version of Volume I. This arose from two sources: Flight Life and Sectors Penetrated are conservative interpretations of the calculated values; the values for Flight Type were calculated after other parameter values had been determined on the basis of previous estimates. Since the difference between calculated and reported values are relatively small and since the back-up model incorporated some rather arbitrary assumptions, it was not felt necessary to report the precise calculated values.

TABLE 2.4.2-1
CALCULATION OF FLIGHT LIFE AND SECTORS PENETRATED DURING FACILITY BACK-UP

ACF 1				BACKUP AIRSPACE						ACF 1 (INCLUDING BACKUP)					
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
FLIGHT TYPE*	NO. OF FLIGHTS	FLIGHT LIFE (MINUTES)	SECTORS PENET'D	FLIGHT TYPE*	NO. OF FLIGHTS	MAXIMUM STRESS FLIGHT LIFE (MINUTES)	% FLIGHT LIFE IN BACKUP AIRSPACE	FLIGHT LIFE (MINUTES) (G x H)	SECTORS PENET'D	FLIGHT TYPE*	NO. OF FLIGHTS (F)	FLIGHT LIFE (MINUTES) (G x I)	WEIGHTED FLIGHT LIFE (MINUTES) (L x M/SUM L)	SECTORS PENET'D (D + J)	WEIGHTED SECTORS PENET'D (L x O/SUM L)
A	45	39	4.4	D	23	31	30%	9.3	1.5	W	23	48.3	0.84	5.9	0.10
				O	23	35	50%	17.5	2.0	A	23	56.5	0.98	6.4	0.11
D	69	31	3.5	A	34	39	30%	11.7	1.5	W	34	42.7	1.10	5.0	0.13
				O	34	35	50%	17.5	2.0	D	34	48.5	1.25	5.5	0.14
O	172	35	3.7	A	15	39	30%	11.7	1.5	A	15	46.7	0.53	5.2	0.06
				D	18	31	30%	9.3	1.5	D	18	44.3	0.60	5.2	0.07
				O	139	35	50%	17.5	2.0	O	139	52.5	5.52	5.7	0.80
A	136	39	4.4							A	136	39.0	4.02	4.4	0.45
D	206	31	3.5							D	205	31.0	4.83	3.5	0.55
O	172	35	3.7							O	172	35.0	4.56	3.7	0.48
W	200	39	4.7							W	200	39.0	5.90	4.7	0.71
				A	76	39	67%	26.1	2.95	A	76	26.1	1.50	2.948	0.17
				D	144	31	67%	20.8	2.35	D	144	20.8	2.26	2.345	0.26
				O	47	35	50%	17.5	1.85	O	47	17.5	0.62	1.85	0.07
				W	54	39	100%	39.0	4.70	W	54	39.0	1.59	4.70	0.19
	1000				607						1321		36.13		4.69

* A = ARRIVAL
D = DEPARTURE
O = OVERFLIGHT
W = WITHIN

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APPENDIX A

WORKLOAD PARAMETER DESCRIPTIONS

Detailed descriptions of each parameter used in the National Airspace System (NAS) Air Traffic Control computer workload definition are provided in Appendix A. Further comments are provided, where needed, to clearify the composition of the workload parameters. For the convenience of the reader, message designator symbols as used in NAS are given in parentheses following message names under parameter number 27. No implications regarding future design or implementation are intended by this association.

TABLE A-1
WORKLOAD PARAMETER DESCRIPTIONS

PARAMETER	DESCRIPTION	COMMENTS
1.0 Flight Plan Load		
1.1 Active Flight Plans/Track	Total actual number of flight plans in the system at peak instant divided by the instantaneous track load.	
1.2 Total Flight Plans/Track		
2.0 Peak Aircraft Track Load		
2.1 Facility Peak Aircraft Track Load	Total number of controlled and uncontrolled aircraft tracks in the system at peak instant. This value does not include those tracks from aircraft outside of the ACP but within coverage of radars reporting to the ACP.	Not all airborne aircraft are tracked. Also, occasionally, there may be duplicate target trails due to reflections, multipath returns, etc.
2.1.1 Controlled Tracks		
2.1.2 Uncontrolled Tracks		
2.1.3 Total Aircraft Track Load		
2.2 Sector Peak Aircraft Track Load		
2.2.1 Controlled Tracks	Number of tracks under the control of the air traffic controller of a specific sector.	
2.2.2 Total Aircraft Track Load	Total track load, both controlled and uncontrolled tracks, within the boundaries of a specific sector.	
3.0 Number of Surveillance Sites		
3.1 Facility-wide	The total number of radar sites providing surveillance data to the facility computer system.	
3.1.1 Short Range Radar		
3.1.2 Long Range Radar		
3.2 Sector	The total number of radar sites providing surveillance data to a given sector.	
3.2.1 Short Range Radar		
3.2.2 Long Range Radar		
3.3 Sector + 150 nmi Beyond Boundary	Like 3.2, but area expanded to 150 nmi beyond sector boundary.	
3.3.1 Short Range Radar		
3.3.2 Long Range Radar		
4.0 Primary Noise		
4.1 Long Range Radars	The average number of false primary targets presented to the system by each radar. A false primary target is one not attributable to an aircraft.	A high weather-cell concentration affecting 75% of all radars is the primary noise scenario. The remaining 25% of all radars are then experiencing a normal noise rate.
4.2 Short Range Radars		

TABLE A-1
WORKLOAD PARAMETER DESCRIPTIONS
(CONTINUED)

PARAMETER	DESCRIPTION	COMMENTS
5.0 Transponder Equipage 5.1 Percentage Controlled Aircraft Equipped with: 5.1.1 ATCRBS Mode A Only 5.1.2 ATCRBS Mode C 5.1.3 Mode S 5.1.4 No Transponder 5.2 Percentage Uncontrolled Aircraft Equipped with: 5.2.1 ATCRBS Mode A Only 5.2.2 ATCRBS Mode C 5.2.3 Mode S 5.2.4 No Transponder	The proportion of aircraft population detected by ATC radars (controlled and uncontrolled) with on-board transponder equippage of either Mode S, Mode C, Mode A only, or no transponder.	
6.0 Flight Filing Status 6.1 Route Distribution (%) 6.1.1 Direct Route Only 6.1.2 Adapted Route Only 6.1.3 Directed Route & Adapted Route	The route initially filed by a flight plan.	The units for parameters under 6.1 are "flights as a percent of all flights."
6.2 Route Segment Count 6.2.1 Direct Route Segment Only 6.2.2 Adapted Route Segment Only 6.2.3 Direct Route & Adapted Route Segments		The units for parameters under 6.2 are "number of segments per route."
7.0 VFR/IFR Target Ratio	The ratio of VFR to IFR surveilled targets, with normalization for multiplicity of radar coverage. Airspace considered is entire surveillance volume associated with the facility.	Each surveilled aircraft is counted once per radar scan; duplicate returns are not counted.
8.0 Altitude Distribution 8.1 Percent of IFR aircraft at the following altitude intervals: 8.1.1 0 - 6,000 ft MSL 8.1.2 6,000 - 12,500 ft MSL 8.1.3 12,500 - 18,000 ft MSL 8.1.4 Above 18,000 ft MSL	The percentage of aircraft (IFR and VFR) at various altitude strata.	

TABLE A-1
WORKLOAD PARAMETER DESCRIPTIONS
(CONTINUED)

PARAMETER	DESCRIPTION	COMMENTS
8.2 % of VFR aircraft at the following altitude intervals:		
8.2.1 0 - 6,000' MSL		
8.2.2 6,000 - 8,000' MSL		
8.2.3 8,000 - 12,000' MSL		
9.0 Speed Distribution Percent of IFR aircraft at the following speed intervals:	The percentage of IFR aircraft at various speed intervals.	This parameter is for scenario design only.
9.1 Under 250 knots		
9.2 250 - 400 knots		
9.3 400 - 600 knots		
9.4 Over 600 knots		
10.0 Flight Life		
10.1 Controlled Track Life (Minutes)	The time during which a flight is controlled and tracked at a given facility.	Parameter 10.1 is the average over the values of Parameter 20.0. Parameter 10.2 is for scenario design purposes only.
10.2 VFR Facility Flight Life (Minutes)		
10.3 Active FP Life (Minutes)		
10.4 Total FP Life (Minutes)	Total FP Life includes Active and Pending FP life	
11.0 Flight Type Distribution (Percentages)	The distribution of controlled aircraft among the four flight types.	
11.1 Arrivals		
11.2 Departures		
11.3 Overflights		
11.4 Withins		
12.0 Flight Generation Process	Average number of new flights initiated over a given period of time. For each flight type, initiation is defined as the beginning of track life.	This parameter is for scenario design only.

TABLE A-1
WORKLOAD PARAMETER DESCRIPTIONS
(CONTINUED)

PARAMETER	DESCRIPTION	COMMENTS
13.0 Airport Operations		
13.1 Distribution to Approach Controlled Airports		
13.1.1 ARTS Arrival	% of all Arrival (and Within) flights arriving at ARTS-equipped approach control facilities.	
13.1.2 ARTS Departure	Similar to 13.1.1 for Departure (and Within) flights.	
13.1.3 ARTS Overflight	% of all flights overflying ARTS controlled airspace.	
13.2 Coded Arrival and Departure Routes		
13.2.1 Departures	% of all Departure (and Withins) using coded routes.	
13.2.1.1 PDR		
13.2.1.2 PDAR		
13.2.1.3 SID		
13.2.2 Arrivals	% of all Arrivals (and Withins) using coded routes.	
13.2.2.1 PAR		
13.2.2.2 PDAR		
13.2.2.3 STAR		
14.0 Metering Arrival Rate, Arrivals/Hr	Total Flights Eligible for Automated Metering.	
14.1 Peak Airport Arrival Rate	Parameter 14.1 is the peak number of arrival flights/hour at an airport eligible for metering.	
14.2 Facility Arrival Rate	Parameter 14.2 is the number of arrival flights/hour at a facility eligible for metering.	
15.0 Sectors Penetrated/Flight	Average number of sectors penetrated by a flight.	Includes approach sectors during consolidation period.
16.0 Control Length 16.1 Facility Control Length 16.2 Sector Control Length	Average distance (nmi) traversed by a flight within the facility or a sector.	Related to other parameters: speed distribution, flight life, sectors per flight.

TABLE A-1
WORKLOAD PARAMETER DESCRIPTIONS
(CONTINUED)

	PARAMETER	DESCRIPTION	COMMENTS
17.0	Trajectories in Conflict (Conflicts/Minute)	Rate at which flight trajectories are in conflict (as declared by conflict probe).	Affected by traffic density, mix of direct routes, etc. Direct routes may be expected to increase over time.
18.0	CTA Updates per Flight	Expected frequency of CTA updates (computed time of arrival) per flight. In AERA, the analogous measure is resynchronizations per flight.	
18.1	Updates/Flight (Automatic)		
18.2	Resynchronizations/ Flight(Automatic)		
19.0	Special Use Airspace		
19.1	Number of Special Use Airspace Blocks	Average number of special use airspace blocks (static and dynamic) active at one time.	
19.2	Probability of Airspace Conflict, Percentage	Probability of a profile penetrating a special use airspace block.	
20.0	Average Track Life in Minutes for the following types:	The average life of a track in the system for each of the four flight types.	
20.1	Arrivals		
20.2	Departures		
20.3	Overflights		
20.4	Withins		
21.0	Probability of Flight Trajectory Conflict (percentage) due to:	Probability that an event which incurs a conflict probe results in a conflict. Such events are:	
21.1	Longitudinal Deviation	An aircraft returns to conformance after a longitudinal deviation.	
21.2	Return to Conformance	Same as above, only in the x-y-z dimension.	
21.3	Filed Plan Activation	A filed flight plan is activated.	
21.4	Requested Flight Plan checking	Trial flight plan before activation.	
21.5	Request for Metering	Assignment of a fix time or arrival time to a metered aircraft.	
21.6	Controller request (Trial Plan Probe)	A trial flight plan before an amendment.	

TABLE A-1
WORKLOAD PARAMETER DESCRIPTIONS
(CONTINUED)

	PARAMETER	DESCRIPTION	COMMENTS
22.0	Conflict Alert Frequency	The alert frequency of the Conflict Alert Function.	The criterion for counting conflict pairs with time gaps is as follows: if a conflict pair were out of conflict for greater than 48 seconds, then a new conflict pair would be counted, if the pair were to come back into conflict.
22.1	Expected number of conflict alerts per 100 tracks per hour		
22.2	Expected number of candidate pairs of aircraft per 100 tracks per hour	Candidate pairs are taken to be the aircraft pairs subjected to the fine lateral filter of the conflict alert algorithm.	
22.3	Peak number of conflict alerts per 100 tracks (instantaneous)		
22.4	Conflict alert duration, minutes		
22.5	Duration of candidate aircraft pairs, minutes		
23.0	MSAW Alert Frequency	The alert frequency of Minimum Safe Altitude Warnings.	
23.1	Expected number of en-route MSAW alerts per 100 tracks per hour		
23.2	Average number candidate tracks per 100 tracks per hour		
23.3	Average number of violations per candidate tracks per hr.		
24.0	Message Origin	A matrix of message origin versus message type.	
25.0	Converted Route Segments Per Flight	A basic flight plan processing parameter—flight segments along a flight path.	
26.0	Target Peaking - Facility-Wide	This is a measure of the maximum target report rate, considering all radar sites in the facility, as received at the computer system.	
26.1	Target Peaking, One-tenth Second		
26.2	Target Peaking, One Second		

TABLE A-1
WORKLOAD PARAMETER DESCRIPTIONS
(CONTINUED)

PARAMETER	DESCRIPTION	COMMENTS
27.0 Message Rates (Units are messages per flight except where noted)	Arrival rate for the following kinds of messages: Radar Site Messages Track Control Messages Flight Plan Data Messages Metering, flow Control & Other Automation messages Supervisory Messages Display Function Related Messages Interfacility Messages Miscellaneous Messages	
27.1 Radar Site Messages		Radar Message Rate is determined as a function of the percentage of Mode-S (vs. ATCRBS) long range radars.
27.1.1 Target Reports for IFR Flights	Radar Message Rate in target reports per radar scan for IFR aircraft under "prepare for backup."	
27.1.2 Target Reports for VFR Flights	Radar Message Rate in target reports per radar scan for IFR aircraft under "prepare for backup."	
27.1.3 Weather Map Messages		
27.1.3.1 WFMU Weather		
27.1.3.2 ASR-9 Weather		
27.1.3.3 CWP Weather		CWP weather data will be in compact image format.
27.2 Track Control Messages		
27.2.1 Accept Handoff(QN,QZ)	Used to accept control of a single flight passing from NAS to sector, ARTS to sector, & sector to sector. If the message is entered for an aircraft already under control of the sector or facility entering the message, it is interpreted as a retraction of the transfer of control.	
27.2.2 Initiate Handoff (QN, QZ)	Used to initiate manually the transfer of control of a tracked aircraft from one sector or facility to another.	
27.2.3 Track		
27.2.3.1 Track Initiation (QT)	Manually starts the tracking process.	
27.2.3.2 Track Termination (QX)	Manually stops the tracking process.	

TABLE A-1
WORKLOAD PARAMETER DESCRIPTIONS
(CONTINUED)

PARAMETER	DESCRIPTION	COMMENTS
27.3 Flight Plan Data Msgs		
27.3.1 Flight Plan (FP)	Establishes Flight Plan Data.	
27.3.2 Flight Data Modifications	Used to modify, add, or delete existing flight plan data. Once accepted, the modification data becomes part of the flight plan data base.	This item thus actually represents 13 possible types of modifications. Probably the most important (i.e., most frequent) ones are altitude and route amendments.
27.3.2.1 Altitude (AM, QN, QZ)		These values are disaggregated in Volume III into AM (27.3.2.1) and QN, QZ (27.3.2.4).
27.3.2.2 Route (AM)		
27.3.2.3 Other (All other AMs)		
27.3.3 Interim Alt (QQ)	Used to set, remove or change an interim altitude for a flight.	
27.3.4 Departure (DM)	Used to activate a proposed departure or a proposed airfiled flight plan.	Optionally, an assigned altitude may be specified.
27.3.5 Drop Flight Plan (QX, RS)	Used to remove from the system all flight data for an entered or tentative flight plan and downgrade the associated track, if any, to an uncontrolled track.	
27.3.6 Traffic Management	Advisory message from local flow control to local radar controller.	
27.4 Metering, Flow Control & Other Automation Msgs		
27.4.1 Trial Plan Build	This message enables the controller to enter a Trial Plan at his position using the interactive capabilities available at the Sector Suite.	
27.4.2 Trial Plan Probe	Used by a controller to activate (call) the conflict probe function for a specific aircraft.	
27.4.2.1 Actual Probe	This message shall enable the controller to perform a trial plan probe on a particular aircraft using the current flight plan or using a proposed route or altitude amendment. The system will check the flight's current or proposed three-dimensional route over time with other flight routes that are in the system and with sector workload thresholds. Appropriate response messages will be provided to the controller describing any problems found by the probe.	Message 27.4.2.1 calls both conflict probe and sector workload probe.

TABLE A-1
WORKLOAD PARAMETER DESCRIPTIONS
(CONTINUED)

PARAMETER	DESCRIPTION	COMMENTS
27.4.2.2 Display Function for Stored Probe Results		
27.5 Sector Workload Probe	Used by a Supervisor to determine sectorization and positional planning (1 person, 2 person, 3 person, etc.) by providing some workload-related measures at the sector level.	
27.6 Display Function Related Messages		
27.6.1 Force Data Block (QN, QZ)	This message is used to cause the forcing or removal of the display of a data block for an individual aircraft on a situation display.	
27.6.2 Date Block Offset (QN, QZ)	This message is used to move data blocks within the situation display, i.e., to avoid overlapping of two or more data blocks.	This will become an automatic message with manual override in 1995.
27.6.3 Data Block Point Out (QP)	This message is used to request the display of a data block at another sector's situation display and if appropriate, cause the established beacon code of the track to be inserted in the associated code selection list.	This will become an automatic message with manual override in 1995.
27.6.4 Route Display Request (QU)	This action is used to display the portion of the specified aircraft's route from the extrapolated flight plan position to a point which takes place at a parameter number of minutes along the route, or if requested, to a point which will be met at a specified time interval.	
27.6.5 Flight Data Readout (QF)	Requests a display or printout of a specified flight plan as stored.	
27.6.6 Data Field Highlight and Mark	This message enables the controller to add, modify, or delete a highlight on certain fields related to flight plan and flight progress data. If so adapted, this highlight shall take effect on the data displayed in the Flight Data Display.	

TABLE A-1
WORKLOAD PARAMETER DESCRIPTIONS
(CONTINUED)

PARAMETER	DESCRIPTION	COMMENTS
27.6.7 Flight Data Entry (FDE) Point-Out	Used to force an FDE displayed at the entering sector to the Flight Data Area at another sector.	
27.6.8 Request (Other) FDE's	Used to request FDEs from another sector to be displayed in the Flight Data Area at the requesting sector.	
27.6.9 Select Logical Display	Used for selecting one or more of the following 15 types of logical displays for viewing: - Situation - Flight Data - Aeronautical and Meteorological - Alert and Resolution - Special Lists - Message Composition and Response - Airport Environment Data - System Status Data - Static Information - Weather - Flow Control Situation - Oceanic Situation - Metering Position - Sector Workload - Flow Control Flight Data	
27.6.10 Sector Data Modifications	Used for modifying aircraft sector unique data.	
27.6.11 Acknowledge New Flight Data/Flight Data Updates	Acknowledges receipt of the following messages: Interim Altitude FP Amendments Altitude Modification Automatic Time Update Departure	

TABLE A-1
WORKLOAD PARAMETER DESCRIPTIONS
(CONTINUED)

PARAMETER	DESCRIPTION	COMMENTS
27.7 Interfacility Messages		
27.7.1 Accept Transfer (TA)	Received from receiving facility to indicate that handoff has been accepted or manual start track initiated, or received from sending facility to indicate handoff is being retracted.	
27.7.2 Initiate Transfer (TI)	Received from sending facility to indicate that a handoff is being initiated.	
27.7.3 Track Update (TU)	Received from sending facility for tracks in crosstell status to provide updated position information.	
27.7.4 Transmission Accepted (TA)	To indicate that the receiving NAS facility has accepted the referenced interfacility message.	
27.7.5 Terminate Beacon Code (TB)	Sent to NAS from ARTS upon the arrival of a flight. Used to reactivate the eligibility of the beacon code.	
27.7.6 Initiate Flight Data on Aircraft Entering Backup Airspace	AAS System Level Specification states that the ACCCs shall support Facility backup by routine exchange of critical flight data in Operational and Failsoft modes.	
27.7.7 Update Flight Data on Aircraft in Backup Airspace		
27.7.8 Delete Flight Data on Aircraft Leaving Backup Airspace		
27.8 Miscellaneous Messages Messages/Min		
27.8.1 General Information (GI)	Used to route a message to any or all positions in the facility and adjacent facilities.	This message is called "ATC Mail" in AAS.
27.8.2 Central Flow Control	Used to forward flight plan cancellation, departure, or information messages originating in adjacent centers to CFCF.	This message is called "Traffic Management Processor" in AAS.

