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NOAA Technical Memorandum NWS SPDD-4

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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Weather Service

A Cost-Effectiveness Model for Evaluating Aviation Weather Dissemination Techniques

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NOAA Technical Memorandum NWS SPDD-4

A COST-EFFECTIVENESS MODEL FOR EVALUATING AVIATION WEATHER DISSEMINATION TECHNIQUES

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Systems Development Office
Systems Plans and Design Division

SILVER SPRING, MD.
March 1972

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551.5	Meteorology
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656.7	Aviation
681.3	Computer models

The results, analyses, and conclusions presented in this publication are from initial exercises of the model, and should not be interpreted as representing National Weather Service plans or policy.

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SUMMARY

This report describes a computer based model which was developed to evaluate ways for improving the dissemination of weather information to general aviation. The model provides a cost-effectiveness analysis for a variety of configurations consisting of combinations of dissemination techniques. Typically, a configuration will consist of three or four different dissemination techniques such as radio, television, telephone, and personal briefers.

The primary impetus for the development of the model was related to the problem of satisfying the ever-increasing weather briefing requirements of the general aviation pilot. The difficulty of trying to meet these needs on an individualized person-to-person basis suggested that other techniques be analyzed to evaluate their suitability in aviation weather dissemination. Therefore, the National Weather Service felt it would be appropriate to develop an analytic means for evaluating the cost-effectiveness of various dissemination techniques currently in use, and also those expected to become available during the next decade. The complexities of the problem--the geographical distribution of demand, the variation in required types of weather information, and the number of dissemination techniques--suggested the development of an analytical tool.

Basic data on which the model operates consist of distributions of registered general aviation aircraft, air traffic activity and total flight services, FAA forecasts of growth in general aviation during the next decade, and the cost of various dissemination techniques and facilities. In addition, judgments were made in developing specific demand factors associated with various portions of the flight profile, (planning, en route, local, etc.), and in assigning values of accessibility and usefulness to each of the techniques evaluated.

As part of the model's output, measures of system performance are given in terms of percentage of demand satisfied by the total system, each technique, and each portion of the flight profile. Computations are made giving cost-per-demand served, cost of the total system, and cost of each technique in terms of capital, operating, and personnel costs. Location of facilities for each technique is given in a listing as well as graphically on a map of the 48 states or a particular region.

Results-to-date indicate that mass dissemination techniques (such as television) tend to be much more cost-effective than "point" dissemination techniques (such as interrogating a computer via a teletypewriter or cathode ray tube), even though the latter is more attractive from the standpoint of product tailoring and the provision of an interactive terminal. Future exercises of the model will help to determine what the optimum mix might be among a variety of dissemination techniques comprising a total system.

1.0 INTRODUCTION

This report describes a computer based model which was developed for use in evaluating ways for improving the dissemination of weather information to general aviation. The model provides a cost-effectiveness analysis for a variety of dissemination configurations consisting of combinations of techniques. Typically, a dissemination configuration will consist of three or four different techniques such as radio, television, telephone, and personal briefers. Before the evaluation of any configuration can take place, the type and number of facilities and/or people must be specified.

1.1 BACKGROUND

The model has been developed under the direction of the Systems Plans and Design Division of the Systems Development Office, with contractual assistance from the Information Systems Corporation. In addition, personnel from the NOAA Office of Aviation Affairs, National Weather Service Office of Meteorological Operations, FAA Systems Research and Development Service and Air Traffic Service have also participated in various aspects of the project.

The development of this model is part of a continuing program of improvement of the weather service provided to aviation by the NOAA National Weather Service and the FAA. This joint effort is formally recognized in the ESSA/FAA Memorandum of Agreement of 1965. The primary impetus for the development of the model was related to the problem of satisfying the ever-increasing weather briefing requirements of the general aviation pilot. The difficulty of trying to meet these needs on an individualized person-to-person basis suggested that other techniques be analyzed to evaluate their suitability in aviation weather dissemination.

1.2 THE PROBLEM

The problem of a steady increase in the demand for weather briefing services, particularly in the face of static manpower levels, has been especially pronounced in the area of dissemination of weather information to general aviation. As can be seen from Table 1* below, some of the indicators of potential demand are expected to at least double or triple during the next decade.

Table 1

Indicators of Potential Demand

GENERAL AVIATION	1972	1977	1982
AIRCRAFT	140,000	180,000	230,000
PILOTS	740,000	1,000,000	1,500,000
BRIEFINGS	15,000,000	26,000,000	48,000,000
FLIGHTS	30,000,000	50,000,000	90,000,000

Therefore, the basic problem being faced is how to meet the steadily growing demand for weather information by general aviation in the most efficient and effective manner. Specifically, what mix of automated dissemination techniques should be employed, in order to cope with the situation.

As one approach, the National Weather Service felt it would be appropriate to develop an analytic means (in the form of a computer based model) for evaluating the various dissemination techniques available currently, and also those expected to become available during the next decade.

The complexities of the problem--the geographical distribution of demand, the variation in required types of weather information and the number of dissemination techniques--suggested the development of an analytical tool.