TABLE A-1
WORKLOAD PARAMETER DESCRIPTIONS
(CONCLUDED)

PARAMETER	DESCRIPTION	COMMENTS
28.0 Number of TCCCs	Total number of Terminal Control Computer Complexes (TCCCs) interfacing to an ACF.	
29.0 Number of Control Positions	Total number of control positions (Enroute, Radar Approach, Non-radar Approach, or Oceanic positions in any combination.)	
30.0 Number of Sector Suites	Total number of sector suites per ACF.	

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APPENDIX B

ACRONYM LIST

AAS	Advanced Automation System
ACF	Area Control Facility
AERA	Advanced En Route Automation
ARTCC	Air Route Traffic Control Centers
ARTS	Automatic Radar Terminal System
ASR	Airport Surveillance Radar
ATC	Air Traffic Control
ATCRBS	Air Traffic Control Radar Beacon System
CA	Conflict Alert
CTA	Calculated Time of Arrival
CONUS	Conterminous US
CWP	Central Weather Processor
CD	Common Digitizer
COMDIG	Common Digitizer
DART	Data Analysis and Reduction Tool
FAA	Federal Aviation Administration
FDE	Flight Data Readout
FP	Flight Plan
FSS	Flight Service Station
GA	General Aviation
IFR	Instrument Flight Rules
ISSS	Initial Sector Suite System
LRR	Long Range Radar
MSPE	Modeling and Simulation Program Element
NAS	National Airspace System
NOSS	NAS Operational Support System
PAR	Preferred Arrival Route
PDAR	Preferred Departure and Arrival Route
PDR	Preferred Departure Route
RRWDS	Remote Radar Weather Display System

SAR	System Analysis Recording
SID	Standard Instrument Departure
SLS	System Load Specification
SRR	Short Range Radar
STAR	Standard Terminal Arrival Route
TCCC	Tower Computer Control Center
TRACON	Terminal Radar Approach Control
TRACAB	Terminal Radar Approach Control in the Tower Cab
ULR	NOSS Recording Data Process Subprogram
VFR	Visual Flight Rules
WFMU	Weather and Fixed Map Unit

APPENDIX C

RADAR SITES

The compilation of radar sites by ACF was done using the preliminary report, NAS Surveillance Radar Network Plan[12] and the Mode-S Project Master Plan.[33] Radars were plotted on a map showing the proposed ACF boundaries[35] so that ACF assignments could be made. The radars located were those planned to be implemented by 1995. Short range radars located within the boundaries of an ACF B were assumed not to be connected to the overhead ACF A. All long range radars were assumed to be shared, with both ACF B and overhead ACF A connected. Long range radars located within 100 nmi outside the boundaries of a facility were considered to report to that facility unless double coverage within the facility was provided as a consequence.

LONG & SHORT RANGE RADARS AFTER IMPLEMENTATION OF NAS SURVEILLANCE NETWORK PLAN

ALBUQUERQUE ACF

LONG RANGE RADARS

ATCRBS	MODE-S
DMN	ABQ
INW[5]	AJO
QLA	CDC[1]
QXP[5]	GUP
YUM[5]	QAS[1]
	QRW

SHORT RANGE RADARS

ATCRBS	MODE-S
LSV[3]	ABQ
LUF[3]	LAS
	PHXA
	TUS

ATLANTA ACF

LONG RANGE RADARS

ATCRBS	MODE-S
ATL	
QPC	
QRI	

SHORT RANGE RADARS

ATCRBS	MODE-S
ABY[2]	AGS
AMG[2]	ATLA
AVL	BHM
CSG	CHA
GSP	MGE
HSV	TRI
MXF	TYS
QRV[3]	WRB
7A0[3]	

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[1] Radar located outside (but within 100 nmi) of ACF boundary.
[2] Radar used as a gapfiller.
[3] Radar used as a gapfiller, but located at a defense terminal.
[4] Radar identifier provided by MITRE.
[5] Beacon only radar.

BOSTON ACF

LONG RANGE RADARS

ATCRBS	MODE-S
QCF[1]	DSV
QHA	QRC[1]
QNT	QSA
QVH[1]	QXV
JAK[4]	QYA

SHORT RANGE RADARS

ATCRBS	MODE-S
BGM	ALB
BTV	BDL
ELM	BGR
FMH	BOS
LIZ	BUF
MHT	OQU
NHZ	PWM
RME	ROC
	SYR

CHICAGO ACF

LONG RANGE RADARS

ATCRBS	MODE-S
IND[1]	QJAA[1]
QDT[1]	
QBZ	
QJF	
QTZ	

SHORT RANGE RADARS

ATCRBS	MODE-S
AZO	GRR
GUS	MKE
MKG	MSN
RFD	ORD
SBN	QXM

---

[1] Radar located outside (but within 100 nmi) of ACF boundary.
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[4] Radar identifier provided by MITRE.
[5] Beacon only radar.

CLEVELAND ACF

LONG RANGE RADARS

ATCRBS	MODE-S
CLE	AST[1]
IND	
PIT	
QCF[1]	
QDT	
QHY[1,5]	
QJF	
QRI[1]	
QTZ	
QWOO	

SHORT RANGE RADARS

ATCRBS	MODE-S
CAKA	CLEA
FNT	DTWA
LAN	ERI
MBS	PITA
MFD	
MTC[3]	
TOL	
YNGA	

DENVER ACF

LONG RANGE RADARS

ATCRBS	MODE-S
ALS[5]	AMAA
ASP[4,5]	GCK
DMN[1]	GJT
GDL[4]	GUP[1]
KMT[1,4]	LSK
KS2	NE2[1]
MCA[4]	NE3
NE1[1]	QJB[1]
PUT[1,4]	QPK
ROW	QWC
	RKS
	TAD

SHORT RANGE RADARS

ATCRBS	MODE-S
AMA	DENA
COS	ELP
CPR	LBB
HMN[3]	MAF
PUB	
RCA[3]	

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[1] Radar located outside (but within 100 nmi) of ACF boundary.
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[4] Radar identifier provided by MITRE.
[5] Beacon only radar.

FORT WORTH ACF

LONG RANGE RADARS

ATCRBS	MODE-S
ADM	TXK
HBZ[1]	
LCH	
MCA[1,4]	
PSN	
PUT[1,4]	
PXS	
QNM[1]	
RSG[1]	

SHORT RANGE RADARS

ATCRBS	MODE-S
AEX[3]	ACT
BPT	AUS
CLL	BAD
GRA[3,4]	DFW
HEZ[3]	DYS
SHP[3]	GGG
	HOU
	IAH
	LCH
	MLU
	QZB

HOUSTON ACF

LONG RANGE RADARS

ATCRBS	MODE-S
ADM	QSA[1]
BWD	QWC[1]
GDL[4]	QZA
HBZ[1]	TXK
KMT[4]	
LCH	
MCA[4]	
NEW	
PSN	
PUT[1,4]	
PXS	
QNM[1]	
ROW	
RSG	

SHORT RANGE RADARS

ATCRBS	MODE-S
BTR	CRPA
HRL	LFT
NIR[3]	MSY
SJT	SATA

---

[1] Radar located outside (but within 100 nmi) of ACF boundary.
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[3] Radar used as a gapfiller, but located at a defense terminal.
[4] Radar identifier provided by MITRE.
[5] Beacon only radar.

INDIANAPOLIS ACF

LONG RANGE RADARS

ATCRBS	MODE-S
IND	
QHY[1]	
QRI[1]	
QTZ[1]	
QWO	

SHORT RANGE RADARS

ATCRBS	MODE-S
HUF[2]	CMH
LEX	CVG
	DAY
	EVV[2]
	FWA[2]
	HTS
	INDA
	SDF

JACKSONVILLE ACF

LONG RANGE RADARS

ATCRBS	MODE-S
ATL[1]	QPL
COF	
CTY	
NEN	
OCE	
PAM[1]	
PIT[1]	
QBE	
QFF	
QHY[5]	
QJT	
QRI[1]	
QRJ	

SHORT RANGE RADARS

ATCRBS	MODE-S
CAE	CHSA
DAB	JAX
FLO[2]	NCZ
MCO	TPA
SAV	

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[1] Radar located outside (but within 100 nmi) of ACF boundary.
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[3] Radar used as a gapfiller, but located at a defense terminal.
[4] Radar identifier provided by MITRE.
[5] Beacon only radar.

KANSAS CITY ACF

LONG RANGE RADARS		SHORT RANGE RADARS	
ATCRBS	MODE-S	ATCRBS	MODE-S
HBZ	GCK[1]	COU[5]	CMI
HTI	IRK	DAK[2]	FSM
IA1[1]		SPI	ICT
KS1		TOP	LIT
KS2			MCI
MO1			OKCA
NE1[1]			PIA
PUT[4]			SGF
QAF			STLA
QHJ[1]			TUL
QHO[1]			
QUZ			
STL			

LOS ANGELES ACF

LONG RANGE RADARS		SHORT RANGE RADARS	
ATCRBS	MODE-S	ATCRBS	MODE-S
QIA	PRB[1]	PSP	BUR
	QRW		GRV[4]
	QVP[1]		LAX
			LAXA
			NKX
			NZJ
			ONT
			SBA

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[4] Radar identifier provided by MITRE.
[5] Beacon only radar.

MEMPHIS ACF

LONG RANGE RADARS

ATCRBS	MODE-S
ATL	QPB
CTY[1]	
HBZ[1]	
NEW[1]	
PAM	
QNM	
QPC	
QRI	

SHORT RANGE RADARS

ATCRBS	MODE-S
BWG[2]	BNA
GPT	JAN
HOP[3]	MEM
MOB	NMM
MVC[2]	PNS
NQA	TLH
OZR[3]	

MIAMI ACF

LONG RANGE RADARS

ATCRBS	MODE-S
COF[1]	NQX
GDT[5]	
MIA	
QJQ	
QJT[1]	

SHORT RANGE RADARS

ATCRBS	MODE-S
PBI	FLL
QJS	MIA
RSW	SRQ
SJU	
STT	

---

[1] Radar located outside (but within 100 nmi) of ACF boundary.
[2] Radar used as a gapfiller.
[3] Radar used as a gapfiller, but located at a defense terminal.
[4] Radar identifier provided by MITRE.
[5] Beacon only radar.

MINNEAPOLIS ACF

LONG RANGE RADARS

ATCRBS	MODE-S
EGV	AST
IA1	CAL
QBZ	IRK[1]
QJE	NE1
QJF[1]	NE2
QJO	QFI
QTZ[1]	QJAA
QUZ[1]	QJB
	QJC
	QJD
	QWA[1]

SHORT RANGE RADARS

ATCRBS	MODE-S
ALO	BIS
FSD	CID
LNK	DLH
MIB[3]	DSM
MLI	FAR
OSC[3]	GRB
RDR[3]	MSP
SAW[3]	OFF
	RST
	SUX

NEW YORK (ACF-A)

LONG RANGE RADARS

ATCRBS	MODE-S
GIB	DSV
JAK[4]	QPL[1]
PIT	QRC
QCF	QSA
QHA	QXV
QNT	QYA
QVH	

SHORT RANGE RADARS

ATCRBS	MODE-S

---

[1] Radar located outside (but within 100 nmi) of ACF boundary.
[2] Radar used as a gapfiller.
[3] Radar used as a gapfiller, but located at a defense terminal.
[4] Radar identifier provided by MITRE.
[5] Beacon only radar.

NEW YORK (ACF-B)

LONG RANGE RADARS

ATCRBS

GIB
PIT[1]
QCF
QHA[1]
QVH

MODE-S

DSV[1]
QPL[1]
QRC

SHORT RANGE RADARS

ATCRBS

ABE
ACY
AVP
NXX
SWF

MODE-S

EWR
HAR
HPN
ISP
JFK
PHL

OAKLAND ACF

LONG RANGE RADARS

ATCRBS

MODE-S

PRB
QMV
QVP[1]

SHORT RANGE RADARS

ATCRBS

MRY
STK

MODE-S

BAB
BFL
FAT
MCC
NUQ
OAKA

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[1] Radar located outside (but within 100 nmi) of ACF boundary.
[2] Radar used as a gapfiller.
[3] Radar used as a gapfiller, but located at a defence terminal.
[4] Radar identifier provided by MITRE.
[5] Beacon only radar.

SALT LAKE CITY ACF

LONG RANGE RADARS

ATCRBS	MODE-S
BRL[1,4]	BAM
LMT[1]	CDC
	CEC[1]
	FLX
	GJT[1]
	PRB
	QAS
	QMY
	QVP
	RBL
	RKS[1]
	SLC
	TPH[5]

SHORT RANGE RADARS

ATCRBS	MODE-S
EDW	RNO
TCA[3,4]	SLCA

SEATTLE ACF

LONG RANGE RADARS

ATCRBS	MODE-S
BRL[4]	BAM[1]
BUM[4]	CEC
HAM[4]	FLX[1]
MAK	GFAA
QMI	LMT
SAL[4,5]	QCK
SEA	QLS
SLE	QSI
SPR[4]	QVA
	QVN
	QWA
	RBL[1]
	RKS[1]
	SLC[1]

SHORT RANGE RADARS

ATCRBS	MODE-S
BOI	BIL
HIO	EUG
MOS[2]	GEG
PSC[2]	GTF
TCM	PDX
WBI[3,4]	SEAA

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[1] Radar located outside (but within 100 nmi) of ACF boundary.
[2] Radar used as a gapfiller.
[3] Radar used as a gapfiller, but located at a defense terminal.
[4] Radar identifier provided by MITRE.
[5] Beacon only radar.

WASHINGTON ACF

LONG RANGE RADARS		SHORT RANGE RADARS	
ATCRBS	MODE-S	ATCRBS	MODE-S
OCE	QPL	FAY	ADW
PIT[1]		GSO	BAL
QBE		QRM[2]	CKB
QFF			CLT
QHY[5]			CRW
QRI[1]			DCA
QRS[1]			IAD
			ILM
			LFI
			ORF
			RDU
			RIC
			ROA

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[1] Radar located outside (but within 100 nmi) of ACF boundary.
[2] Radar used as a gapfiller.
[3] Radar used as a gapfiller, but located at a defense terminal.
[4] Radar identifier provided by MITRE.
[5] Beacon only radar.

ANCHORAGE ACF

LONG RANGE RADARS		SHORT RANGE RADARS	
ATCRBS	MODE-S	ATCRBS	MODE-S
AKN		ANC	
BKA[5]		BET	
BTI[5]		ENA	
CBD		FAI	
CZF[5]			
FHM[5]			
ENA			
FYU[5]			
GAL[5]			
LUR[5]			
MDO[5]			
MPY			
NUD[5]			
OLI[5]			
OTZ[5]			
PBA[5]			
PTZ[5]			
SCC[5]			
SNP[5]			
SVW[5]			
SYA[5]			
TLI[5]			
TNC[5]			
UTO[5]			
YAK[5]			

HONOLULU ACF

LONG RANGE RADARS		SHORT RANGE RADARS	
ATCRBS	MODE-S	ATCRBS	MODE-S
QKK[5]		ITO	HNL
QXA[5]		LIH	
UPP		OGG	
		UAM	

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[1] Radar located outside (but within 100 nmi) of ACF boundary.
[2] Radar used as a gapfiller.
[3] Radar used as a gapfiller, but located at a defense terminal.
[4] Radar identifier provided by MITRE.
[5] Beacon only radar.

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APPENDIX D

PROJECTED TRACK LEVELS TAKEN FROM FAA FORECAST

The table presented in this appendix contains FAA forecasts of controlled track levels on a facility basis, for the years 1985, 1990, 1995, 2000, and 2010. They are taken from Reference 10, a June 1981 report where IFR aircraft handles and IFR instantaneous airborne counts were forecast from 1981 through 2011 using an econometric model.

These track levels are used in this report to determine the workload scenario parameter 2.1, Peak Track Load: Controlled Tracks. For the years 1985 and 1990, the maximum across the 20 centers (Chicago) is used. For the years 1995, 2000, and 2010, after consolidation, an amalgam of current ARTCCs trackloads is used.

TABLE D-1
PROJECTED TRACK LEVELS

ARTCC	PROJECTION YEAR 1985	1990	1995	2000	2010
ZAB (Albuquerque)	298	346	392	432	480
ZTL (Atlanta)	313	392	479	569	734
ZBW (Boston)	191	227	255	301	353
ZAU (Chicago)	384	486	597	714	937
ZOB (Cleveland)	340	408	477	541	640
ZDV (Denver)	380	476	581	687	879
ZFW (Fort Worth)	359	437	517	595	721
ZHU (Houston)	277	355	438	527	697
ZID (Indianapolis)	308	383	465	550	703
ZJX (Jacksonville)	235	283	335	386	467
ZKC (Kansas City)	346	422	496	568	682
ZLA (Los Angeles)	297	357	421	482	577
ZME (Memphis)	314	387	467	550	696
ZMA (Miami)	279	349	424	500	635
ZMP (Minneapolis)	263	333	412	496	657
ZNY (New York)	248	290	330	365	410
ZOA (Oakland)	274	319	364	404	455
ZLC (Salt Lake City)	266	315	363	407	468
ZSE (Seattle)	276	357	439	527	695
ZDC (Washington)	296	357	420	479	571
$\bar{X}$	297.2	364.0	434.1	504.0	622.9
Maximum	384	486	597	714	937

APPENDIX E

CALCULATION OF METERING POSITIONS

The metering positions for each ACF are presented in the following tables. These estimated positions are based on the definition of two kinds of metering:

> Destination metering - providing sequencing and separation to flights requesting metering assistance to airports located within ACF controlled airspace.
>
> Upstream metering - providing sequencing and separation to flights requesting metering assistance to airports located in an adjacent ACF. No limitation in distance to the airport in an upstream ACF was considered.

It was assumed that one metering position would be assigned to each airport receiving upstream metering service by an ACF and one position be assigned to each destination airport depending on the proximity to another airport. Only one position was assigned to provide metering to HOU and IAH, for example.

The fifty busiest IFR airports were chosen to represent the demand for metering. No assumptions about future growth in airports needing metering were made.

TABLE E-1
CALCULATION OF METERING POSITIONS SERVING THE 50 BUSIEST AIR CARRIER AIRPORTS

ACF	UPSTREAM METERING	DESTINATION METERING	TOTAL METERING POSITIONS
Albuquerque	DEN SLC LAX/SAN	PHX LAS	5
Atlanta		ATL	1
Boston	JFK LGA EWR	BOS BDL BUF	4
Chicago	MSP	ORD MKE	3
Cleveland	ORD MSP MKE MCI IND STL CVG MEM CMH BUF DAY OKC	DTW CLE PIT	15
Denver	SLC MSP PHX SAT LAS SEA/PDX MCI MSY STL OKC	DEN	11
Fort Worth	MSY SAT	FTW/DFW HOU/IAH	7
Houston	DFW DEN IAH MCI PHX STL LAS MEM	SAT MSY	11
Indianapolis	DTW PIT CLE	IND CMH CVG DAY	7
Jacksonville	MIA BWI FLL PBI ATL MEM CLT CLE DCA DTW IAD PIT	TPA/MCO	14
Kansas City	DEN SAT MSP CLE MEM DTW MSY PIT	MCI STL OKC	11

TABLE E-1
(Concluded)

ACF	UPSTREAM METERING	DESTINATION METERING	TOTAL METERING POSITIONS
Los Angeles		LAX SAN	2
Memphis	MSY SAT MCI CLE STL PIT ATL DTW TPA OKC MCO	MEM	12
Miami		MIA PBI FLL	3
Minneapolis	ORD DEN MKE SEA/PDX MCI OKC STL	MSP	8
New York (A)	JFK PIT LGA BUF EWR SYR PHL BDL DTW BOS CLE MCO/TPA		12
New York (B)	BDL	JFK EWR LGA PHL	5
Oakland		SFO SMF OAK SIC	4
Salt Lake City	DEN SAN PHX SEA LAS PDX LAX	SLC	10
Seattle	MSP SLC DEN	SEA PDX	5
Washington	PIT	DCA BWI IAD CLT	5
Anchorage		ANC	1
Honolulu		HNL LIH OGG	3

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APPENDIX F

TCCC LOCATIONS

The identification of ATCTs at which TCCCs will be installed was derived from the FAA answers to AAS contractor questions. The FAA directed the contractors to consider the busiest 300 ATCTs as candidates for TCCCs. These cities are listed in this appendix with associated ACFs identified.

TABLE F-1
FAA OPERATED AIRPORT TRAFFIC CONTROL TOWERS BY RANK ORDER OF TOTAL AIRPORT OPERATIONS

TOWER ID	TOWER NAME	ACF	TOWER ID	TOWER NAME	ACF
ORD	Chicago	CHI	EWR	Newark	NYB
ATL	Atlanta International	ATL	CDW	Caldwell	NYB
LAX	Los Angeles International	LAX	HWD	Hayward	OAK
VNY	Van Nuys	LAX	DVT	Dee Valley	ABQ
DEN	Denver Stapleton Intl	DEN	BWI	Baltimore Wash. Intl.	DCA
SNA	Santa Ana	LAX	OPF	Opalocka	MIA
DFW	Dallas Ft. Worth Regional	FTW	FLL	Ft. Lauderdale	MIA
LGB	Long Beach	LAX	TUS	Tucson	ABQ
SEA	Seattle Boeing	SEA	CMN	Columbus International	IND
OAK	Oakland International	OAK	ISP	Islip MacArthur	NYB
APA	Denver Arapahoe County	DEN	PBI	West Palm Beach	MIA
SFO	San Francisco	OAK	TUL	Tulsa International	MKC
STL	St. Louis International	MKC	ANC	Anchorage International	ANC
JFK	John F. Kennedy Intl.	NYB	MLB	Melbourne	JAX
PHX	Phoenix Sky Harbor Intl.	ABQ	MDW	Chicago Midway	CHI
MIA	Miami International	MIA	NEW	New Orleans Lakefront	HOU
LGA	La Guardia	NYB	MYF	San Diego Montgomery	LAX
BOS	Boston Logan	BOS	BED	Bedford	BOS
MRI	Anchorage Merrill	ANC	SBA	Santa Barbara	LAX
IAH	Houston Intercontinental	HOU	ABQ	Albuquerque Intl.	ABQ
DCA	Washington National	DCA	SMO	Santa Monica	LAX
HNL	Honolulu	HON	SAT	San Antonio Intl.	HOU
PHL	Philadelphia Intl.	NYB	CLE	Cleveland Hopkins Intl.	CLE
SJC	San Jose Municipal	LAX	RVS	Tulsa Riverside	MKC
PIT	Pittsburgh Greater Intl.	CLE	SEA	Seattle Tacoma Intl.	SEA
FTW	Fort Worth Meacham	FTW	CCR	Concord	OAK
HOU	Houston Hobby	HOU	PDX	Portland International	SEA
TMB	TA Miami	MIA	ROC	Rochester Monroe County	BOS
DAL	Dallas Love Field	FTW	PDK	Atlanta Dekalb Peachtree	ATL
MSP	Minneapolis St. Paul Intl.	MSP	FRG	Farmindale	BOS
LAS	Las Vegas McCarran Intl.	SLC	BHM	Birmingham	ATL
MEM	Memphis International	MEM	BNA	Nashville Metropolitan	MEM
TEB	Teterboro	NYB	DAB	Daytona Beach	JAX
PTK	Pontiac	MSP	SEE	San Diego Gillespi	LAX
CLT	Charlotte Douglas	DCA	FAT	Fresno Air Terminal	OAK
SLC	Salt Lake City Intl.	SLC	DWH	Tomball D H Hooks	FTW
TPA	Tampa International	JAX	PVD	Providence	BOS
DTW	Detroit Metro Wayne CC	MSP	CRQ	Carlsbad Palomar	LAX
TOA	Torrance Municipal	LAX	AUS	Austin	FTW

TABLE F-1
(Continued)

TOWER ID	TOWER NAME	ACF	TOWER ID	TOWER NAME	ACF
BUR	Burbank	LAX	RHV	San Jose Reid Hillview	DCA
HWO	Hollywood	MIA	IAD	Washington Dulles Intl.	DCA
ELP	El Paso International	DEN	SUS	St. Louis Spirit of St. Lou.	MKC
CNO	Chino	LAX	VRB	Vero Beach	JAX
GFK	Grand Forks Intl.	MSP	HYA	Hyannis	BOS
HPN	White Plains Westchester	NYB	PWK	Chicago Palwaukee	CHI
RDU	Raleigh Durham	DCA	ADS	Dallas Addison	FTW
MMU	Morristown	NYB	BTR	Baton Rouge Ryan Field	HOU
DPA	Chicago Du Page	CHI	LIT	Little Rock Adams Field	MKC
LFT	Lafayette	HOU	SQL	San Carlos	OAK
FXE	Fort Lauderdale Executive	MIA	ORL	Orlando Jetport	JAX
RNT	Renton	SEA	COS	Colorado Springs	DEN
PIE	St. Petersburg Clearwater	MIA	RIC	Richmond Byrd Intl.	DCA
IND	Indianapolis Intl.	IND	SDL	Scottsdale	ABQ
MSY	New Orleans Moisant	HOU	BOI	Boise	SEA
DWD	Norwood	BOS	MSN	Madison	CHI
EMT	El Monte	LAX	MCI	Kansas City International	MKC
LOU	Louisville Bowman	IND	ALB	Albany County	BOS
LVK	Livermore Municipal	OAK	RNO	Reno International	SLC
SJU	San Juan International	MIA	FTY	Atlanta Fulton County	ATL
BDR	Bridgeport	BOS	HVN	New Haven	BOS
PAO	Palo Alto	OAK	DAY	Dayton	IND
ICT	Wichita Mid Continental	MKC	OMA	Omaha	BCS
PNE	North Philadelphia	NYB	MAF	Midland	DEN
ORF	Norfolk Regional	DCA	SYR	Syracuse Hancock Intl.	BOS
TTN	Trenton	NYB	YIP	Detroit Willow Run	CLE
SQR	Sarasota Bradenton	JAX	HIO	Hillsboro	SEA
DSM	Des Moines Municipal	MSP	BJC	Broomfield Jefferson Co.	DEN
FUL	Fullerton Municipal	LAX	SDF	Louisville Standiford	IND
FCM	Minneapolis Flying Cloud	MSP	BDL	Windsor Locks	BOS
POC	LaVerne Brackett	LAX	SAN	San Diego Lindberg	LAX
PWA	Oklahoma City Wiley Post	MKC	MIC	Minneapolis Crystal	MSP
MKE	Milwaukee Mitchell	CHI	MKC	Kansas City Municipal	MKC
CVG	Cincinnati Greater	IND	FAI	Fairbanks	ANC
BUF	Buffalo International	BOS	VGT	North Las Vegas	ABQ
PHF	Newport News	DCA	JAX	Jacksonville Intl.	JAX
OSU	Columbus Ohio St	IND	GSO	Greensboro Regional	DCA
OKC	Oklahoma City Will Rogers	MKC	LUK	Cincinnati Lunken	IND
MCO	Orlando Intl. Airport	JAX	ILG	Wilmington Gr Wilm	DCA

APPENDIX G

MISCELLANEOUS

This appendix contains data sources that, by themselves, are not of sufficient stature or size to warrant a separate appendix.

FLIGHT SERVICE STATIONS (FSS)

Criteria: 12 month Total of Flight Service Activity Factor (Two times Pilot Briefs plus Aircraft Contacted) or 12 Month Total of Pilot Briefs

		EITHER:		OR:	
Level	FPL Grade	Flight Service Activity Factor	(5% Buffer)	Pilot Briefs	(5% Buffer)
I	GS-9	0 - 74,999	-	0 - 24,999	-
II	GS-10	75,000 - 299,999	(71,250)	25,000 - 124,999	(23,750)
III	GS-11	300,000 - or more	(285,000)	125,000 - or more	(118,750)

Note: For FSSs which provide EFAS service, the activity attributable to the EFAS position is deleted from the total facility count to determine the grade level for the facility. For determining the grade level of the EFAS specialist, the combined activity count of EFAS plus the rest of the facility is used.

TERMINALS AND CENTERS

Criteria: Hourly Traffic Density Factor (Sum of daily traffic for the busiest 183 days; divided by 183 days; divided by 16 hours or actual hours of operation if a facility is open less then 16 hours). Traffic data to be used is determined by facility type.

TERMINAL TYPES						CENTERS		
Terminal Level	FPL Grade	Non-Approach VFR Tower	Non-Radar Approach	Limited Radar Approach	Radar Approach	Center Level	FPL Grade	Density Factor
I	GS-10	0 - 34.9	0 - 24.9	—	—			
II	GS-11	35 - 89.9 (33.25)	25 - 79.9 (23.75)	0 - 24.9	0 - 19.9			
III	GS-12	90 or more (85.5)	80 or more (76.0)	25 - 59.9 (23.75)	20 - 59.9 (19.0)	I	GS-12	0 - 169.9
IV	GS-13	—	—	60 or more (57.0)	60 - 99.9 (57.0)	II	GS-13	170 - 274.9 (161.5)
V	GS-14	—	—	—	100 or more (95.0)	III	GS-14	275 or more (261.25)
TRAFFIC DATA USED:		Airport Operations	Airport Ops. & Instr. Ops	Instr. Ops.	Instr. Ops.	IFR Aircraft Handled		

( ) = 5% Buffer

Downgrading action must be initiated if a facility's grade level criteria falls below the buffer for 6 consecutive months.

FIGURE G-1

ATC FACILITY GRADE LEVEL CRITERIA — QUICK REFERENCE

TABLE G-1
CONTROLLER REDUCTIONS ASCRIBED TO EFFICIENCIES OF SCALE DUE TO CONSOLIDATION

ACF	YEAR OF CONSOLIDATION	POSITIONS REDUCED
Albuquerque	1993	0
Atlanta	1996	7
Boston	1998	6
Chicago	1997	3
Cleveland	1997	4
Denver	1994	4
Fort Worth	1996	4
Houston	1995	2
Indianapolis	1997	4
Jacksonville	1996	3
Kansas City	1995	4
Los Angeles	1994	2
Memphis	1996	4
Miami	1997	1
Minneapolis	1995	9
New York/Boston (A)	--	0
New York (B)	1998	4
Oakland	1994	3
Salt Lake City	1994	0
Seattle	1993	6
Washington	1998	5
Anchorage	1996	0
Honolulu	1996	1

TABLE G-2
ACF-AREAS CALCULATED USING DOT GRID

ACF	AREA (NM) 2
Albuquerque	218,988
Atlanta	97,020
Boston	105,336
Chicago	44,352
Cleveland	118,272
Denver	317,856
Fort Worth	134,904
Houston	386,232
Indianapolis	58,212
Jacksonville	303,072
Kansas City	182,952
Los Angeles	20,328
Memphis	239,316
Miami	66,528
Minneapolis	333,564
New York (A)	178,332
New York (B)	70,041
Oakland	36,036
Salt Lake City	221,760
Seattle	403,788
Washington	144,144

TABLE G-3
CURRENT SECTORS AUTHORIZED FOR 1985

NATIONAL RESECTORIZATION PROGRAM ATO-330 DATE 11-21-85

FACILITY I.D.	FULL-TIME	PART-TIME	NON-RADAR	OCEAN	AREAS	PRE-STRIKE	RESECTOR-IZATION	CURRENT AUTHORIZED
1. ZTL	45	0	0	0	6	43	39	45
2. ZJX	29	0	0	0	5	37	25	29
3. ZMA	19	3	0	2	4	31	20	24
4. ZME	28	0	0	0	5	36	28	28
5. ZID	24	3	0	0	4	35	22	27
6. ZOB	37	1	0	0	6	47	34	38
7. ZAU	36	6	0	0	6	44	31	42
8. ZMP	28	1	0	0	5	35	28	29
9. ZKC	34	1	0	0	5	37	27	35
10. ZAB	26	7	0	0	5	34	28	33
11. ZFW	37	0	0	0	5	40	34	37
12. ZHU	35	0	1	1	5	39	35	37
13. ZBW	24	0	0	0	4	32	24	24
14. ZNY*	25	0	1	4	6	44	29	30
15. ZDC*	32	6	0	0	6	36	30	38
16. ZLA	30	3	0	0	5	39	29	33
17. ZOA	22	1	0	7	5	29	24	30
18. ZDV	34	2	0	0	5	37	33	36
19. ZSE	23	1	0	0	4	25	19	24
20. ZLC	19	3	0	0	3	21	19	22
TOTALS -	588	38	2	14	99	721	588	642

* ZNY + 3 departure sectors not included or authorized. MINUS WOODSTOWN.

* ZDC - Woodstown sector from New York Center.

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APPENDIX H

CALCULATION OF APPROACH CONTROL POSITIONS

This appendix contains the results of a spreadsheet used to determine the number of approach control positions needed in the period, 1995-2010. A description of the algorithm used to create this output is found in section 2.3.3.

TABLE H-1
APPROACH CONTROL POSITIONS

ACF
Abuquerque

Approach Control Facilities		Peak Average Ratio Of Total Airport Operation	Rate of Traffic Increase	Airport Capacity (1000 IOs)	Instrument Operations (1000)					Terminal Level					Control Positions				
					1980	1990	1995	2000	2010	1982	1990	1995	2000	2010	1982	1990	1995	2000	2010
ALBUQUERQUE	ABQ	1.58	1.25	376	238	307	383	376	376	3	4	4	4	4	4	5	6	6	6
LAS VEGAS	LAS	1.62	1.13	690	426	593	670	690	690	4	5	5	5	5	7	8	9	9	9
PHOENIX	PHX	1.42	1.11	510	359	458	509	510	510	4	4	5	5	5	7	7	7	7	7
TUCSON	TUS	1.62	1.15	272	168	236	272	272	272	3	3	3	3	3	4	4	5	5	5
Totals (Gross)					1191	1594	1834	1848	1848						22	24	27	27	27
Adjustment for Consolidation															0	0	0	0	0
Adjustment for Sector Suite																0	0	-3	-3
Totals (Net)															22	24	27	24	24

TABLE H-1
(Continued)

ACF
Chicago

Approach Control Facilities		Peak Of Total Airport Operation	Rate of Traffic Increase	Airport Capacity (1000 IOs)	Instrument Operations (1000)					Terminal Level					Control Positions				
					1980	1990	1995	2000	2010	1982	1990	1995	2000	2010	1982	1990	1995	2000	2010
Chicago				1563	1043	1575	1743	1488	1563	5	5	5	5	5	8	13	13	13	13
Chicago	ORD	1.19	1.09	873	734	1115	1213	873	873										
Aurora	ARR	2.44	1.23	388	159	219	269	330	388										
Dupage	DPA	2.27	1.16	54	24	32	37	43	54										
Midway	MDW	1.74	1.01	153	88	152	153	153	153										
Pal-Waukee	PWK	2.46	1.25	93	38	57	71	88	93										
21 GA Towers																			
Grand Rapids	GRR	2.22	1.27	286	129	184	233	286	286	3	3	3	3	3	3	3	4	5	5
3 GA Towers																			
Kalamazoo				271	112	152	174	199	261	3	3	3	3	3	2	2	2	4	5
Kalamazoo	AZO	2.31	1.15	217	94	122	140	161	212										
Battle Creek	BTL	3.00	1.13	54	18	30	34	39	49										
4 GA Towers																			
Lafayette	LAF	2.41	1.28	58	24	40	51	58	58	2	2	2	2	2	1	1	2	2	2
4 GA Towers																			
Madison	MSN	2.60	1.20	348	134	193	231	276	349	3	3	3	3	4	1	4	4	5	5
3 GA Towers																			
Milwaukee	MKE	1.94	1.21	545	281	392	473	545	545	3	4	4	5	5	5	6	7	7	7
8 GA Towers																			
Muskegon	MKG	2.47	1.25	138	56	92	115	138	138	2	2	3	3	3	2	2	2	2	2
4 GA Towers																			
Rockford				977	298	400	462	534	712	4	4	4	5	5	2	6	7	7	9
Rockford	RFD	3.27	1.16	487	149	200	231	267	356										
Janesville	JVL	3.29	1.16	490	149	200	231	267	356										
8 GA Towers																			
South Bend				346	153	213	258	313	346	3	3	3	4	4	3	4	5	5	5
South Bend	SBN	2.23	1.21	319	143	199	240	289	319										
Benton Harbor	BEH	2.74	1.29	27	10	14	18	23	27										
12 GA Towers																			
Totals (Gross)					2230	3241	3740	3830	4258						27	41	46	50	53
Adjustment for Consolidation															0	0	0	-3	-3
Adjustment for Sector Suite																0	0	-5	-5
Totals (Net)															27	41	46	42	45

TABLE H-1
(Continued)

ACF
Denver

Approach Control Facilities		Peak Of Total Airport Operation	Rate of Traffic Increase	Airport Capacity (1000 IOs)	Instrument Operations (1000)					Terminal Level					Control Positions				
					1980	1990	1995	2000	2010	1982	1990	1995	2000	2010	1982	1990	1995	2000	2010
Amarillo	AMA	2.20	1.39	249	113	99	138	192	249	3	3	3	3	3	2	2	2	3	5
5 GA Towers																			
Casper	CPR	2.17	1.17	54	25	36	42	49	54	2	2	2	2	2	2	2	2	2	2
Cheyenne	CYS	2.05	1.15	47	23	33	38	44	47	2	2	2	2	2	1	1	1	1	2
Colorado Springs	COS	1.67	1.13	202	121	166	187	202	202	3	3	3	3	3	3	3	3	4	4
Denver	DEN	1.29	1.07	746	578	700	746	746	746	5	5	5	5	5	7	9	10	10	10
2 GA Towers																			
El Paso	ELP	1.66	1.27	274	165	218	277	274	274	3	3	3	3	3	3	4	5	5	5
1 GA Tower																			
Grand Junction	GJT	2.24	1.26	34	15	23	29	34	34	2	2	2	2	2	1	1	1	1	1
Lubbock	LBB	1.75	1.29	499	285	263	338	434	499	3	3	4	4	5	5	5	5	7	7
1 GA Tower																			
Odessa	MAF	1.73	1.59	220	127	126	200	220	220	3	3	3	3	3	2	2	4	[illegible]	4
4 GA Towers																			
Pueblo	PUB	3.80	1.25	129	34	51	64	80	126	2	2	2	2	3	2	2	2	2	2
Roswell	ROW	2.79	1.31	59	21	29	38	50	59	2	2	2	2	2	1	1	1	2	2
Totals (Gross)					1507	1744	2097	2325	2509						29	32	36	41	44
Adjustment for Consolidation															0	0	-4	-4	-4
Adjustment for Sector Suite																0	-3	-4	-4
Totals (Net)															29	32	29	33	36

TABLE H-1
(Continued)

ACF
Cleveland

Approach Control Facilities		Peak Average Airport Operation	Traffic Increase	Capacity (1000 IOs)	Instrument Operations (1000)					Terminal Level					Control Positions				
					1980	1990	1995	2000	2010	1982	1990	1995	2000	2010	1982	1990	1995	2000	2010
Canton-Akron	CAK	1.99	1.14	299	159	211	241	275	299	3	3	3	3	4	2	4	4	5	5
10 GA Towers																			
Cleveland				774	384	549	646	738	774	4	5	5	5	5	5	7	9	10	10
Cleveland	CLE	1.77	1.15	632	357	500	574	632	632										
Burke	BKL	5.25	1.47	142	27	49	72	106	142										
8 GA Towers																			
Detroit				890	580	758	849	804	890	5	5	5	5	5	8	10	11	12	12
Detroit	DTW	1.38	1.10	638	462	579	638	638	638										
Detroit City	DET	1.83	1.11	92	50	72	80	89	92										
Willow Run	YIP	2.05	1.26	70	34	46	58	70	70										
Pontiac	PTK	2.18	1.20	92	42	61	73	87	92										
12 GA Towers																			
Erie	ERI	2.70	1.20	248	92	132	159	192	248	2	3	3	3	3	2	2	2	3	5
5 GA Towers																			
Flint	FNT	2.53	1.23	314	124	186	229	282	314	3	3	3	3	4	1	3	4	5	5
4 GA Towers																			
Jackson	JXN	3.04	1.24	88	29	46	57	71	88	2	2	2	2	2	1	2	2	2	2
1 GA Tower																			
Lansing	LAN	2.27	1.30	291	128	185	240	291	291	3	3	3	3	3	2	3	4	5	5
3 GA Towers																			
Mansfield	MFD	2.42	1.23	94	39	60	74	91	94	2	2	2	2	2	2	2	2	2	2
7 GA Towers																			
Pittsburgh				756	544	723	734	741	756	5	5	5	5	5	6	10	10	10	10
Pittsburgh	PIT	1.33	1.01	670	504	665	670	670	670										
Allegheny	AGC	2.14	1.10	86	40	58	64	71	86										
8 GA Towers																			
Saginaw	MBS	2.44	1.18	242	99	135	159	187	242	3	3	3	3	3	2	2	2	3	4
9 GA Towers																			
Toledo	TOL	1.92	1.21	257	134	200	242	257	257	3	3	3	3	3	4	4	4	5	5
13 GA Towers																			
Youngstown	YNG	2.23	1.21	250	112	159	192	232	250	3	3	3	3	3	3	3	3	4	5
8 GA Towers																			
Totals (Gross)					2423	3344	3822	4240	4502						38	52	57	66	70
Adjustment for Consolidation															0	0	0	−4	−4
Adjustment for Sector Suite																0	0	−6	−7
Totals (Net)															38	52	57	56	59

TABLE H-1
(Continued)

ACT
New York

Approach Control Facilities		A Peak Average Ratio	Rate of Of Total Airport Operations	Airport Capacity	Instrument Operations (1000) 1980	1990	1995	2000	2010	Terminal Level 1982	1990	1995	2000	2010	Approach Positions 1982	1990	1995	2000	2010
Allentown	ABE	2.23	1.12	225	101	139	155	173	215	3	3	3	3	3	2	2	2	2	4
7 GA Towers																			
Atlantic City	ACY	2.87	1.12	350	122	163	182	203	253	3	3	3	3	3	2	2	3	4	5
9 GA Towers																			
Harrisburg				446	185	284	320	355	431	4	5	5	5	5	3	4	5	5	6
Harrisburg	CXY	2.57	1.15	332	129	182	209	240	316										
Lancaster	LNS	2.05	1.21	39	19	22	35	39	39										
Middleton	MDT	2.95	1.04	76	37	73	76	76	76										
9 GA Towers																			
New York				1668	1163	1415	1555	1553	1617	5	5	5	5	5	23	23	23	23	23
Bridgeport	BDR	2.42	1.12	44	18	26	29	32	40										
Farmingdale	FRG	1.84	1.14	28	15	21	24	27	25										
J.F. Kennedy	JFK	1.28	1.03	426	333	345	355	365	387										
La Guardia	LGA	1.32	1.14	536	406	512	546	556	536										
New Haven	HVN	2.00	1.14	29	14	22	25	25	28										
Islip	ISP	2.00	1.10	154	77	99	109	120	145										
Newark	EWR	1.37	1.09	322	225	293	318	322	322										
Teterboro	TEB	2.01	1.12	131	65	97	109	122	131										
18 GA Towers																			
Reading	RDG	4.39	1.26	114	25	46	58	73	114	2	2	2	2	3	2	2	2	2	2
Philadelphia				872	567	744	810	833	868	5	5	5	5	5	7	10	11	11	12
Philadelphia	PHL	1.35	1.06	662	491	675	663	663	662										
N. Philadelphia	PNE	4.00	1.24	84	21	34	42	52	79										
Trenton	TTN	2.62	1.20	60	23	35	42	59	60										
Wilmington	ILG	2.06	1.29	66	32	49	63	66	66										
White Plains	HPN	2.04	1.18	312	153	232	274	312	312	3	3	3	4	4	3	4	5	5	5
1 GA Tower																			
Wilkes Barre	AVP	2.80	1.20	126	45	87	104	124	126	2	2	3	3	3	2	2	2	2	2
4 GA Towers																			
Williams Port	IPT	2.69	1.21	65	24	39	43	57	65	2	2	2	2	2	1	1	2	2	2
Totals (Gross)					2385	3149	3505	3682	4001						45	50	55	56	61
Adjustment for Consolidation															0	0	0	-4	-4
Adjustment for Sector Suite																0	0	-5	-6
Totals (Net)															45	50	55	47	51