The approach taken involved the development of a computer program which allows for an evaluation of various dissemination techniques in terms of cost/performance tradeoffs. This is done by using data reflecting both the user population and existing dissemination systems as well as doing some limited simulation.

A basic, three step approach was utilized in the overall task:

Phase I - Conceptualization and Modeling
Phase II - Computer Program Development
Phase III - Validation/Exercise/Documentation

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*Derived from Aviation Forecasts FY 1971-82, DOT/FAA, January 1971.

The first phase involved problem definition, establishing boundaries and constraints, attempting to focus on a specific end product, developing basic ideas for model structure and use, and allocating resources and assignments in a specific manner. In addition, a substantial effort in developing a data base preceded the above.

The second phase tended to be much more straightforward and required considerably less contractor-client interaction. Software development was almost entirely handled by the contractor. However, upon termination of the contract, a decision was made to convert the program to another computer, thereby requiring a substantial additional effort by in-house personnel.

The third phase primarily involved the exercise of the model using various combinations of dissemination techniques. In addition, verification of input data and manual checking of the model's output took place. It was also necessary to gain a higher level of experience in exercising the model and interpreting the results, prior to conveying pertinent information to management and the general aviation community. Finally, in a separate document, comprehensive documentation of the computer program was undertaken, including subroutine flow charts, definition of terms and variables, examples of model operation for potential users, and samples of raw output, as well as a copy of the input data and program.

1.3 CONSTRAINTS

Several ground rules were established at the outset of the project. One of these was that the study be limited to general aviation (as distinguished from commercial or military). Other constraints had to do with limiting the geographical boundaries to the 48 contiguous United States and selecting the time periods of 1971, 1975,and 1980 for evaluation purposes.

The modeling process involved some subjective judgment in establishing certain basic measurements such as the demand existing in a given area and the demand served by any dissemination facility installed in that area. The manner in which these judgments were arrived at is discussed in the next section.

2.0 SERVICE REQUIREMENTS

The weather information requirements of general aviation were placed in seven general categories as shown in the following table.

Table 2

Categories of Support by Flight Lengths and Flight Phase

SUPPORT	FLIGHT LENGTHS		
	<50 NM	50-200 NM	>200 NM
PLANNING	1	3	5
PREFLIGHT	2	4	6
EN ROUTE	7		

Planning support is defined here as the provision of forecasts from five days up to two hours prior to takeoff. Preflight support is that which is required in the two hour period ending with takeoff, while en route support is provided to an airborne pilot. Both FAA and NWS studies have shown that general aviation flight lengths tend to fall about equally into the segments listed above, that is, 1/3 of all flights are less than 50 nautical miles, 1/3 are 50-200 nautical miles, and the remainder are greater than 200 nautical miles.

From the above table, therefore, there are seven basic types of service requirements or support functions. The first six categories, may be collectively classed as ground support. Demand estimates for these six support functions were developed from the number of general aviation aircraft in each one degree square of latitude/longitude in the 48 states as listed in FAA records.

2.1 DEMAND FACTORS

The demand associated with a flight of length "x" can only be subjectively estimated. However, it appears safe to assume that many local flights are conducted with no more weather information than a look at the sky and that briefing demands rise with longer flights. In addition, longer flights will often involve preflight weather briefings to verify previous forecasts, computing estimated time of arrival (ETA), flight altitude, etc. These longer flights may also require additional information while en route. Therefore, based on the foregoing considerations and FAA statistics on total flight services, the following estimates of relative demand associated with different flight lengths were arrived at.

Table 3

Average Demands Per Flight by Support Category

SUPPORT	FLIGHT LENGTHS		
	< 50 NM	50-200 NM	> 200 NM
PLANNING	0.2	1.5	3.0
PREFLIGHT	0.3	1.0	1.0
EN ROUTE	4.3		

The above table indicates the ratio of one type of demand to another. For example, in the flight segment over 200 miles, it is felt that there are likely to be three times as many demands for weather information of a planning nature as for preflight. These ratios allow for a fairly liberal estimate of the total potential demand for general aviation weather briefing services. However, these ratios can be altered, if subsequent sensitivity tests indicate that they should be more conservative.

From the foregoing table, the demand factors for converting numbers of aircraft per grid square into annual demands were computed via the following formula:

$$D = \frac{(.333)(N_f)(d_{f_1})}{N_a}(A_g)$$

D = Demand factor
.333= 1/3 of flights (as discussed in Section 2.0)
N_f = National number of flights for period
N_a = National number of aircraft for period
d_{f_1} = Demands per flight for WSF_1 (Weighted Support Function 1)
Ag = Number of aircraft in the grid square

For most analysis purposes within the model, the demand must be expressed in terms of an hourly design load to be satisfied. A two year study of aircraft departures, conducted by the FAA, indicated that on the average approximately 8% of the daily departures took place each hour between 0800 and 1700 hours. A study of two FSSs indicated that the maximum daily load on weather briefers was approximately 160% of the average daily load. An assumption that the variation from average in the hourly load is approximately twice the variation from average in the daily load would put the peak hourly load at approximately 25.6% of the daily load (320% x 8%). The design hourly load selected was 20% of the daily load. Design hour factors were then established by multiplying annual demand factors by .20 and dividing by 365.