TABLE H-1
(Continued)

ACF
Houston

Approach Control Facilities		Peak Of Total Airport Operation	Rate of Traffic Increase	Airport Capacity (1000 IOs)	Instrument Operations (1000)					Terminal Level					Control Positions				
					1980	1990	1995	2000	2010	1982	1990	1995	2000	2010	1982	1990	1995	2000	2010
Baton Rouge	BTR	1.60	1.26	194	121	154	194	194	194	2	3	3	3	3	2	2	4	4	4
Brownsville				119	44	59	68	79	85	2	2	2	2	2	1	2	2	2	2
Brownsville	BRO	2.07	1.19	64	31	43	51	60	64										
Harlingen	HRL	4.19	1.06	54	13	16	17	18	20										
Corpus Christi	CRP	2.12	1.24	390	184	185	230	286	390	3	3	3	3	4	4	4	4	5	6
3 GA Towers																			
Lafayette	LFT	2.02	1.63	368	162	224	364	368	368	3	3	4	4	4	3	4	5	5	5
6 GA Towers																			
McAllen	MFE	1.93	1.28	33	17	25	32	33	33	2	2	2	2	2	1	1	1	1	1
New Orleans	MSY	1.84	1.17	592	322	402	472	554	592	4	4	4	5	5	6	6	7	7	8
8 GA Towers																			
San Angelo	SJT	3.30	1.22	83	25	36	44	54	80	2	2	2	2	2	1	1	1	2	2
San Antonio	SAT	1.47	1.32	526	358	374	492	526	526	4	4	5	5	5	7	7	7	7	7
2 GA Towers																			
Totals (Gross)					1253	1459	1896	2093	2268						25	27	31	33	35
Adjustment for Consolidation															0	0	-2	-2	-2
Adjustment for Sector Suite																0	-3	-3	-3
Totals (Net)															25	27	26	28	30

TABLE H-1
(Continued)

ACF
Fort Worth

Approach Control Facilities		Peak Of Total Airport Operation	Rate of Traffic Increase	Airport Capacity (1000 IOs)	Instrument Operations (1000)					Terminal Level					Control Positions				
					1980	1990	1995	2000	2010	1982	1990	1995	2000	2010	1982	1990	1995	2000	2010
Abilene	ABI	1.85	1.18	113	61	78	92	109	113	2	2	2	3	3	2	2	2	2	2
1 GA Tower																			
Alexandria	AEX	2.04	1.31	31	15	26	34	31	31	2	2	2	2	2	4	4	4	4	4
15 GA Towers																			
Austin	AUS	1.83	1.46	324	177	214	313	324	324	3	3	4	4	4	4	4	5	5	5
15 GA Towers																			
Beaumont	BPT	1.86	1.32	203	109	91	120	158	203	3	2	3	3	3	2	2	2	2	4
5 GA Towers																			
College Station	CLL	2.27	1.25	48	21	28	35	44	48	2	2	2	2	2	1	1	1	1	2
4 GA Towers																			
Dallas				1201	946	1243	1380	1201	1201	5	5	5	5	5	13	13	13	13	13
Dallas	DFW	1.18	1.10	884	749	972	1067	884	884										
Addison	ADS	1.67	1.07	30	18	28	30	30	30										
Love	DAL	1.59	1.16	250	157	213	248	250	250										
Meachem	FTW	1.71	1.17	38	22	30	35	38	38										
6 GA Towers																			
Houston				1096	785	1240	1384	1096	1096	5	5	5	5	5	8	13	13	13	13
Houston	IAH	1.35	1.08	825	611	947	1019	825	825										
Hobby	HOU	1.56	1.25	271	174	293	365	271	271										
17 GA Towers																			
Lake Charles	LCH	2.17	1.32	202	93	120	158	202	202	2	3	3	3	3	2	2	2	4	4
5 GA Towers																			
Longview	GGG	2.14	1.78	146	68	68	121	146	146	2	2	3	3	3	2	2	2	2	2
6 GA Towers																			
Shreveport	SHE	2.36	1.26	354	150	156	196	246	354	3	3	3	3	4	3	3	4	4	5
1 GA Tower																			
Tyler	TYR	2.06	1.08	27	13	25	27	27	27	2	2	2	2	2	1	1	1	1	1
1 GA Tower																			
Waco	ACT	3.14	1.26	75	24	39	49	62	75	2	2	2	2	2	2	2	2	2	2
3 GA Towers																			
Totals (Gross)					2462	3228	3909	3644	3819						44	49	51	53	57
Adjustment for Consolidation															0	0	0	-4	-4
Adjustment for Sector Suite																0	0	-5	-5
Totals (Net)															44	49	51	44	48

TABLE H-1
(Continued)

ACT
Atlanta

Approach Control Facilities		Peak Average Ratio Of Total Airport Operation	Rate of Traffic Increase	Airport Capacity (1000 IOs)	Instrument Operations (1000)					Terminal Level					Control Positions				
					1980	1990	1995	2000	2010	1982	1990	1995	2000	2010	1982	1990	1995	2000	2010
Albany	ABY	2.54	1.14	66	26	35	40	46	60	2	2	2	2	2	1	1	1	2	2
Asheville	AVL	1.80	1.14	128	71	104	119	128	128	2	3	3	3	3	2	2	2	2	2
Atlanta				1070	879	1113	1252	1067	1070	5	5	5	5	5	13	13	13	13	13
Atlanta Inter	ATL	1.16	1.13	907	782	979	1105	907	907										
Dekalb	PDK	1.69	1.11	78	46	64	71	78	78										
Fulton	FTY	1.66	1.09	85	51	70	76	83	85										
Augusta	AGS	1.94	1.20	147	76	115	138	147	147	2	3	3	3	3	2	2	2	2	2
Birmingham				336	221	322	334	336	336	3	4	4	4	4	4	5	5	5	5
Birmingham	BHM	1.49	1.02	308	207	303	308	308	308										
Tuscaloosa	TCL	1.95	1.37	27	14	19	26	27	27										
Bristol	TRI	1.88	1.16	184	98	158	184	184	184	3	3	3	3	3	2	2	3	3	3
Chatanooga	CHA	2.73	1.15	325	119	176	203	234	311	3	3	3	3	4	2	3	4	4	5
Columbus	CSG	1.97	1.15	238	121	173	199	229	238	3	3	3	3	3	3	3	4	4	4
Greenvile				274	141	215	263	267	272	3	3	3	3	3	4	4	5	5	5
Greenvile	GSP	1.94	1.25	235	121	187	233	235	235										
Municipal	GMU	1.95	1.07	39	20	28	30	32	37										
7 GA Towers																			
Huntsville	HSV	2.21	1.16	270	122	164	191	222	270	3	3	3	3	3	3	3	3	4	5
6 GA Towers																			
Knoxville	TYS	1.84	1.15	261	142	206	236	261	261	3	3	3	3	3	3	4	4	5	5
4 GA Towers																			
Macon	MCN	2.15	1.17	269	125	184	215	251	269	3	3	3	3	3	3	3	4	5	5
9 GA Towers																			
Montgomery	MGM	1.74	1.13	224	129	173	195	220	224	3	3	3	3	3	3	3	4	4	4
Valdosta	VLD	2.24	1.15	92	41	54	62	71	92	2	2	2	2	2	3	3	3	3	3
5 GA Towers																			
Totals (Gross)					2311	3192	3631	3664	3862						48	51	57	61	63
Adjustment for Consolidation															0	0	0	7	-7
Adjustment for Sector Suite																0	0	-5	-6
Totals (Net)															48	51	57	49	50

TABLE H-1
(Continued)

ACF
Boston

Approach Control Facilities		Peak Of Total Airport Operation	Rate of Traffic Increase	Airport Capacity (1000 IOs)	Instrument Operations (1000)					Terminal Level					Control Positions				
					1980	1990	1995	2000	2010	1982	1990	1995	2000	2010	1982	1990	1995	2000	2010
Albany	ALB	2.04	1.18	359	176	258	305	359	359	3	3	4	4	4	3	5	5	5	5
5 GA Towers																			
Bangor	BGR	2.15	1.15	172	80	111	128	148	172	2	3	3	3	3	2	2	2	2	2
4 GA Towers																			
Binghamton	BGM	1.80	1.25	99	55	92	116	99	99	2	2	3	3	3	1	2	2	2	2
1 GA Tower																			
Boston				806	524	689	784	809	822	5	5	5	5	5	8	9	10	11	11
Boston	BOS	1.51	1.14	738	459	633	722	738	738										
Bedford	BED	1.89	1.08	51	27	38	41	44	51										
Lawrence	LWM			1	0	6	8	12	16										
Norwood	OWD	2.02	1.08	16	8	12	13	14	16										
8 GA Towers																			
Buffalo				356	215	299	321	324	328	3	4	4	4	4	3	5	5	5	5
Buffalo	BUF	1.52	1.07	293	193	273	293	293	293										
Niagra Falls	IAG	2.83	1.08	62	22	26	28	30	35										
3 GA Towers																			
Burlington	BTV	1.88	1.11	250	133	170	168	208	250	3	3	3	3	3	3	3	3	4	5
3 GA Towers																			
Elmira				291	65	92	106	122	162	2	2	3	3	3	2	2	2	2	2
Elmira	ELM	4.90	1.15	235	48	67	77	88	117										
Ithaca	ITH	3.29	1.16	56	17	25	29	34	45										
2 GA Towers																			
Falmouth	FMH	3.52	1.09	282	80	96	105	115	137	2	2	3	3	3	3	3	3	3	3
Portland	PWM	2.13	1.26	207	97	161	203	207	207	2	3	3	3	3	3	3	4	4	4
6 GA Towers																			
Quonset	OQU			120	62	85	97	107	118	2	2	2	3	3	3	3	3	3	3
Groton	GON	2.26	1.08	18	8	12	13	14	17										
New Bedford	EWB	2.31	1.28	25	11	18	23	25	25										
Providence	PVD	1.77	1.11	76	43	55	61	68	76										
9 GA Towers																			
Rochester	ROC	2.81	1.21	377	134	197	239	290	377	3	3	3	3	4	3	4	4	5	6
6 GA Towers																			
Rome				957	115	181	214	240	306	3	3	3	3	4	3	3	4	4	5
Griffis AFB	RME	10.00	1.18	890	89	125	147	173	239										
Utica	UCA	2.59	1.20	67	26	56	67	67	67										
1 GA Tower																			
Syracuse	SYR	2.54	1.15	394	155	219	251	288	378	3	3	3	3	4	3	4	5	5	6
4 GA Towers																			
Windsor Locks				654	372	542	621	635	646	4	5	5	5	5	5	7	8	8	9
Windsor Locks	BDL	1.67	1.14	538	322	471	538	538	538										
Hartford	HFD	2.04	1.16	27	13	19	22	25	27										
Westfield	BAF	2.50	1.11	50	20	28	31	34	42										
Worcester	ORH	2.36	1.25	40	17	24	30	38	40										
6 GA Towers																			
Totals (Gross)					2263	3193	3678	3949	4361						45	55	60	63	63
Adjustment for Consolidation															0	0	0	−6	−6
Adjustment for Sector Suite																0	0	−6	−6
Totals (Net)															45	55	60	51	56

TABLE H-1
(Continued)

ACF
Los Angeles

Approach Control Facilities		Peak Of Total Airport Operation	Rate of Traffic Increase	Airport Capacity (1000 IOs)	Instrument Operations (1000)					Terminal Level					Control Positions				
					1980	1990	1995	2000	2010	1982	1990	1995	2000	2010	1982	1990	1995	2000	2010
Burbank				568	351	395	562	568	568	4	4	5	5	5	4	6	7	8	8
Burbank	BUR	1.62	1.47	510	315	343	505	510	510										
Van Nuys	VNY	1.59	1.10	57	35	52	57	57	57										
Los Angeles	LAX	1.22	1.01	664	544	535	542	549	564	5	5	5	5	5	6	7	7	7	7
2 GA Towers																			
Ontario					114	183	227	283	303	3	3	3	3	4	5	5	5	5	5
Chino	CNO	3.53	1.23	32	9	13	16	20	30										
El Monte	EMT	1.76	1.07	19	11	15	16	17	19										
La Verne	POC	1.90	1.10	29	15	21	23	25	29										
Ontario	ONT	2.85	1.28	225	79	134	172	221	225										
3 GA Towers																			
Palm Springs	PSP	2.54	1.20	221	87	128	154	185	221	2	3	3	3	3	2	2	2	3	4
1 GA Tower																			
San Diego				333	433	558	626	624	624	5	5	5	5	5	8	8	8	8	8
San Diego	SAN	1.61	1.13	243	151	215	243	243	243										
Carlsbad	CRQ	1.56	1.00	56	36	57	57	56	56										
Montgomery	MYF	1.54	1.00	34	22	38	38	34	34										
Navy		1.30	1.16	291	224	248	288	291	291										
4 GA Towers																			
Coast Tracon					207	379	570	352	352	4	5	5	5	5	8	8	8	8	8
Santa Anna	SNA	1.74	1.74	191	110	235	410	191	191										
Long Beach	LGB	1.66	1.10	139	84	126	139	139	139										
Torrence	TOA	1.64	1.17	21	13	18	21	21	21										
1 GA Tower																			
Santa Barbara	SBA	2.06	1.20	76	37	60	72	76	76	2	2	2	2	2	2	2	2	2	2
Totals (Gross)					1422	2238	2753	2637	2708						35	38	39	41	42
Adjustment for Consolidation															0	0	-2	-2	-2
Adjustment for Sector Suite																0	-4	-4	-4
Totals (Net)															35	38	33	35	36

TABLE H-1
(Continued)

ACF
Kansas City

Approach Control Facilities		Peak Of Total Airport Operation	Rate of Traffic Increase	Airport Capacity (1000 IOs)	Instrument Operations (1000)					Terminal Level					Control Positions				
					1980	1990	1995	2000	2010	1982	1990	1995	2000	2010	1982	1990	1995	2000	2010
Bruns Flat	CSM	3.39	1.12	47	14	17	19	21	27	2	2	2	2	2	1	1	1	1	1
3 GA Towers																			
Champaign				448	149	215	261	317	447	3	3	3	4	4	2	4	5	5	7
Champaign	CMI	2.96	1.20	346	117	169	202	241	345										
Danville	DNV	4.14	1.33	33	8	12	16	21	33										
Decatur	DEC	2.86	1.26	69	24	34	43	54	69										
1 GA Tower																			
Columbia	COU	2.26	1.35	59	26	43	58	59	59	2	2	2	2	2	1	1	2	2	2
3 GA Tower																			
Fayetteville	FYV	2.15	1.20	75	35	45	54	65	75	2	2	2	2	2	1	2	2	2	2
5 GA Towers																			
Fort Smith	FSM	1.91	1.60	130	68	81	130	130	130	2	2	3	3	3	1	2	2	2	2
2 GA Towers																			
Hutchinson	HUT	2.17	1.30	48	22	37	48	48	48	2	2	2	2	2	1	1	2	2	2
2 GA Towers																			
Joplin	JLN	3.34	1.33	57	17	27	36	48	57	2	2	2	2	2	1	1	1	2	2
Kansas City					387	537	610	614	614	4	5	5	5	5	5	7	8	8	8
Kansas City	MCI	1.56	1.13	505	324	446	505	505	505										
K. C. Muni.	MKC	1.73	1.15	109	63	91	105	109	109										
9 GA Towers																			
Little Rock	LIT	1.14	1.00	233	204	233	233	233	233	3	3	3	3	3	4	4	4	4	4
12 GA Towers																			
Oklahoma City				548	314	323	443	539	547	4	4	4	5	5	4	5	7	7	7
Oklahoma City	OKC	1.74	1.40	501	288	291	408	501	501										
Wiley Post	PWA	1.79	1.09	47	26	32	35	33	46										
5 GA Towers																			
Peoria	PIA	2.20	1.13	246	112	156	176	199	246	3	3	3	3	3	2	2	3	4	4
4 GA Towers																			
Saligna	SLN	2.02	1.03	38	19	37	38	38	38	2	2	2	2	2	1	1	1	1	1
St. Joseph	STJ	2.31	1.32	25	11	19	25	25	25	2	2	2	2	2	1	1	1	1	1
St. Louis	STL	1.71	1.10	752	440	495	544	598	722	4	5	5	5	5	6	7	7	8	10
2 GA Towers																			
Springfield, Il.	SPI	2.02	1.21	218	198	162	196	218	218	3	3	3	3	3	2	2	4	4	4
7 GA Towers																			
Springfield, Mo	SGF	1.99	1.13	86	43	76	86	86	86	2	2	2	2	2	2	2	2	2	2
3 GA Towers																			
Tulsa	TUL	1.57	1.43	316	201	221	316	316	316	3	3	4	4	4	3	4	5	5	5
4 GA Towers																			
Wichita	ICT	1.61	1.07	319	198	299	319	319	319	3	4	4	4	4	3	5	5	5	5
10 GA Towers																			
Totals (Gross)					2368	3023	3592	3872	4206						41	52	62	65	69
Adjustment for Consolidation															0	0	-4	-4	-4
Adjustment for Sector Suite																0	-6	-6	-6
Totals (Net)															41	52	52	55	59

TABLE H-1
(Continued)

ACF
Minneapolis

Approach Control Facilities		A Peak Average Ratio	Rate of Increase Of Total Airport Operations	Airport Capacity	Instrument Operations (1000)					Terminal Level									
					1980	1990	1995	2000	2010	1982	1990	1995	2000	2010	1982	1990	1995	2000	2010
Bismark	BIS	2.08	1.22	58	28	37	45	55	58	2	2	2	2	2	2	2	2	2	2
Cedar Rapids	CID	2.00	1.26	198	99	157	198	198	198	3	3	3	3	3	2	2	4	4	4
1 GA Tower																			
Des Moines	DSM	1.93	1.12	317	164	283	317	317	317	3	3	4	4	4	4	5	5	5	5
7 GA Towers																			
Duluth	DLH	3.13	1.20	185	59	82	98	117	167	2	2	3	3	3	2	2	2	2	2
6 GA Towers																			
Fargo	FAR	2.36	1.38	156	66	113	156	156	156	2	3	3	3	3	1	2	2	2	2
Green Bay				291	136	177	217	266	291	3	3	3	3	3	2	3	4	5	5
Green Bay	GRB	2.11	1.23	251	119	151	186	229	251										
Appleton	ATW	2.34	1.19	40	17	26	31	37	40										
6 GA Towers																			
La Crosse	LSE	2.12	1.27	53	25	33	42	53	53	2	2	2	2	2	1	1	1	2	2
3 GA Towers																			
Lincoln	LNK	2.07	1.25	217	105	174	217	217	217	3	3	3	3	3	2	2	4	4	4
1 GA Towers																			
Minneapolis	MSP	1.42	1.06	531	374	501	531	531	531	4	5	5	5	5	6	7	7	7	7
9 GA Towers																			
Moline	MLI	1.88	1.15	226	120	165	189	216	226	3	3	3	3	3	1	2	3	4	4
2 GA Towers																			
Minot	MOT	2.46	1.27	20	8	11	14	18	20	2	2	2	2	2	1	1	1	1	1
Omaha	OMA	1.77	1.20	143	81	119	143	143	143	2	3	3	3	3	4	4	4	4	4
8 GA Towers																			
Rochester	RST	2.30	1.22	179	78	90	110	134	179	2	2	3	3	3	2	2	2	2	3
2 GA Towers																			
Sioux City	SUX	1.69	1.27	70	37	55	70	70	70	2	2	2	2	2	2	2	2	2	2
2 GA Towers																			
Sioux Falls	FSD	2.43	1.17	180	74	103	121	142	180	2	3	3	3	3	2	2	2	2	3
6 GA Towers																			
Waterloo	ALO	2.07	1.23	70	34	57	70	70	70	2	2	2	2	2	2	2	2	2	2
6 GA Towers																			
Totals (Gross)					1488	2157	2538	2704	2876						36	41	47	50	52
Adjustment for Consolidation															0	0	-9	-9	-9
Adjustment for Sector Suite																0	-4	-4	-4
Totals (Net)															36	41	34	37	39

TABLE H-1
(Continued)

					ACF Memphis														
Approach Control Facilities		A Peak Average Ratio	Rate of Of Total Airport Operations	Airport Capacity	Instrument Operations (1000)					Terminal Level									
					1980	1990	1995	2000	2010	1982	1990	1995	2000	2010	1982	1990	1995	2000	2010
Gulfport	GPT	2.26	1.16	183	81	114	132	153	183	3	3	3	3	3	2	2	2	2	3
3 GA Towers																			
Jackson	JAN	2.16	1.25	270	125	192	240	270	270	3	3	3	3	3	2	3	4	5	5
3 GA Towers																			
Memphis	MEM	1.42	1.05	527	371	502	527	527	527	4	5	5	5	5	6	7	7	7	7
7 GA Towers																			
Meridan					90	103	109	115	129	2	3	3	3	3	3	3	3	3	3
Meridan	MEI	3.25	1.06	293	90	103	109	115	129										
3 GA Towers																			
Mobile	MOB	1.76	1.13	211	120	165	187	211	211	3	3	3	3	3	2	2	3	4	4
4 GA Towers																			
Nashvilee	BNA	1.46	1.00	372	255	389	389	372	372	3	4	4	4	4	5	6	6	6	6
4 GA Towers																			
Panama City	PFN	1.89	1.15	49	26	34	39	45	49	2	2	2	2	2	7	7	7	7	7
Pensacola	PNS	1.71	1.54	563	329	365	563	563	563	4	4	5	5	5	7	7	7	7	7
Tallahasse	TLH	1.68	1.16	81	48	145	168	81	81	3	3	3	2	2	2	2	2	2	2
4 GA Towers																			
Totals (Gross)					1445	2009	2354	2336	2385						36	39	41	43	44
Adjustment for Consolidation															0	0	0	−4	−4
Adjustment for Sector Suite																0	0	−4	−4
Totals (Net)															35	39	41	35	36

TABLE H-1
(Continued)

ACF
Jacksonville

Approach Control Facilities		Peak Of Total Airport Operation	Rate of Traffic Increase	Airport Capacity (1000 IOs)	Instrument Operations (1000)					Terminal Level					Control Positions				
					1980	1990	1995	2000	2010	1982	1990	1995	2000	2010	1982	1990	1995	2000	2010
Charlestown	CHS	1.86	1.11	259	139	180	200	222	259	3	3	3	3	3	2	3	4	4	5
5 GA Towers																			
Columbia	CAE	1.80	1.14	239	133	194	221	239	239	3	3	3	3	3	2	4	4	4	4
2 GA Towers																			
Daytona Beach	DAB	2.20	1.17	317	144	206	242	284	317	3	3	3	3	4	4	4	4	5	5
4 GA Towers																			
Florence	FLO	2.12	1.28	61	29	47	60	61	61	2	2	2	2	2	1	2	2	2	2
4 GA Towers																			
Jacksonville	JAX	1.76	1.12	530	301	395	444	499	530	4	4	4	5	5	6	6	7	7	7
2 GA Towers																			
Orlando				625	362	522	604	625	625	4	5	5	5	5	6	7	8	8	8
Orlando	MCO	1.76	1.17	570	324	470	550	570	570										
Orlando Exec.	ORL	1.43	1.04	54	38	52	54	54	54										
3 GA Towers																			
Savannah	SAV	1.60	1.14	218	136	190	216	218	218	3	3	3	3	3	3	3	4	4	4
1 GA Tower																			
Tampa				799	511	703	795	798	799	5	5	5	5	5	5	9	11	11	11
Tampa	TPA	1.59	1.14	706	444	617	706	706	706										
Sarasota	SRQ	1.24	1.00	55	44	55	55	55	55										
St. Petersburg	PIE	1.69	1.10	39	23	31	34	37	39										
9 GA Towers																			
Totals (Gross)					1755	2437	2782	2946	3048						29	38	44	45	45
Adjustment for Consolidation															0	0	0	-3	-3
Adjustment for Sector Suite																0	0	-4	-4
Totals (Net)															29	38	44	38	39

TABLE H-1
(Continued)

ACF
Indianapolis

Approach Control Facilities		Peak Of Total Airport Operation	Rate of Traffic Increase	Airport Capacity (1000 IOs)	Instrument Operations (1000)					Terminal Level					Control Positions				
					1980	1990	1995	2000	2010	1982	1990	1995	2000	2010	1982	1990	1995	2000	2010
Columbus				672	348	493	571	659	672	4	5	5	5	5	6	7	8	9	9
Columbus	CMH	1.87	1.15	606	324	458	528	606	606										
Ohio ST	DSU	2.75	1.23	66	24	35	43	53	66										
11 GA Towers																			
Cincinnati				408	247	352	385	401	408	3	4	4	4	4	4	5	6	6	6
Cincinnati	CVG	1.52	1.07	316	208	296	316	316	316										
Lunken	LUK	2.35	1.23	92	39	56	69	85	92										
6 GA Towers																			
Dayton	DAY	2.98	1.14	334	280	333	381	436	571	2	4	4	4	5	5	5	6	7	8
13 GA Towers																			
Evansville	EVV	2.12	1.23	233	110	168	206	233	233	3	3	3	3	3	3	3	4	4	4
8 GA Towers																			
Ft. Wayne	FWA	2.05	1.20	281	137	203	244	281	281	3	3	3	3	3	2	4	4	5	5
6 GA Towers																			
Huntington	HTS	2.34	1.20	166	71	103	124	149	166	2	3	3	3	3	2	2	2	2	2
4 GA Towers																			
Indianapolis				541	299	430	500	530	535	3	4	5	5	5	5	7	7	7	7
Indianapolis	IND	1.77	1.17	508	287	412	480	508	508										
Bloomington	BMG	2.75	1.11	32	12	18	20	22	27										
14 GA Towers																			
Lexington	LEX	2.02	1.15	244	121	178	204	234	244	3	3	3	3	3	3	3	4	4	4
9 GA Towers																			
Louisville	SDF	1.63	1.09	337	207	310	337	337	337	3	4	4	4	4	4	5	5	5	5
1 GA Tower																			
Terre Haute	HUF	2.24	1.16	83	37	51	59	68	83	2	2	2	2	2	2	2	2	2	2
8 GA Towers																			
Totals (Gross)					1509	2128	2440	2670	2859						36	43	48	51	52
Adjustment for Consolidation															0	0	0	-4	-4
Adjustment for Sector Suite																0	0	-5	-5
Totals (Net)															36	43	48	42	43

TABLE H-1
(Continued)

			Rate of		ACF Seattle														
Approach Control Facilities		A Peak Average Ratio	Of Total Airport Operations	Airport Capacity	Instrument Operations (1000) 1980	1990	1995	2000	2010	Terminal Level 1982	1990	1995	2000	2010	Approach Positions 1982	1990	1995	2000	2010
Billings	BIL	1.81	1.16	176	97	150	174	176	176	2	3	3	3	3	2	2	2	2	2
Boise	BOI	1.93	1.07	284	147	187	200	214	245	3	3	3	3	3	2	3	4	4	4
Eugene	EUG	1.76	1.13	79	45	63	71	79	79	2	2	2	2	2	2	2	2	2	2
Great Falls				161	80	98	105	113	130	2	3	3	3	3	1	2	2	2	2
Great Falls	GTF	2.06	1.03	49	24	30	31	32	34										
Malmstrom	GFA	2.00	1.09	112	56	68	74	81	95										
Helena	HLN	2.40	1.20	29	12	15	18	22	29	2	2	2	2	2	1	1	1	1	1
Medford	MFR	2.44	1.35	59	24	40	54	59	59	2	2	2	2	2	1	1	2	2	2
Missoula	MSO	2.35	1.13	28	12	16	16	20	26	2	2	2	2	2	1	1	1	1	1
Moses Lake	MWH	2.53	1.33	61	24	39	52	61	61	2	2	2	2	2	1	1	2	2	2
1 GA Tower																			
Portland	PDX	1.50	1.10	453	302	411	453	453	453	4	4	4	4	4	3	6	7	7	7
7 GA Towers																			
Seattle				626	429	545	625	626	626	4	5	5	5	5	5	7	8	8	8
Seattle	SEA	1.36	1.12	499	367	446	499	499	499										
Seattle Boeing	BFI	2.04	1.27	126	62	99	126	126	126										
2 GA Towers																			
Spokane	GEG	1.88	1.14	248	132	218	240	248	248	3	3	3	3	3	2	4	5	5	5
2 GA Towers																			
Tacoma	TCM	2.00	1.12	246	123	161	181	203	246	3	3	3	3	3	2	2	3	4	4
5 GA Towers																			
Yakima	YKM	1.90	1.18	46	24	39	45	46	46	2	2	2	2	2	1	1	2	2	2
Totals (Gross)					1451	1982	2245	2318	2421						24	33	41	42	42
Adjustment for Consolidation															0	0	-6	-6	-6
Adjustment for Sector Suite																0	-4	-4	-4
Totals (Net)															24	33	32	32	32

TABLE H-1
(Continued)

ACF
Oakland

Approach Control Facilities		A Peak Average Ratio	Rate of Of Total Airport Operations	Airport Capacity	Instrument Operations (1000) 1980	1990	1995	2000	2010	Terminal Level 1982	1990	1995	2000	2010	Approach Positions 1982	1990	1995	2000	2010
Bakers Field	BFL	1.71	1.17	82	48	70	82	82	82	2	2	2	2	2	2	2	2	2	2
2 GA Towers																			
Fresno				176	101	139	163	172	172	3	3	3	3	3	3	3	3	3	3
Fresno	FAT	1.71	1.18	166	97	133	157	166	166										
Chandler	FCH	2.51	1.00	10	4	6	6	6	6										
4 GA Towers																			
Monterey	MRY	3.17	1.16	333	105	142	165	192	259	3	3	3	3	3	2	2	2	3	5
1 GA Tower																			
Oakland				852	605	694	743	760	768	5	5	5	5	5	10	10	10	10	10
Hayward	HWD	1.87	1.09	30	16	22	24	26	30										
Oak. Inter.	OAK	1.61	1.10	196	122	168	184	196	196										
San Fransico	SFO	1.23	1.01	459	373	367	369	371	375										
San Jose	SJF	1.77	1.21	166	94	137	166	166	165										
Sacramento				266	145	211	248	265	266	3	3	3	3	3	8	8	8	8	8
Marysville	MYV	2.27	1.33	14	6	9	12	14	14										
Sacram. Exec.	SAC	1.86	1.13	78	42	69	78	78	78										
Sacram. Metro	SMF	1.78	1.19	174	93	133	158	174	174										
4 GA Towers																			
Stockton				99	54	78	92	99	99	2	2	2	3	3		2	2	2	2
Stockton	SCK	1.88	1.20	79	42	60	72	79	79										
Modasto City	MOD	1.66	1.11	20	12	18	20	20	20										
3 GA Towers																			
Totals (Gross)					1059	1334	1493	1571	1546						25	27	27	28	30
Adjustment for Consolidation															0	0	-3	-3	-3
Adjustment for Sector Suite																0	-2	-3	-3
Totals (Net)															25	27	22	23	24

TABLE H-1
(Continued)

					ACF Miami														
Approach Control Facilities		A Peak Average Ratio	Rate of Of Total Airport Operations	Airport Capacity	Instrument Operations (1000)					Terminal Level									
					1980	1990	1995	2000	2010	1982	1990	1995	2000	2010	1982	1990	1995	2000	2010
Fort Lauderdale	FLL	1.39	1.06	443	319	418	443	443	443	4	4	4	4	4	4	6	7	7	7
5 GA Towers																			
Fort Meyers				86	56	72	80	86	88	2	2	2	2	2	2	2	2	2	2
Page Field	FMY	1.57	1.11	88	56	72	80	88	88										
3 GA Towers																			
Miami	MIA	1.34	1.10	931	695	840	925	931	931	5	5	5	5	5	11	11	12	12	12
Palm Beach	PBI	1.53	1.05	471	308	448	471	471	471	4	4	4	4	4	4	7	7	7	7
Puerto Rico	SJU	1.37	1.19	230	168	280	333	230	230	3	3	4	3	3	3	5	5	4	4
Virgin Islands	STT	1.53	1.11	35	23	38	42	35	35	2	2	2	2	2	2	2	2	2	2
Totals (Gross)					874	1256	1369	1268	1268						26	33	35	34	34
Adjustment for Consolidation															0	0	0	-1	-1
Adjustment for Sector Suite																0	0	-3	-3
Totals (Net)															26	33	35	30	30

TABLE H-1
(Continued)

ACF
Salt Lake City

Approach Control Facilities		A Peak Average Ratio	Rate of Of Total Airport Operations	Airport Capacity	Instrument Operations (1000)					Terminal Level					Approach Positions				
					1980	1990	1995	2000	2010	1982	1990	1995	2000	2010	1982	1990	1995	2000	2010
Edwards	EDW	4.00	1.04	1120	280	303	315	327	354	3	4	4	4	4	4	5	5	5	5
2 GA Towers																			
Reno	RNO	1.77	1.11	204	115	276	305	204	204	3	3	4	3	3	3	5	5	4	4
Salt Lake City	SLC	1.54	1.11	474	308	412	457	474	474	4	4	4	4	4	6	6	7	7	7
3 GA Towers																			
Totals (Gross)					703	991	1077	1005	4687						13	16	17	16	16
Adjustment for Consolidation															0	0	0	0	0
Adjustment for Sector Suite																0	-2	-2	-2
Totals (Net)															13	16	15	14	14

TABLE H-1
(Concluded)

Approach Control Facilities		A Peak Average Ratio	Rate of Of Total Airport Operations	Airport Capacity	ACF Washington Instrument Operations (1000)					Terminal Level					Approach Positions				
					1980	1990	1995	2000	2010	1982	1990	1995	2000	2010	1982	1990	1995	2000	2010
Baltimore	BWI	1.46	1.00	508	348	508	508	508	508	4	5	5	5	5	6	7	7	7	7
11 GA Towers																			
Camp Springs	ADW	2.00	1.06	292	146	154	164	175	196	3	3	3	3	3	4	4	4	4	4
5 GA Towers																			
Chantilly	IAD	1.72	1.10	447	260	408	447	447	447	3	4	4	4	4	5	6	7	7	7
7 GA Towers																			
Charleston	CRW	1.89	1.14	242	128	183	208	236	242	3	3	3	3	3	3	3	4	4	4
3 GA Towers																			
Charlotte	CLT	1.48	1.20	437	295	441	527	437	437	4	4	5	4	4	5	7	7	7	7
9 GA Towers																			
Clarksburg				166	47	71	86	104	147	2	2	2	3	3	2	2	2	2	2
Clarksburg	CKB	3.95	1.24	138	35	51	63	78	119										
Morgantown	MGW	2.34	1.15	28	12	20	23	26	28										
2 GA Towers																			
Fayetteville	FAY	1.96	1.12	265	135	177	199	224	265	3	3	3	3	3	3	3	4	4	5
11 GA Towers																			
Greensboro				449	260	396	448	449	449	3	4	4	4	4	4	6	7	7	7
Greensboro	GSO	1.70	1.14	394	232	347	394	394	394										
Winston Salem	INT	1.94	1.10	54	28	49	54	54	54										
10 GA Towers																			
Norfolk				617	349	455	492	531	617	4	4	5	5	5	6	7	7	7	8
Norfolk	ORF	1.74	1.09	569	327	408	444	483	569										
Newport News	PHF	2.19	1.02	48	22	47	48	48	48										
10 GA Towers																			
Parkersburg	PKB	2.32	1.28	72	25	43	55	70	72	2	2	2	2	2	1	1	2	2	2
Raleigh-Durham	RDU	1.51	1.05	293	194	260	293	293	293	3	3	4	4	4	4	5	5	5	5
3 GA Towers																			
Richmond	RIC	1.81	1.14	300	166	237	270	300	300	3	3	3	4	4	3	4	5	5	5
4 GA Towers																			
Roanoke	ROA	2.38	1.25	283	119	181	226	282	283	3	3	3	3	3	3	3	4	5	5
4 GA Towers																			
Seymour Johnson AFB										2	2	2	2	2	1	1	1	1	1
Kinston	ISO	2.93	1.16	41	14	19	22	25	34										
4 GA Towers																			
Washington D.C.	DCA	1.29	1.05	642	493	610	642	642	642	5	5	5	5	5	8	8	9	9	9
2 GA Towers																			
Wilmington	ILM	1.98	1.23	156	79	110	135	156	156	2	3	3	3	3	2	2	2	2	2
2 GA Towers																			
Totals (Gross)					3063	4273	4722	4881	5091						60	69	77	78	80
Adjustment for Consolidation															0	0	0	-5	-5
Adjustment for Sector Suite																0	0	-7	-7
Totals (Net)															60	69	77	66	68

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APPENDIX I

CALCULATION OF RADAR COVERAGE

I. CALCULATION OF RADAR COVERAGE

Radar coverage is the average number of radars detecting an aircraft at any one time. This value depends on the relative positions of the radars to each other as well as the altitude distribution of aircraft. Radar coverage is lowest where radars are spaced far apart and traffic is bunched in the low altitudes--below the radar horizon. Coverage is highest where radars are closely spaced and aircraft are assumed to be flying at high altitudes; aircraft over 27,000 feet can be detected at 200 nmi, the full range of a long range radar.

A value for radar coverage was calculated for every ACF. Because of the various uses of radar coverage values, the following categories of radar coverage were calculated:

IFR and VFR

Long range radars and short range radars

En Route airspace and terminal airspace

A total of eight radar coverage values was calculated using the FORTRAN program listed in this appendix.

I.1 Radar Coverage Algorithm

The algorithm for calculating radar coverage allows the determination of a value for any latitude/longitude location. The approach is to use the proximity of radars to the specified point and the altitude distribution of aircraft at that point to calculate the sum of the probabilities of being detected by the radars located within range of the point.

I.2 Sampling Plan

Each ACF was modeled as a number of radars, each with sea level latitude/longitude location and a maximum range. A set of 40-50 sample points, systematically located within the geographic boundaries of the controlled airspace, was selected. Using the following rules at each of these points, radar coverage was determined:

1. Each radar was assessed for range; long range radars must be closer than 200 nmi; Mode-S short range radars must be closer than 100 nmi.; non-Mode-S short range radars must be closer than 60 nmi:

2. ACF-As located above an ACF-B were not eligible to receive reports from short range radars.

3. Linear regression equations were created from both IFR and VFR maximum stress altitude distributions. The dependent variable is the proportion of aircraft above a certain altitude; the altitude being the independent variable. These equations were used by calculating, for each sample point, the lowest altitude surveilled by a radar. This altitude is used as the independent variable. The assumption was made that no IFR aircraft fly below 3000 feet. Therefore, although the altitude distribution equation for IFR can be evaluated at 0 altitude to yield a value higher than 1, the radar coverage program assumes that maximum radar coverage for that radar at that point is 1. The sum of contributions from all radars was determined to be the radar coverage at that sample point.

4. The coverage at each sample was used to calculate an average coverage for each of the eight radar coverage categories.

I.3 Determination of ACF-specific Values

The algorithm for calculating radar coverage required information on radar site location and samples of aircraft position. Latitude/longitude of all radars planned to be deployed[33] by 1995 were entered as were the latitude/longitude of sample aircraft positions. A typical output sheet is presented in Figure I.3-1. ACF-specific radar coverage values can be seen in Table 2.3.6-2.

```
                    En Route Radar Coverage Report

                                 MKC

   Long Range Radars Used              Short Range Radars Used
        GCK                                 CMI
        HBZ                                 COU
        HTI                                 DAK
        IA1                                 FSM
        IRK                                 ICT
        KS1                                 LIT
        KS2                                 MCI
        MO1                                 OKC
        NE1                                 PIA
        PUT                                 SGF
        QAF                                 SPI
        QHJ                                 STL
        QHO                                 TOP
        QUZ                                 TUL
        STL

The entire center was sampled with          58 points.

For IFR
          Average En Route Radar Coverage by LRR Radars was 3.73191
          Average En Route Radar Coverage by SRR Radars was 1.40451

IFR altitude distribution
                      0-6000    ft.        10%
                   6000-1250    ft         10%
                  12500-18000   ft.        10%
                  18000-26000   ft.        22%
                  26000 and up             34%

For VFR
          Average En Route Radar Coverage by LRR Radars was 1.09112
          Average En Route Radar Coverage by SRR Radars was 0.53985

VFR altitude distribution
                      0-6000   ft.         70%
                   6000-8000   ft.         20%
                   8000-12000  ft.         10%
```

FIGURE I.3-1
EXAMPLE OF RAD-COV OUTPUT

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APPENDIX J

ANALYSIS OF RADAR SITE DATA TO OBTAIN VFR/IFR TARGET RATIO

Radar-site-specific ratios of VFR to IFR targets are presented in Table J-1 with corresponding target counts, computed by examining beacon messages from CD-Record tapes. Each target count represents an average over 20 to 30 scans at a busy IFR hour for the ARTCC to which the radar site reports.

An adjustment was made to the VFR target count to account for the number of non-transponder-equipped VFR aircraft, since only beacon reports (with the assumption that non-discrete beacon are VFR aircraft) were considered from the source data. This adjustment was made by dividing the beacon-only VFR target count by the proportion of VFR traffic equipped with transponder. The maximum stress value for parameter 5, Table 2-1, Volume I (0.92) was used. For example, if 80 beacon-only VFR targets were counted, this count was adjusted upward via division by 0.92 (i.e., 80/.92 = 87) to account for the (uncounted) primary-only aircraft targets.

Table J-1 presents two columns of data. The first column contains ratios and target counts for the range 0-60 nmi from the radar site, i.e., only reports within a 60 nmi radius were used to produce these counts. This radius is used as an estimate of the short range radar surveillance area, as if a short range radar were sited at that location. Column two contains ratios and actual target counts for the long range radar sites. (One exception is the LAX site at ZLA ARTCC--it is a short range radar. Note that its surveillance range extends beyond 60 nmi.) A number of radar sites are presented. For the ARTCCs ZLA, ZDC, and ZNY, all of the reporting radars were evaluated, so that center-specific average ratios could be developed. Others sensors were also selected for this analysis, from various locations around the country.

Presented at the bottom of the table are the average and maximum of VFR/IFR target ratios for each column, average total targets (VFR + IFR) per scan, and center-specific average ratios.

TABLE J-1
VFR/IFR TARGET COUNTS AND RATIOS FOR 38 RADAR SITES*

Center:	Site	Range 0-60 nmi	Range 0-200 nmi
ZAB	PHX(Beacon-only)	.51 = 21.5/42.5	.24 = 33.7/141.1
ZBW	DSV	.30 = 10.9/36.2	.14 = 24.1/173.3
ZDC	HAL	.29 = 5.2/18.2	.06 = 10.5/165.3
	QCF	.01 = .22/21.8	.01 = 1.5/147.5
	QRC	.04 = 1.1/28.5	.05 = 8.4/167.1
	QDP	.36 = 27.9/77.5	.16 = 32.8/204.8
	QBA	.49 = 13.3/27.2	.27 = 14.9/55.0
	QHA	.26 = 6.5/25.1	.15 = 15.0/100.1
	QYA	.36 = 28.2/78.3	.16 = 32.7/204.3
ZFW	FTW	.92 = 55.8/60.5	.43 = 81.4/191.1
ZHU	QZA	.31 = 3.2/10.3	.17 = 11.2/65.4
ZKC	STL	.87 = 46.4/53.2	.41 = 75.9/186.3
ZLA	CDC	.28 = 3.2/11.4	.16 = 13.4/81.7
	TPH	.11 = 1.2/10.8	.07 = 4.7/65.4
	QAS	.30 = 6.3/20.8	.15 = 13.4/91.4
	PRB	.55 = 15.9/24.2	.29 = 35.1/120.5
	QRW	1.34 = 40.8/28.2	.67 = 90.8/134.8
	QSR	.78 = 25.4/32.5	.31 = 40.3/127
	QLA	.68 = 51.2/75.6	.37 = 63.0/168.2
	LAX	.56 = 93.2/165.8	.44 = 96.1/217.3
ZMA	FTL	.76 = 34.2/45.1	.37 = 52.7/141.8
ZMP	EGV	.14 = .34/2.4	.01 = .33/32.6
	QJC	.56 = 4.9/8.7	.17 = 11.9/70.1
	QJE	.14 = 5.3/37.5	.07 = 6.2/88.3
	QHO	.34 = 6.6/19.4	.15 = 15.1/100.4
	QJD	.00 = 0/.6	.01 = 0.2/22.2
	IRK	.22 = 3.2/14.6	.11 = 13.6/123.3
	QHZ	.24 = 8.1/33.7	.06 = 11.6/192.7
	QWA	3.06 = 3.7/1.2	.26 = 4.1/15.9

---

*Table entries are of the form: $\text{Ratio} = \dfrac{\text{VFR target count (beacon plus primary)}}{\text{IFR target count (beacon only)}}$

TABLE J-1
(Concluded)

Center:	Site	Range 0-60 nmi	Range 0-200 nmi
ZMP (Concluded)			
	QFI	1.06 = 11.9/11.2	.18 = 12.6/70.2
	QJA	.09 = .32/3.6	.01 = .7/70.4
	QJB	1.05 = 2.1/2	.22 = 7.3/33.3
	QJM	.33 = 3.9/11.8	.07 = 7.1/101.1
ZNY	QVH	.33 = 12.6/38.0	.16 = 22.0/135.6
	QPL	.44 = 21.5/48.6	.18 = 36.9/204.0
ZSE	SEA	.59 = 19.5/33.2	.38 = 21.1/55.4
ZTL	ATL	.10 = 9.5/93.9	.06 = 13.9/251.6
	MGM	.20 = 6.0/29.5	.08 = 13.0/165.0
Average Ratio (all sites in table)		0.48	0.19
Maximum Ratio (over all sites in table)		3.06	0.67
Average Targets (VFR+IFR) per scan (all sites in table)		50	155
Average Ratios for Centers			
ZLA**		.64	.35
ZMP		.34	.08
ZDC		.30	.12

**Center with largest average ratio.

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APPENDIX K

CALCULATION OF ARTCC-SPECIFIC RADAR MESSAGE RATES

Determination of the radar message workload for the Host/ISSS years for IFR aircraft is similar to the method used for the consolidation period. Exceptions include that: 1) apportionment of forecasted traffic to high and low altitude strata is not necessary, 2) the apportionment of adjacent facility aircraft counts for the Host/ISSS period will be different than that for the consolidation period, and 3) approach control traffic is not handled by the ARTCCs.

The number of aircraft detected by ARTCC radars which are outside of the center boundaries is determined by:

1. calculating the aircraft density in each of the adjacent centers (i.e., aircraft per 100 mi^2).
2. estimating the average density of aircraft outside the ARTCC.
3. multiplying the average aircraft density by the "outside" area of the ARTCC.

The average aircraft density is calculated by dividing the average IFR and VFR count for each ARTCC (Table K-1) by their respective areas. The average density of traffic outside the ARTCC is estimated by apportionment of the aircraft densities of the adjacent ACFs. Table K-2 shows the percentage of each of the adjacent facility aircraft densities used to calculate the average aircraft density of the aircraft outside of the ARTCC. The table shows that the aircraft density outside of the Boston ARTCC is equal to 80% of the aircraft density of the New York ARTCC plus 20% of that of the Cleveland ARTCC. Table K-3 shows some of the calculations used to calculate the number of outside IFR and VFR aircraft.

The calculations performed are identical to those performed in Appendix L for the consolidation period. Table K-3 shows the detailed results of calculations performed for the ARTCCs in 1985. Table K-4 shows a summary of the radar target message rates for the ARTCCs in the Host/ISSS period. From this table, the maximum stress center for each of the three years is seen to be the Kansas City ARTCC. Kansas City's relatively high radar coverage causes it to be the maximum stress center over candidates with high track loads such as Chicago.

TABLE K-1
VFR & IFR TRAFFIC FORECAST, 1985-1995

ARTCC ID	YR=1985		YR=1990		YR=1995	
	IFR	VFR	IFR	VFR	IFR	VFR
ALBUQUERQUE	298	129	346	157	392	178
ATLANTA	313	219	392	288	479	352
BOSTON	191	187	227	233	265	272
CHICAGO	384	324	486	430	597	529
CLEVELAND	340	87	408	109	477	128
DENVER	380	126	476	165	581	202
FORT WORTH	359	338	437	432	517	511
HOUSTON	277	97	355	131	438	161
INDIANAPOLIS	308	186	383	242	465	294
JACKSONVILLE	235	61	283	77	335	91
KANSAS CITY	346	147	422	188	496	221
LOS ANGELES	297	327	357	413	421	487
MEMPHIS	314	112	387	145	467	175
MIAMI	279	118	349	155	424	188
MINNEAPOLIS	263	110	333	146	412	180
NEW YORK	248	277	290	340	330	387
OAKLAND	274	261	319	319	364	364
SALT LAKE CITY	266	116	315	145	363	167
SEATTLE	276	126	357	171	439	210
WASHINGTON	296	243	357	307	420	361

TABLE K-2
APPORTIONMENT OF AIRCRAFT OUTSIDE OF THE ARTCCs

			APPORTIONMENT OF ADJACENT ARTCC AIRCRAFT DENSITIES																				
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
			ZAB	ZTL	ZBW	ZAU	ZOB	ZDV	ZFW	ZHU	ZID	ZJX	ZKC	ZLA	ZME	ZMA	ZMP	ZNY	ZOA	ZLC	ZSE	ZDC	TOTAL
ARTCC_ID																							
ALBUQUERQUE	1	ZAB						25%		10%			15%	25%					25%				100%
ATLANTA	2	ZTL								5%	20%	40%			20%							15%	100%
BOSTON	3	ZBW					20%											80%					100%
CHICAGO	4	ZAU					20%				10%		20%				50%						100%
CLEVELAND	5	ZOB			10%	20%					20%		20%				10%	20%					100%
DENVER	6	ZDV	25%										10%	15%			25%			25%			100%
FORT WORTH	7	ZFW	20%							40%			20%		20%								100%
HOUSTON	8	ZHU		10%					50%			30%			10%								100%
INDIANAPOLIS	9	ZID		20%		15%	15%						15%		20%							15%	100%
JACKSONVILLE	10	ZJX		20%						20%						40%						20%	100%
KANSAS CITY	11	ZKC	10%			20%		10%	20%		10%				20%		10%						100%
LOS ANGELES	12	ZLA	25%					25%											25%	25%			100%
MEMPHIS	13	ZME							20%	20%	20%	20%	20%										100%
MIAMI	14	ZMA										100%											100%
MINNEAPOLIS	15	ZMP				10%	10%	40%												40%			100%
NEW YORK	16	ZNY			40%		20%															40%	100%
OAKLAND	17	ZOA												35%						30%	35%		100%
SALT LAKE CITY	18	ZLC						20%						25%			10%		25%		20%		100%
SEATTLE	19	ZSE																	30%	70%			100%
WASHINGTON	20	ZDC		15%			15%				10%	30%						30%					100%

EXAMPLE: The density of aircraft operating outside of the Boston(ZBW) ARTCC which are seen by radars reporting to the Boston ARTCC is equal to 80% of the New York(ZNY) density plus 20% of the Cleveland(ZOB) aircraft density.

TABLE K-3
SUMMARY OF TARGET REPORT CALCULATIONS, 1985

ARTCC_ID		FACILITY AREA, M-SQ MI	IFR PER M-SQ MI	VFR PER M-SQ MI	EQUIV OUTSIDE IFR AREA M-SQ MI	OUTSIDE IFR TRACKS	EQUIV OUTSIDE VFR AREA M-SQ MI	OUTSIDE VFR TRACKS	***** AIRCRAFT ONLY******* INSIDE MESSAGES PER SEC	OUTSIDE MESSAGES PER SEC	TOTAL MESSAGES PER SEC
ALBUQUERQUE	1	178	1.67	0.72	358	782	91	112	91	89	180
ATLANTA	2	60	5.22	3.65	121	287	31	36	38	32	70
BOSTON	3	108	1.77	1.73	217	598	55	126	54	72	126
CHICAGO	4	88	4.36	3.68	177	442	45	43	100	49	149
CLEVELAND	5	74	4.59	1.17	149	368	38	62	167	43	210
DENVER	6	240	1.58	0.52	482	739	122	106	120	84	204
FORT WORTH	7	125	2.67	2.70	251	531	64	52	64	58	122
HOUSTON	8	160	1.73	0.61	322	769	82	142	84	91	175
INDIANAPOLIS	9	82	3.76	2.26	165	622	42	92	59	71	131
JACKSONVILLE	10	166	1.42	0.37	334	1005	85	150	73	115	188
KANSAS CITY	11	127	2.72	1.26	255	720	65	121	128	84	212
LOS ANGELES	12	141	2.11	2.32	283	433	72	64	69	50	119
MEMPHIS	13	116	2.71	0.96	233	595	59	88	79	68	147
MIAMI	14	107	2.61	1.10	215	304	55	20	78	32	111
MINNEAPOLIS	15	200	1.32	0.55	402	741	102	85	77	83	159
NEW YORK	16	108	2.30	2.56	217	590	55	77	96	67	163
OAKLAND	17	132	2.08	1.30	265	326	67	69	44	40	83
SALT LAKE CITY	18	340	0.73	0.34	683	1121	173	226	84	91	175
SEATTLE	19	375	0.74	0.34	754	882	191	159	92	104	196
WASHINGTON	20	102	2.90	2.38	205	607	52	95	68	70	139

TABLE K-4
RADAR TARGET REPORT MESSAGE RATE
HOST/ISSS PERIOD

ARTCC_ID	YEAR=1985							YEAR=1990							YEAR=1995						
	ATCRBS RADAR COVERAGE							ATCRBS RADAR COVERAGE							ATCRBS RADAR COVERAGE						
	IFR AIRCRAFT			VFR AIRCRAFT			TOTAL	IFR AIRCRAFT			VFR AIRCRAFT			TOTAL	IFR AIRCRAFT			VFR AIRCRAFT			TOTAL
	IN	OUT	TOT	IN	OUT	TOT	RATE	IN	OUT	TOT	IN	OUT	TOT	RATE	IN	OUT	TOT	IN	OUT	TOT	RATE
ALBUQUERQUE	80	78	158	11	11	22	180	93	99	192	14	15	28	220	105	118	223	16	17	33	256
ATLANTA	28	29	57	10	4	14	70	35	35	70	13	5	18	88	43	42	85	16	6	22	106
BOSTON	38	60	97	16	13	29	126	45	71	115	20	16	36	151	52	81	133	24	18	41	175
CHICAGO	74	44	119	26	4	30	149	94	54	148	34	6	40	188	116	65	180	42	7	49	229
CLEVELAND	156	37	193	11	6	17	210	187	46	233	14	8	22	255	219	55	274	16	10	26	300
DENVER	108	74	182	11	11	22	204	136	80	216	15	12	27	242	166	94	259	18	14	32	291
FORT WORTH	42	53	95	22	5	27	122	51	66	116	28	7	35	151	60	78	138	33	8	41	180
HOUSTON	77	77	154	7	14	22	175	99	94	193	10	18	28	221	122	112	234	12	22	34	267
INDIANAPOLIS	47	62	109	13	9	22	131	58	77	135	17	12	29	163	70	92	162	20	14	35	197
JACKSONVILLE	68	101	169	5	15	20	188	82	125	207	6	20	25	233	97	152	249	7	24	31	280
KANSAS CITY	114	72	186	14	12	26	212	140	90	230	17	16	33	263	164	109	273	21	19	40	313
LOS ANGELES	45	43	88	21	6	30	119	54	57	111	30	9	39	150	64	67	130	36	10	45	176
MEMPHIS	71	59	130	9	9	17	147	87	73	160	11	11	22	182	105	87	192	13	14	27	219
MIAMI	68	30	98	10	2	12	111	85	37	122	13	3	16	137	103	43	147	16	3	19	166
MINNEAPOLIS	69	74	143	8	8	17	159	87	104	191	11	12	23	214	108	124	232	13	15	28	261
NEW YORK	65	59	124	31	8	39	163	76	71	147	38	10	48	195	86	83	169	44	11	55	224
OAKLAND	30	33	63	14	7	20	83	35	45	81	17	10	26	107	40	54	94	19	11	30	124
SALT LAKE CITY	74	76	150	10	15	25	175	87	98	185	12	20	32	217	101	116	217	14	23	37	255
SEATTLE	80	88	168	11	16	27	196	104	102	205	16	18	33	239	128	117	244	19	20	40	284
WASHINGTON	50	61	110	19	10	28	139	60	74	133	24	12	36	169	70	87	157	28	14	43	200

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APPENDIX L

CALCULATION OF ACF-SPECIFIC WORKLOAD DATA FROM NAS-BASED INFORMATION

In 1995, the FAA is scheduled to divide the conterminous US (CONUS) into 21 Area Control Facilities (ACFs). A Type B ACF will control low altitude airspace (up to approximately 18,000 ft.) where several high activity airports are in operation. They will handle both approach control and low altitude en route control. Type A ACFs will be responsible for high altitude en route control and will handle the low altitude functions where Type B ACFs do not operate.

Because both en route and approach control functions are consolidated in the ACFs, FAA forecast data pertaining to the ARTCCs are not directly usable to determine some workload parameter values for specific facilities. Table K-1 shows the forecast of IFR & VFR aircraft for the year 1995. In order to use the available data to estimate ACF workload, methods were devised to:

1. estimate the level of approach control traffic to be added to the current forecasts for IFR and VFR traffic in the ARTCCs
2. allocate the resultant traffic to the ACFs and
3. calculate the level of radar target reports associated with each facility for the consolidation period.

Each method used involved construction of a mathematical model in the form of a computerized spreadsheet. The advantage of using the spreadsheet was that: the model could be built in a modular fashion, and results could be easily verified. Figure L-1 is a flow diagram which depicts the three modules along with their associated inputs and outputs. A detailed description of each of the spreadsheets follows:

L1. Approach Control Traffic Estimate (SPREAD1)

Aircraft in the approach control area are to be controlled at the ACF in the consolidation period. An estimate of the number of aircraft tracks in the approach control areas of ACFs is based on the assumption that the traffic operating solely in the approach control areas is negligible compared to the traffic passing into (out of) approach control areas from (into) en route areas. In this case, the activation rate of tracks in the approach areas is the same as the activation rate of tracks in the en route areas. This can be expressed mathematically:

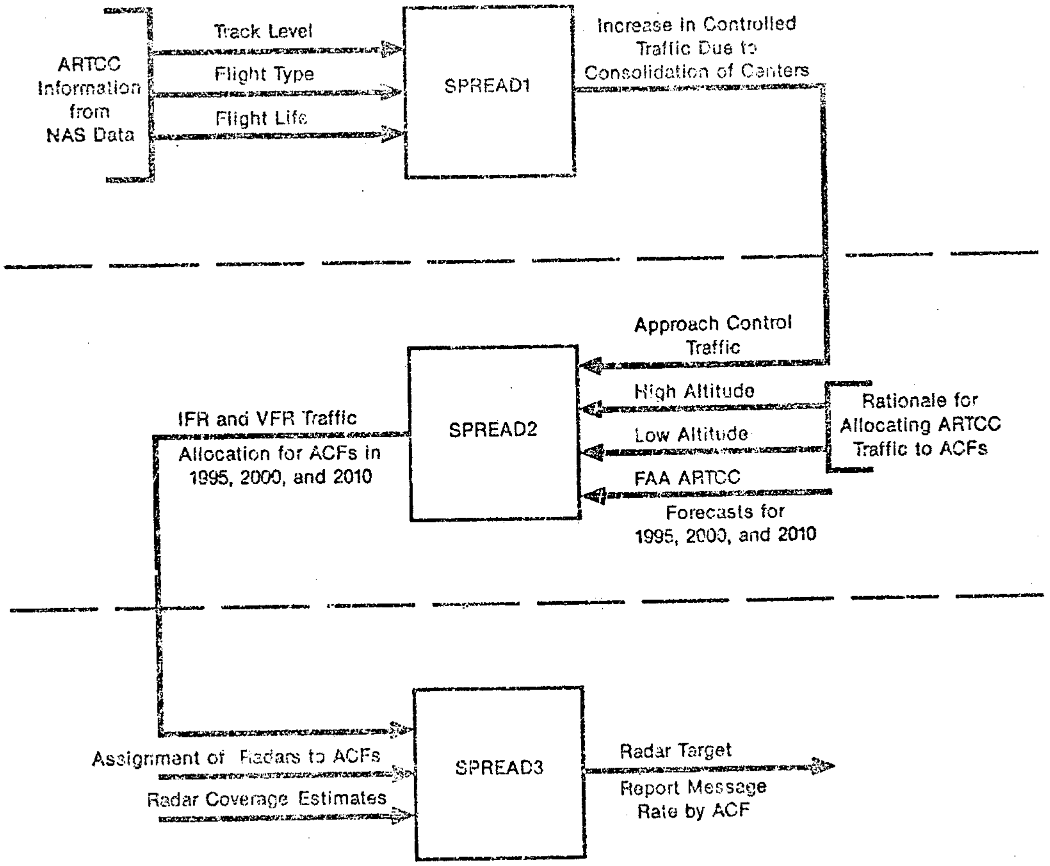

FIGURE L-1
RADAR TARGET REPORT MESSAGE RATE

$$\frac{T_1}{L_1} = \frac{T_2}{L_2}$$

where T = track count
L = track life
1, refers to en route track count/track life ratio
2, refers to track count/track life ratio after major terminals are consolidated

$$L_1 = D_o \cdot L_o + D_d \cdot L_d + D_a \cdot L_a + D_w \cdot L_w$$

where D = flight type distribution respectively for "over," "departure," arrival, and within flights.

Table L.1-1 contains data to calculate L_1. For the Albuquerque ARTCC (ZAB):

$D_o = 0.44$, $L_o = 40$

$D_d = 0.20$, $L_d = 30$

$D_a = 0.16$, $L_a = 30$

$D_w = 0.20$, $L_w = 30$

resulting in $L_1 = 34.4$ minutes.

After consolidation, the track life for arrivals and departures into and out of terminal areas can be estimated by adding to L_1 the additional track life in the terminal areas as follows:

$$L_2 = L_1 + P_d \cdot D_d \cdot I_d + P_a \cdot D_a + I_a \cdot P_d \cdot D_w \cdot I_d + P_a \cdot D_w \cdot I_a$$

where P = fraction of departures/arrivals using major airports
D = flight type distribution
I = increase in flight life as a result of consolidation.

Values of P and D are to be found in Table L.1-1.

($I_d = 3$, $I_a = 12$ minutes)

Having obtained T_1, L_1 and L_2, T_2 can be estimated using the basic assumption of equal activation rates. The resulting T_2 must be apportioned between ARTCCs based on the location and capacity of major airports. The increase in tracks, $T_2 - T_1$, due to consolidation is made in the low altitude region of an ACF.

TABLE L.1-1
APPROACH CONTROL AIRCRAFT ESTIMATES FOR ARTCCs, YR=1995

ARTCC	OVERS		DEPARTURES		ARRIVALS		WITHINS		L1,	AIRPORT		L2,	T2-T1
	LIFE	DIST.%	LIFE	DIST.%	LIFE	DIST.%	LIFE	DIST.%	MINS	DEP.%	ARR.%	MINS	IFR
Albuquerque	40	44.0	30	20.0	30	16.0	30	20.0	34.4	60.0	60.0	37.6	38
Atlanta	31	25.0	28	29.0	29	22.0	22	24.0	27.5	73.0	83.3	33.3	100
Boston	27	13.4	23	27.9	22	18.4	24	40.3	23.8	77.0	67.9	30.1	71
Chicago	30	28.0	25	28.0	25	21.0	20	24.0	25.5	75.0	75.0	30.7	122
Cleveland	28	29.5	24	27.6	21	11.6	24	31.3	24.8	62.0	74.0	29.7	94
Denver	33	35.0	20	22.0	23	22.0	22	21.0	25.6	59.0	62.0	29.6	90
Fort Worth	37	22.0	50	26.4	27	21.6	32	30.0	36.8	72.0	77.0	42.8	84
Houston	41	8.2	27	30.0	28	23.4	30	38.4	29.5	68.0	61.0	35.5	88
Indianapolis	37	33.0	26	30.0	24	21.0	22	16.0	28.6	64.0	65.0	32.3	61
Jacksonville	48	40.0	29	22.0	36	20.0	42	18.0	40.3	60.0	56.0	43.6	27
Kansas City	27	44.0	28	19.7	32	16.1	28	19.5	28.2	75.0	75.0	32.3	72
Los Angeles	30	4.4	30	29.6	30	27.6	20	38.4	26.2	72.0	67.0	32.9	109
Memphis	38	38.8	29	23.9	30	17.0	32	20.3	33.3	50.0	53.0	36.3	43
Miami	27	25.0	23	33.0	22	25.0	24	17.0	23.9	75.0	75.0	28.8	87
Minneapolis	33	37.4	20	21.3	23	19.3	22	22.0	25.9	50.0	73.0	30.1	68
New York	27	25.4	23	32.9	22	25.4	24	16.3	23.9	75.0	76.0	28.8	69
Oakland	30	9.8	30	31.4	30	22.0	20	36.8	26.3	73.0	69.0	32.7	88
Salt Lake City	50	10.0	40	20.0	50	15.0	30	55.0	37.0	60.0	60.0	43.4	63
Seattle	52	8.3	40	19.8	48	14.4	32	57.0	37.6	37.0	42.0	42.1	52
Washington	39	27.5	28	28.4	31	20.5	33	23.6	32.8	77.0	74.0	37.9	65

IFR instantaneous track levels (i.e., T_1) for the peak IFR hour of the peak IFR day at each ARTCC are forecasted by FAA for the year 1995 (Reference 9). Values of L_1, L_2 and $T_2 - T_1$ are listed for each CONUS ARTCC in Table L.1-1.

As an example, for ZAB,

$$P_d = 0.60, \; P_a = 0.60,$$

resulting in $L_2 = 37.7$ mins. The increase in IFR tracks due to consolidation is represented in the following equation:

$$T_2 - T_1 = T_1 * \frac{(L_2 - L_1)}{L_1}$$

$$= 392 * \frac{(37.7-34.4)}{34.4} = 37.6 \text{ tracks}$$

A summary of these calculations for each ARTCC is found in Table L.1-1.

L2. IFR & VFR Estimate for ACFs (SPREAD2)

The peak IFR track levels forecasted for each of the ARTCCs for the years 1995 through 2010 are presented in Table D-1, Appendix D. Since the ARTCCs are scheduled to be replaced by ACFs during these years, the problem exists to determine the allocation of en route IFR tracks predicted for the ARTCCs to the ACFs. VFR tracks must also be allocated, as well as the approach control traffic estimated in SPREAD1.

IFR track estimates (for each ARTCC) are obtained from Table D-1 and reproduced in Table L.2-1. VFR traffic estimates are based on unpublished VFR traffic estimates for each ARTCC for the year 1995,[11] and VFR/IFR ratios estimated in Parameter 7.2. The unpublished VFR traffic estimates are made for each ARTCC at the peak IFR-hour on the peak IFR-day. The ratio of VFR/IFR was calculated for each ARTCC and an overall CONUS average of 2.4 was calculated. The relative values of the ratio for each ARTCC was retained throughout the model. The actual value for each ARTCC and ACF for a specific year was scaled to the average VFR/IFR ratios in Parameter 7.2. For instance, the VFR/IFR ratio for the Indianapolis ARTCC, based on forecast data was calculated to be 1.54. For the year 1990, the overall CONUS average was estimated (Parameter 7.2) to be 1.2. The VFR/IFR ratio for Indianapolis for 1990 was reestimated as the following:

TABLE L.2-1
VFR & IFR ARTCC FORECAST, 1995-2010

	YR=1995		YR=2000		YR=2010	
ARTCC_ID	IFR	VFR	IFR	VFR	IFR	VFR
ALBUQUERQUE	392	292	432	322	480	358
ATLANTA	479	241	569	286	734	369
BOSTON	265	222	301	252	353	295
CHICAGO	597	425	714	508	937	667
CLEVELAND	477	341	541	387	640	458
DENVER	581	138	687	163	879	208
FORT WORTH	517	337	595	388	721	470
HOUSTON	438	472	527	567	697	751
INDIANAPOLIS	465	210	550	248	703	318
JACKSONVILLE	335	419	386	482	467	584
KANSAS CITY	496	324	568	372	682	446
LOS ANGELES	421	446	482	511	577	612
MEMPHIS	467	259	550	305	696	386
MIAMI	424	245	500	288	635	366
MINNEAPOLIS	421	320	496	378	657	500
NEW YORK	330	301	365	333	410	374
OAKLAND	364	321	404	356	455	401
SALT LAKE CITY	363	192	407	215	468	247
SEATTLE	439	336	527	404	695	533
WASHINGTON	420	285	479	325	571	388

$$1.54 \times \frac{1.2}{2.4} = 0.77$$

Apportionment by Altitude

Since separate ACFs may control different altitude strata over the same land area, the forecast for each ARTCC is divided into a high and low altitude sector, (i.e., above and below 18,000 ft.). From Parameter 8.0, it is estimated that 56% of all IFR traffic occur in the high altitude sectors, and the remainder in the low altitude sectors. For instance, the IFR track forecast for Washington in 1995 was estimated to be 420. It is estimated that

$0.56 \times 420 = 235$ tracks occur at high altitudes and

$0.44 \times 420 = 185$ tracks occur at low altitudes.

VFR traffic estimates are calculated from the product of the IFR track level and the appropriate VFR/IFR ratio. Since the airspace above 18,000 feet is positive controlled airspace, no VFR traffic occurs above 18,000 ft. (i.e., in the high altitude stratum). Therefore, all VFR traffic is allocated to the low altitude. As a consequence the New York Type A ACF, which controls high altitude traffic exclusively, will monitor no VFR traffic. Approach control traffic will also be assigned exclusively to the low altitude sectors.

Apportionment of High Altitude Traffic to the ACFs

In the spreadsheet model, the high altitude traffic from the ARTCCs was apportioned to the high altitude sector of the ACFs. The apportionment is shown in Table 2.3.5-1 and is based both on estimates of area apportioned to each ACF from an ARTCC and on an estimate of relative density of aircraft in each part of the ARTCC. The areas were estimated from a map of the US with overlays of ARTCC and ACF boundaries. Relative densities were assigned to the parts of the ARTCC commensurate with the known aircraft activity. Sectors of the ARTCC which contained relatively large hubs (i.e. - Los Angeles & Chicago) were assigned high densities, and the remainder of the ATCC was assigned comparably lower values.

For instance, in the table, the entry for the Cleveland ARTCC shows an apportionment of 0.65 x 1.0 to the Cleveland ACF. The first term "0.65" is the fraction of ARTCC area apportioned to the Cleveland ACF. The second term "1.0" is a measure of the aircraft density in that area relative to the other areas in the Cleveland ARTCC. A density of 1.0 is considered average. From Table D-1, the projected track levels for 1995 for the Chicago ARTCC is 597. The Cleveland ARTCC apportionment to the high altitude Cleveland ACF is

$$477 \times 0.56 \times 0.65 \times 1.0 = 174.$$

Comparable calculations are done for the other ARTCCs and the results for the ARTCC apportionment to the high altitude sector of the ACFs in 1995 is shown in Table L.2-2.

Apportionment of Low Altitude Traffic to the ACFs

In the low altitude sector of the ACFs, apportionments are made from:

- low altitude IFR aircraft
- approach control aircraft
- VFR aircraft

Table 2.3.5-2 shows the apportionment made of the forecasted ARTCC aircraft to the ACF. In comparable fashion to the above calculations, the apportionment of IFR forecasted traffic from the Cleveland ARTCC for 1995 to the low altitude sector is

$$477 \times 0.44 \times 0.65 \times 1.0 = 137.$$

Table 2.3.5-3 shows the apportionment of approach control traffic from the ARTCCs to the low altitude sector of the ACFs. From Table L.1-1, an approach control estimate of 94 IFR aircraft is obtained for the Cleveland ARTCC. The apportionment of approach control traffic from the Cleveland ARTCC to the Cleveland ACF is 0.79 (Table 2.3.5-3). The approach control IFR traffic is calculated as:

$$94 \times 0.79 = 74.$$

Total IFR traffic apportioned from the Cleveland ARTCC to the low altitude sector of the Cleveland ACF is:

$$137 + 74 = 211.$$

TABLE L.2-2
APPORTIONMENT OF IFR ACTCC TRAFFIC TO ACF HIGH ALTITUDE SECTORS, 1995

		ACF/TYPE A												ACF/TYPE B									
ARTCC	ID	CLEV	JAX	KANS	HOUS	MINN	MEM	MIA	SLC	DEN	SEA	ALB	B/NY	LAX	BOS	NY	DCA	CHI	IND	ATL	DFW	OAK
ALBUQUERQUE	ZAB	0	0	0	66	0	0	0	0	44	0	110	0	0	0	0	0	0	0	0	0	0
CHICAGO	ZAU	120	0	80	0	134	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BOSTON	ZBW	0	0	0	0	0	0	0	0	0	0	0	148	0	0	0	0	0	0	0	0	0
WASHINGTON	ZDC	0	235	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DENVER	ZDV	0	0	0	0	0	0	0	16	260	10	39	0	0	0	0	0	0	0	0	0	0
FORT WORTH	ZFW	0	0	43	246	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HOUSTON	ZHU	0	0	0	221	0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
INDIANAPOLIS	ZID	208	26	0	0	0	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
JACKSONVILLE	ZJX	0	103	0	0	0	42	45	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KANSAS CITY	ZKC	0	0	222	0	0	0	0	0	56	0	0	0	0	0	0	0	0	0	0	0	0
LOS ANGELES	ZLA	0	0	0	0	0	0	0	118	0	0	118	0	0	0	0	0	0	0	0	0	0
SALT LAKE CITY	ZLC	0	0	0	0	0	0	0	73	24	104	0	0	0	0	0	0	0	0	0	0	0
MIAMI	ZMA	0	0	0	0	0	0	237	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MEMPHIS	ZME	0	0	78	26	0	157	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MINNEAPOLIS	ZMP	0	0	35	0	202	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NEW YORK	ZNY	0	0	0	0	0	0	0	0	0	0	0	185	0	0	0	0	0	0	0	0	0
OAKLAND	ZOA	0	0	0	0	0	0	0	193	0	12	0	0	0	0	0	0	0	0	0	0	0
CLEVELAND	ZOB	174	13	0	0	13	0	0	0	0	0	0	67	0	0	0	0	0	0	0	0	0
SEATTLE	ZSE	0	0	0	0	0	0	0	0	0	246	0	0	0	0	0	0	0	0	0	0	0
ATLANTA	ZTL	0	134	0	0	0	134	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table L.2-3 is a summary of the apportionment of IFR traffic from the ARTCC to the low altitude sector of the ACFs.

VFR traffic is handled in a similar fashion to the low altitude IFR aircraft. From Table L.1-1 the VFR aircraft forecast is 823 for the Cleveland ARTCC in 1995. The apportionment to the Cleveland ACF in the low altitude sector is:

$$823 \times 0.65 \times 1.0 = 535.$$

The apportionment of VFR traffic in the approach control is equal to the IFR value x the VFR/IFR ratio:

$$74 \times 1.73 = 128.$$

The total VFR traffic apportioned from the Cleveland ARTCC to the Cleveland ACF in the low altitude sector is:

$$535 + 128 = 663$$

Table L.2-4 is a summary of the apportionment of VFR traffic from the ARTCCs to the low altitude sectors of the ACFs.

Table L.2-5 is a summation of the apportionment of ARTCC aircraft traffic, both IFR and VFR, to the ACFs for the consolidation period.

L.3 Calculation of Radar Target Report Message Rates for ACFs

Determination of the radar target report message rate for a facility is a function not only of the characteristics of the facility, but also of the aircraft activity in adjacent facilities. In the current NAS system, radars reporting to an ARTCC detect aircraft which are outside of but in the proximity of the ARTCC borders. This is also true in the consolidation period, but the geometric architecture of the ACFs adds an additional load since radars reporting to Type B facilities will also detect aircraft in the high altitude sector and radars reporting to the Type A will detect aircraft in the low altitude sector.

TABLE L.2-3
APPORTIONMENT OF IFR ARTCC TRAFFIC TO ACF LOW ALTITUDE SECTORS, 1995

		ACF/TYPE A												ACF/TYPE B								
ARTCC	ID	CLEV	JAX	KANS	HOUS	MINN	MEM	MIA	SLC	DEN	SEA	ALB	B/NY	LAX	BOS	NY	DCA	CHI	IND	ATL	DFW	OAK
ALBUQUERQUE	ZAB	0	0	0	9	0	0	0	0	84	0	118	0	0	0	0	0	0	0	0	0	0
CHICAGO	ZAU	0	0	53	0	45	0	0	0	0	0	0	0	0	0	0	0	268	20	0	0	0
BOSTON	ZBW	0	0	0	0	0	0	0	0	0	0	0	0	0	188	0	0	0	0	0	0	0
WASHINGTON	ZDC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	250	0	0	0	0	0
DENVER	ZDV	0	0	0	0	0	0	0	13	294	8	31	0	0	0	0	0	0	0	0	0	0
FORT WORTH	ZFW	0	0	56	23	0	0	0	0	67	0	0	0	0	0	0	0	0	0	0	166	0
HOUSTON	ZHU	0	0	0	170	0	27	0	0	0	0	0	0	0	0	0	0	0	0	0	83	0
INDIANAPOLIS	ZID	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	26	11	209	20	0	0
JACKSONVILLE	ZJX	0	88	0	0	0	40	27	0	0	0	0	0	0	0	0	1	0	0	19	0	0
KANSAS CITY	ZKC	0	0	246	0	0	0	0	0	44	0	0	0	0	0	0	0	0	0	0	0	0
LOS ANGELES	ZLA	0	0	0	0	0	0	0	83	0	0	61	0	149	0	0	0	0	0	0	0	2
SALT LAKE CITY	ZLC	0	0	0	0	0	0	0	90	19	112	0	0	0	0	0	0	0	0	0	0	0
MIAMI	ZMA	0	43	0	0	0	0	231	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MEMPHIS	ZME	0	0	72	0	0	131	0	0	0	0	0	0	0	0	0	0	0	0	24	21	0
MINNEAPOLIS	ZMP	0	0	28	0	228	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NEW YORK	ZNY	0	0	0	0	0	0	0	0	0	0	0	0	0	32	181	0	0	0	0	0	0
OAKLAND	ZOA	0	0	0	0	0	0	0	92	0	10	0	0	0	0	0	0	0	0	0	0	145
CLEVELAND	ZOB	211	0	0	0	10	0	0	0	0	0	0	0	0	39	31	12	0	0	0	0	0
SEATTLE	ZSE	0	0	0	0	0	0	0	0	0	245	0	0	0	0	0	0	0	0	0	0	0
ATLANTA	ZTL	0	0	0	0	0	21	0	0	0	0	0	0	0	0	0	47	0	0	243	0	0

TABLE L.2-4
APPORTIONMENT OF VFR ARTCC TRAFFIC TO ACF LOW ALTITUDE SECTORS, 1995

		ACF/TYPE A												ACF/TYPE B								
ARTCC	ID	CLEV	JAX	KANS	HOUS	MINN	MEM	MIA	SLC	DEN	SEA	ALB	B/NY	LAX	BOS	NY	DCA	CHI	IND	ATL	DFW	OAK
ALBUQUERQUE	ZAB	0	0	0	15	0	0	0	0	136	0	170	0	0	0	0	0	0	0	0	0	0
CHICAGO	ZAU	0	0	85	0	56	0	0	0	0	0	0	0	0	0	0	0	345	26	0	0	0
BOSTON	ZBW	0	0	0	0	0	0	0	0	0	0	0	0	0	281	0	0	0	0	0	0	0
WASHINGTON	ZDC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	330	0	0	0	0	0
DENVER	ZDV	0	0	0	0	0	0	0	7	132	4	17	0	0	0	0	0	0	0	0	0	0
FORT WORTH	ZFW	0	0	63	34	0	0	0	0	91	0	0	0	0	0	0	0	0	0	0	202	0
HOUSTON	ZHU	0	0	0	355	0	55	0	0	0	0	0	0	0	0	0	0	0	0	0	156	0
INDIANAPOLIS	ZID	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23	11	183	21	0	0
JACKSONVILLE	ZJX	0	226	0	0	0	100	75	0	0	0	0	0	0	0	0	1	0	0	52	0	0
KANSAS CITY	ZKC	0	0	307	0	0	0	0	0	65	0	0	0	0	0	0	0	0	0	0	0	0
LOS ANGELES	ZLA	0	0	0	0	0	0	0	188	0	0	124	0	248	0	0	0	0	0	0	0	2
SALT LAKE CITY	ZLC	0	0	0	0	0	0	0	86	23	114	0	0	0	0	0	0	0	0	0	0	0
MIAMI	ZMA	0	25	0	0	0	0	270	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MEMPHIS	ZME	0	0	63	0	0	145	0	0	0	0	0	0	0	0	0	0	0	0	28	26	0
MINNEAPOLIS	ZMP	0	0	48	0	327	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NEW YORK	ZNY	0	0	0	0	0	0	0	0	0	0	0	0	0	54	308	0	0	0	0	0	0
OAKLAND	ZOA	0	0	0	0	0	0	0	167	0	19	0	0	0	0	0	0	0	0	0	0	208
CLEVELAND	ZOB	275	0	0	0	17	0	0	0	0	0	0	0	0	47	51	14	0	0	0	0	0
SEATTLE	ZSE	0	0	0	0	0	0	0	0	0	376	0	0	0	0	0	0	0	0	0	0	0
ATLANTA	ZTL	0	0	0	0	0	24	0	0	0	0	0	0	0	0	0	44	0	0	223	0	0

TABLE L.2-5
NUMBER OF CONTROLLED (IFR) & UNCONTROLLED (VFR) AIRCRAFT (INSTANTANEOUS)

ACF ID	CY 1995		CY 2000		CY 2010	
	IFR	VFR	IFR	VFR	IFR	VFR
ALBUQUERQUE	476	295	538	334	629	390
ATLANTA	307	308	363	365	466	468
BOSTON	259	364	293	411	342	480
CHICAGO	279	338	333	403	436	528
CLEVELAND	713	262	826	303	1020	374
DENVER	892	424	1036	492	1281	608
FORT WORTH	270	365	315	426	395	534
HOUSTON	761	383	893	450	1127	568
INDIANAPOLIS	229	198	271	235	347	300
JACKSONVILLE	643	239	744	276	913	339
KANSAS CITY	913	557	1061	648	1314	802
LOS ANGELES	149	236	171	271	204	323
MEMPHIS	603	308	712	364	904	462
MIAMI	540	328	635	386	801	487
MINNEAPOLIS	623	373	747	447	983	589
NEW YORK(A)	400	0	449	0	517	0
NEW YORK(B)	213	342	236	379	267	428
OAKLAND	146	200	162	221	183	250
SALT LAKE CITY	677	426	763	480	885	556
SEATTLE	746	488	876	573	1109	725
WASHINGTON	336	396	387	456	469	552

NOTE: Track forecasts for Anchorage and Honolulu are not available.

Determination of the radar target report message rates is made first by determining the workload caused by aircraft operating within the confines of each facility and, then, by adding to that load the aircraft outside the facility which are detected by the facilities radars. As an example, since the Memphis and Jacksonville facility are horizontally adjacent to each other, they detect a significant number of aircraft within the other's boundaries. These "outside" aircraft contribute a workload to each facility. Also, since the Washington Type B facility is entirely within the land area of the Jacksonville facility, the Jacksonville facility detects all of the aircraft detected by Washington long range radars. Conversely, the Washington facility sees all of the aircraft in high altitude strata, outside of its control area. The overlapping of the facilities in this regard provides additional load on each facility.

Figure L.3-1 is a diagram showing the steps used to calculate the radar target report message rate for a facility. A distribution of radar sensors consisting of either ATCRBS or Mode-S types is shown in Table 2.3.6-1. The scan rate for the long range Mode-S is 5 seconds/scan, and for long range ATCRBS, is 10 seconds/scan. Because the facility receives more scans from a Mode-S radar than from an ATCRBs radar in a fixed amount of time, the Mode-S radar generates a higher message rate for a given number of aircraft.

Radar coverage is the number of radars that detect a given aircraft. Appendix I describes the method of estimating radar coverage and Table 2.3.6-2 shows the radar coverage for both IFR and VFR aircraft from both long and short range radars in both en route and terminal airspace. Radar coverage on VFR aircraft is lower than on IFR aircraft because VFR aircraft tend to stay at lower altitudes where the "visibility" to radars is lower. Radar coverage for flights in terminal airspace is different from that for flights in en route airspace. The factor, 0.7, is used to modify radar target report rate to reflect the average time (70%) that a flight spends in en route airspace. An average of 30% of flight life is spent in terminal airspace.

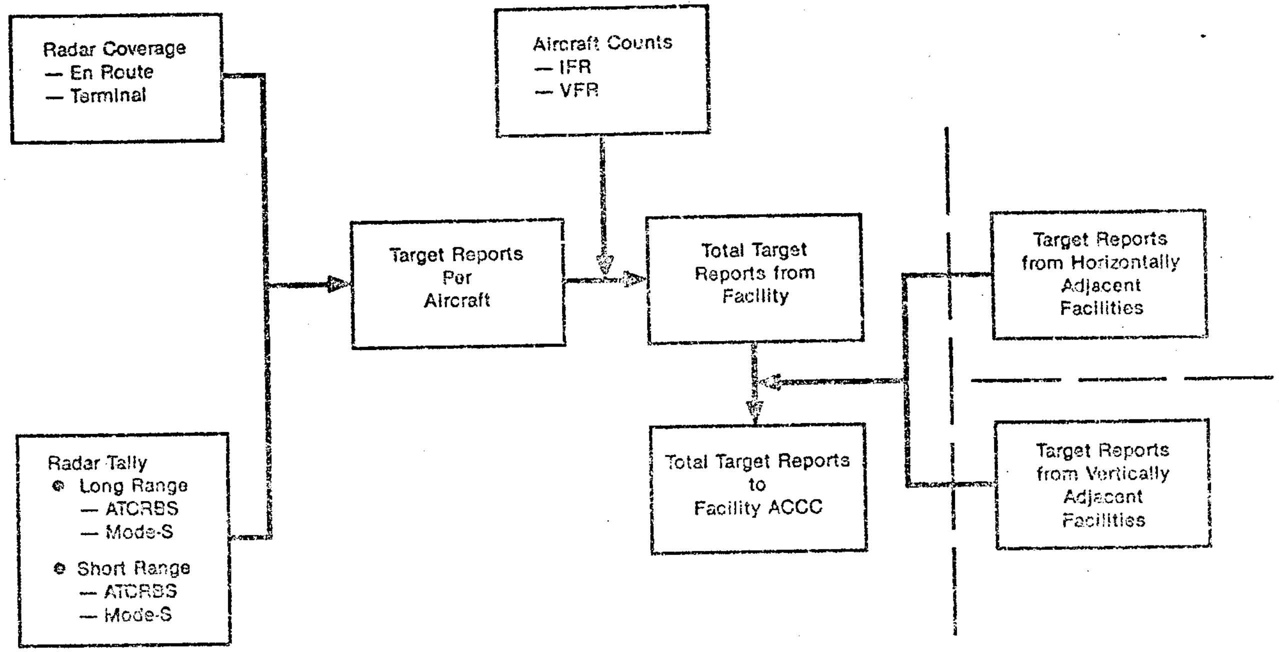

FIGURE L.3-1
CALCULATION OF RADAR TARGET REPORT MESSAGE RATE FOR A FACILITY

The number of target reports per aircraft is calculated based on radar coverage and scan rate. The product of the aircraft traffic count and the number of target reports per aircraft is calculated for each radar type (i.e., long and short range) and each aircraft type (i.e., IFR and VFR). Allocations from other facilities (i.e., horizontally adjacent and vertically adjacent) are added to obtain the total radar message rate for the facility. Table L.3-1 is a summary of these calculations for the Cleveland ACF in 1995. The projected count of Cleveland radar sensors for 1995 is shown in Column A. The target reports per aircraft is calculated in Column F and the total message rate shown in Column L. The calculations are modularized to separate IFR and VFR aircraft and long range and short range radars.

Long range radars detect aircraft not only within the facility confines, but also outside the facility. Table L.3-2 shows the apportionment of aircraft in horizontally adjacent facilities which are detected by facility radars. The number of aircraft shown was determined for a radar coverage for outside aircraft that was equivalent to 1.0. For instance, Table L.3-2 shows that of the aircraft detected by the Cleveland ACF (#5) outside of its control area, 40% of the aircraft were in the Minneapolis ACF (#15), 30% of the aircraft were in the Jacksonville (#10) and 20% of aircraft in the New York-A (#16) facility.

Table 2.3.6-3 shows the percentage of radar messages which represent aircraft in the lower altitude sector and which are also sent to the Type A facility which is adjacent in altitude. The Cleveland ACF, for instance receives 50% of all messages sent to the Chicago ACF and 100% of all radar messages sent to the Indianapolis ACF. Table 2.3.6-4, in turn, shows the percentage of radar messages which detect aircraft in the upper altitude sector which are also received by the Type B ACF which is adjacent in altitude. For instance, the Chicago ACF receives 25% of all messages pertaining to aircraft in the Cleveland ACF.

Table L.3-1 is a summary of the messages representing IFR and VFR aircraft both inside and outside of the control airspace of the facility of the Cleveland ACF. Similar calculations were performed for all 21 of the CONUS ACFs. Table L.3-3 shows the results of this analysis.

TABLE L.3-1
RADAR MESSAGE RATE SUMMARY, CLEVELAND ACF
YEAR=1995

	5 CLEVELAND	A	B	C	D	E	F B*C(0.85*D+0.15*E)	G		I F(100%-G)	J	K	L (J*F)		
CONTROL STATUS	TYPE	NUMBER	DIST	SCAN RATE TARGET REPORTS /SEC /RADAR	ENROUTE RADAR COVER	TERMINAL RADAR COVER	POTENTIAL TARGET REPORTS /FLIGHT /SEC	TRANSP EQUIP %	BEACON REPORTS /FLIGHT /SEC	SEARCH REPORTS /FLIGHT /SEC	UNIT FLIGHT LEVEL	PRIMARY NOISE RATE	BEACON TARGET REPORTS PER SECOND	PRIMARY TARGET REPORTS PER SECOND	INCR FOR 100% MODE-S
CONTROLLED	LONG RANGE														
	ATCRBS-IN	10	91%	0.1	5.11	1.63	0.42	99%	0.41	.00	713	175	294	3	147
	MODE-S-IN	1	9%	0.2	5.11	1.63	0.03	99%	0.05	.00	713	175	59	0	
	ATCRBS-OUT	10	91%	0.1	1.00		0.03	99%	0.09	.00	848		76	1	38
	MODE-S-OUT	1	9%	0.2	1.00		0.02	99%	0.02	.00	848		15	0	
	(B-FACILITIES)		100% #9(IND),50% #4(CHI)										64		
	SHORT RANGE														
	ATCRBS	8	67%	0.2	1.40	1.98	0.20	99%	0.20	.00	713	287	140	1	
	MODE-S	4	33%	0.2	1.40	1.98	0.10	99%	0.10	.00	713	287	70	0	
UNCONTROLLED	LONG RANGE														
	ATCRBS--IN	10	91%	0.1	1.49	0.00	0.12	93%	0.11	0.01	262	0	28	2	14
	MODE-S-IN	1	9%	0.2	1.49	0.00	0.02	93%	0.02	.00	262	0	6	0	
	ATCRBS-OUT	10	91%	0.1	1.00		0.09	93%	0.08	0.01	68		6	0	3
	MODE-S-OUT	1	9%	0.2	1.00		0.02	93%	0.02	.00	68		1	0	
	(B-FACILITIES)		100% #9(IND),50% #4(CHI)										47		
	SHORT RANGE														
	ATCRBS	8	67%	0.2	1.04	0.00	0.12	93%	0.11	0.01	262	0	29	2	
	MODE-S	4	33%	0.2	1.04	0.00	0.06	93%	0.05	.00	262	0	14	1	
INSIDE MESSAGE RATE													763		
OUTSIDE MESSAGE RATE													100		
AIRCRAFT MESSAGE RATE													863		
PRIMARY MESSAGE RATE													11		
PRIMARY NOISE RATE			SUM(A*K*C)										899		
TOTAL MESSAGE RATE													1761		
VFR MESSAGE RATE(PREP FOR BACKUP)													136		
INSIDE													122		143
OUTSIDE													7		10
IFR MESSAGE RATE(PREP FOR BACKUP)													726		
INSIDE													634		781
OUTSIDE													92		131

TABLE L.3-2
APPORTIONMENT OF AIRCRAFT OUTSIDE OF THE ACFs

			APPORTIONMENT OF ADJACENT ACF AIRCRAFT DENSITIES																				
			1 ZAB	2 ZTL	3 ZEW	4 ZAU	5 ZOB	6 ZDV	7 ZFW	8 ZHU	9 ZID	10 ZJX	11 ZKC	12 ZLA	13 ZME	14 ZMA	15 ZMP	16 ZLI	17 ZNY	18 ZOA	19 ZLC	20 ZSE	21 ZDC
ACF_ID																							
ALBUQUERQUE	1	ZAB	25%					25%													50%		
ATLANTA	2	ZTL					25%					25%			50%								
BOSTON	3	ZEW			50%														50%				
CHICAGO	4	ZAU					50%						20%				30%						
CLEVELAND	5	ZOB										30%					40%	30%					
DENVER	6	ZDV	20%							40%					20%							20%	
FORT WORTH	7	ZFW						20%		40%			30%		10%								
HOUSTON	8	ZHU						40%		20%			30%		10%								
INDIANAPOLIS	9	ZID				20%	30%					20%	20%		10%								
JACKSONVILLE	10	ZJX													50%		50%						
KANSAS CITY	11	ZKC					20%	20%		10%					10%		40%						
LOS ANGELES	12	ZLA																			100%		
MEMPHIS	13	ZME								30%		30%	40%										
MIAMI	14	ZMA														100%							
MINNEAPOLIS	15	ZMP					10%	20%					10%				40%					20%	
NEW YORK(A)	16	ZLI					30%					30%						40%					
NEW YORK(B)	17	ZNY			40%		30%					30%											
OAKLAND	18	ZOA																		100%			
SALT LAKE CITY	19	ZLC	20%					20%														60%	
SEATTLE	20	ZSE						20%									10%				50%	20%	
WASHINGTON	21	ZDC					40%					10%			30%								20%

EXAMPLE:The density of aircraft operating outside of the Atlanta(ZTL) ACF which are seen by radars reporting to the Atlanta ACF is equal to 50% of the Memphis(ZME) density, 25% of the Jacksonville(ZJX) density, plus 25% of the Cleveland(ZOB) aircraft density.

TABLE L.3-3
SUMMARY OF VFR & IFR TARGET REPORT MESSAGE RATES, 1995

			******************IFR AIRCRAFT ONLY******************						******************VFR AIRCRAFT ONLY******************					
		PERCENT MODE-S LR RADAR	NORMAL RADAR COVERAGE			100% MODE-S RADAR COVERAGE			NORMAL RADAR COVERAGE			100% MODE-S RADAR COVERAGE		
ACF_ID			INSIDE MESSAGE PER SEC	OUTSIDE MESSAGE PER SEC	TOTAL MESSAGES PER SEC	INSIDE MESSAGE PER SEC	OUTSIDE MESSAGE PER SEC	TOTAL MESSAGES PER SEC	INSIDE MESSAGE PER SEC	OUTSIDE MESSAGE PER SEC	TOTAL MESSAGES PER SEC	INSIDE MESSAGE PER SEC	OUTSIDE MESSAGE PER SEC	TOTAL MESSAGES PER SEC
ALBUQUERQUE	1	54.55%	280	122	402	309	140	449	75	16	91	80	19	99
ATLANTA	2	0.00%	219	35	254	233	52	285	56	3	60	63	5	68
BOSTON	3	50.00%	329	111	441	342	130	472	94	40	134	101	46	148
CHICAGO	4	16.67%	302	142	444	325	192	517	77	18	96	88	24	112
CLEVELAND	5	9.09%	634	92	726	781	131	912	129	7	136	143	10	152
DENVER	6	54.55%	530	219	749	588	251	838	67	29	96	75	33	108
FORT WORTH	7	10.00%	239	135	373	252	189	442	65	28	93	75	39	114
HOUSTON	8	22.22%	505	175	679	586	230	816	99	27	125	109	35	144
INDIANAPOLIS	9	0.00%	242	112	355	260	168	427	40	19	59	47	28	75
JACKSONVILLE	10	7.14%	349	178	527	435	254	689	102	19	121	110	27	137
KANSAS CITY	11	13.33%	592	149	742	722	206	928	108	16	124	129	22	151
LOS ANGELES	12	75.00%	198	86	284	201	92	293	96	14	110	98	15	113
MEMPHIS	13	11.11%	302	130	432	362	182	544	76	17	94	86	24	110
MIAMI	14	16.67%	367	23	389	421	31	452	72	2	74	83	3	86
MINNEAPOLIS	15	57.89%	399	244	643	433	276	709	87	30	116	92	33	126
NEW YORK(A)	16	46.15%	420	181	602	470	215	684	96	11	108	98	12	110
NEW YORK(B)	17	37.50%	289	175	464	306	214	520	107	31	138	119	37	156
OAKLAND	18	66.67%	178	109	287	180	120	300	47	39	86	49	42	91
SALT LAKE CITY	19	86.67%	420	322	743	433	334	766	99	49	149	102	51	153
SEATTLE	20	60.87%	452	221	673	494	248	742	94	31	125	102	35	137
WASHINGTON	21	12.50%	312	141	453	337	196	532	101	19	119	113	25	139

Table L.3-4 is a summary of the target report message rates for each of the ACFs for each of the consolidation years, and assuming that all of the long range radars are Mode-S type. Note that for each of the three years, the Houston ACF has the maximum loading. Table L.3-5 shows a similar set of figures but for the situation where each ACF has a mix of Mode-S and ATCRBS long range radars.

TABLE L.3-4
RADAR TARGET REPORT MESSAGE RATE
100% MODE-S LONG RANGE RADARS

	PERCENT	************YEAR=1995			**************				************YEAR=2000			**************				************YEAR=2010			**************			
	MODE-S	VFR AIRCRAFT			IFR AIRCRAFT			TOTAL	VFR AIRCRAFT			IFR AIRCRAFT			TOTAL	VFR AIRCRAFT			IFR AIRCRAFT			TOTAL
ACF_ID	RADAR	IN	OUT	TOT	IN	OUT	TOT	RATE	IN	OUT	TOT	IN	OUT	TOT	RATE	IN	OUT	TOT	IN	OUT	TOT	RATE
ALBUQUERQUE	100.00%	80	19	99	309	140	449	548	92	21	113	350	159	508	622	110	26	136	410	188	597	733
ATLANTA	100.00%	63	5	68	233	52	285	353	75	6	80	274	60	335	415	97	7	104	349	75	424	528
BOSTON	100.00%	101	46	148	342	130	472	619	115	52	167	386	145	531	698	136	60	196	447	167	614	811
CHICAGO	100.00%	88	24	112	325	192	517	629	105	28	134	384	224	608	742	139	36	175	496	279	775	950
CLEVELAND	100.00%	143	10	153	781	131	912	1065	168	12	180	907	152	1058	1239	214	16	230	1124	188	1312	1542
DENVER	100.00%	75	33	108	588	251	838	947	87	39	126	683	291	975	1101	109	48	158	847	360	1207	1365
FORT WORTH	100.00%	75	39	114	252	189	442	556	88	46	134	295	220	516	650	111	58	169	372	275	647	816
HOUSTON	100.00%	109	35	144	586	230	816	960	129	40	169	686	268	954	1123	165	51	216	861	333	1194	1410
INDIANAPOLIS	100.00%	47	28	75	260	168	427	502	55	33	89	304	196	500	589	72	43	114	383	247	629	744
JACKSONVILLE	100.00%	110	27	137	435	254	689	826	129	31	160	503	296	799	959	162	39	201	617	369	986	1187
KANSAS CITY	100.00%	129	22	151	722	206	928	1078	150	26	176	839	241	1080	1256	188	33	221	1039	304	1343	1564
LOS ANGELES	100.00%	98	15	113	201	92	293	405	113	17	130	229	104	333	463	136	20	156	273	121	393	549
MEMPHIS	100.00%	86	24	110	362	182	544	654	102	28	130	427	212	639	769	132	35	167	543	262	805	972
MIAMI	100.00%	83	3	86	421	31	452	538	97	4	101	495	36	531	632	124	5	129	624	44	668	797
MINNEAPOLIS	100.00%	92	33	126	433	276	709	835	111	39	150	519	324	843	993	148	51	199	683	409	1092	1291
NEW YORK(A)	100.00%	98	12	110	470	215	684	795	111	14	125	527	247	773	898	131	18	149	606	299	905	1054
NEW YORK(B)	100.00%	119	37	156	306	214	520	676	132	43	175	341	246	587	762	151	52	203	388	299	687	890
OAKLAND	100.00%	49	42	91	180	120	300	391	54	47	102	202	133	335	436	62	54	116	231	150	381	497
SALT LAKE CITY	100.00%	102	51	153	433	334	766	919	115	59	174	487	385	872	1046	135	73	208	564	470	1035	1242
SEATTLE	100.00%	102	35	137	494	248	742	879	120	40	161	580	284	864	1025	154	49	203	734	342	1076	1279
WASHINGTON	100.00%	113	25	139	337	196	532	671	131	30	161	388	227	615	776	160	37	197	472	281	754	951

TABLE L.3-5
RADAR TARGET REPORT MESSAGE RATE
NORMAL MIX LONG RANGE RADARS

ACF_ID	PERCENT MODE-3 RADAR	YEAR=1995 VFR AIRCRAFT IN	OUT	TOT	IFR AIRCRAFT IN	OUT	TOT	TOTAL RATE	YEAR=2000 VFR AIRCRAFT IN	OUT	TOT	IFR AIRCRAFT IN	OUT	TOT	TOTAL RATE	YEAR=2010 VFR AIRCRAFT IN	OUT	TOT	IFR AIRCRAFT IN	OUT	TOT	TOTAL RATE
ALBUQUERQUE	54.55%	75	16	91	280	122	402	493	86	19	104	317	139	456	560	103	22	125	372	164	536	661
ATLANTA	0.00%	56	3	60	219	35	254	314	67	4	71	258	40	299	369	86	5	91	328	50	379	470
BOSTON	50.00%	94	40	134	329	111	441	575	107	45	152	371	125	496	648	126	52	178	430	143	574	752
CHICAGO	16.67%	77	18	96	302	142	444	540	93	21	114	358	165	523	637	122	26	149	461	206	667	816
CLEVELAND	9.09%	129	7	136	634	92	726	863	152	9	160	736	107	843	1004	193	11	205	914	132	1046	1251
DENVER	54.55%	67	29	96	530	219	749	845	78	34	112	617	254	871	983	97	42	140	764	314	1079	1219
FORT WORTH	10.00%	65	28	93	239	135	373	466	76	33	109	279	157	436	545	96	42	137	351	196	547	684
HOUSTON	22.22%	99	27	125	505	175	679	805	116	31	147	590	204	794	941	149	39	187	740	253	994	1181
INDIANAPOLIS	0.00%	40	19	59	242	112	355	414	48	23	70	284	131	415	485	62	29	90	357	165	522	612
JACKSONVILLE	7.14%	102	19	121	349	178	527	648	120	22	142	404	207	611	753	150	28	178	496	258	754	931
KANSAS CITY	13.33%	108	16	124	592	149	742	866	126	19	145	688	175	863	1008	157	24	181	853	220	1073	1254
LOS ANGELES	75.00%	96	14	110	198	86	284	394	110	16	126	226	97	323	449	133	19	152	269	113	381	533
MEMPHIS	11.11%	76	17	94	302	130	432	526	91	20	111	357	152	508	619	117	25	142	453	188	641	783
MIAMI	16.67%	72	2	74	367	23	389	464	84	3	87	431	26	458	545	107	4	111	544	32	576	687
MINNEAPOLIS	57.89%	87	30	116	399	244	643	759	104	35	139	479	286	764	904	139	45	184	629	361	990	1174
NEW YORK(A)	46.15%	98	11	108	420	181	602	710	111	12	123	472	208	680	803	131	15	146	543	253	795	941
NEW YORK(B)	37.50%	107	31	138	289	175	464	602	119	35	155	321	201	523	677	136	42	179	366	244	610	789
OAKLAND	66.67%	47	39	86	176	109	287	373	53	43	96	199	121	320	415	60	49	109	228	137	364	474
SALT LAKE CITY	86.67%	99	49	149	420	322	743	891	112	57	169	473	372	845	1014	132	71	202	548	454	1002	1205
SEATTLE	60.87%	94	31	125	452	221	673	799	111	36	147	530	254	784	931	142	44	185	672	305	977	1162
WASHINGTON	12.50%	101	19	119	312	141	453	573	116	22	138	360	164	524	662	142	27	169	438	203	641	810

APPENDIX M

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