For the seven support functions for 1971 the factors are as follows:

Table 4

Design Hour Demand Factors by Support Category

SUPPORT	FLIGHT LENGTHS		
	< 50 NM	50-200 NM	> 200 NM
PLANNING	.009	.070	.140
PREFLIGHT	.014	.047	.047
EN ROUTE	.20		

These support functions may be weighted in each exercise of the model if one wishes to stress serving a particular segment of general aviation operations. For example, one might wish to emphasize support for flights over 200 miles, which would mean weighting support functions 5 and 6 more heavily.

Developing a demand estimate for en route weather support proved much more difficult, since no distinct measure is made of airborne contacts which are exclusively weather related. Furthermore, the distribution of demands along flight paths is not known, and is likely to be greatly dependent on the weather. Therefore, an estimate of this number was made from the statistics on total flight services kept by the FAA. As a result, the basis for en route demand is somewhat indirectly related to the basis for planning and preflight demand, since the latter is based on numbers of aircraft.

The following assumptions were made in establishing conversion factors to be used in determining en route demand in each square or grid block:

- That demand for en route weather support is generally about 30% of all flight services.
- That growth in demand for en route weather support will be approximately proportional to the growth in general aviation flights.
- That distribution of demand around a flight service station (FSS) is about as follows (because contacts with airborne pilots could originate from any point within radio range):

5%	5%	5%
5%	(FSS) 60%	5%
5%	5%	5%

(1° squares)

Design hour factors for en route weather support were then developed via the following formula:

$$D_e = \frac{(.30)(N_f)}{N_b}(F_g)\left(\frac{.2}{365}\right)$$

D_e = Demand factor for converting flight services into en route demands

$.30$ = Fraction of total flight services assumed to be primarily weather related

N_f = National number of flights for period being evaluated

N_b = National number of flights for base year (1969)

F_g = Number of flight services requested from the grid block

$\left(\frac{.2}{365}\right)$ = Hourly load

Computations indicate that for 1971, $D_e = .20$, while for 1980 D_e increases to .70.

3.0 DISSEMINATION TECHNIQUES

The dissemination techniques listed in the following table were utilized in this study. Each of the techniques tends to be somewhat better suited for supporting one phase of the flight profile than another. However, the techniques could support all phases of the flight profile, with the exception of the en route phase, which can only be supported by radio, TV and personal briefers.

Table 5

Applicability of Dissemination Techniques by Support Category

Dissemination Technique	Product Support Objectives						
	Planning <50 NM	Preflight <50 NM	Planning 50-200 NM	Preflight 50-200 NM	Planning >200 NM	Preflight >200 NM	En Route
Recorded Radio Broadcast	x	x	x	x	x	x	x
Recorded Telephone Broadcast	x	x	x	x	x	x	
Request/Reply	x	x	x	x	x	x	
Cable TV Broadcast	x	x	x	x	x	x	
Broadcast TV (Commercial)	x	x	x	x	x	x	x
Teletypewriter Terminal	x	x	x	x	x	x	
Pilot Self-Briefing Display	x	x	x	x	x	x	
Personal Briefer	x	x	x	x	x	x	x

Determining the effectiveness of a particular technique in satisfying demand was particularly difficult. The approach taken was to utilize three qualitative factors and attempt to quantify them. The three factors are: accessibility, usefulness, and presentation. The values (from 0.0 - 1.0) of the accessibility and usefulness factors were arrived at through the Delphi Method (a method of quantifying a consensus reached by experts), while the value for the third factor (presentation) is based on information theory--a theory that deals statistically with the efficiency of processes of communication between men and machines (and indicates relative values of audio, audio-visual, and visual methods of presentation). The three effectiveness factors can be defined as follows:

1. The accessibility afforded by a given technique is the relative ease or difficulty with which a product can be obtained.

2. The usefulness of a product is how well the product meets weather support requirements. Usefulness may also depend on the characteristics of the dissemination technique.

3. The effectiveness of presentation is how well the product is understood by those who receive it and can use it.

The accessibility and usefulness factors are applied in the demand component of the model. These factors determine the proportion in which a number of techniques will divide demand in any particular 1° square. The presentation factor is used in the model's evaluation component in making comparisons among techniques comprising a total system.

3.1 TECHNIQUE/DEMAND ALLOCATION EXAMPLE

This section gives an example of how demand and facilities are allocated by the model to a particular technique. In this example, the technique is request/reply (interrogating a computer via teletypewriter terminals), and is only one of the techniques in the total (hypothetical) system.

A sample request/reply configuration might include five computer centers each of which serves 20% of the airports in the 100 grid squares containing the highest number of registered aircraft. (See Sections 5.1 and 5.2 for an actual model exercise including request/reply.) Part of this configuration might look as follows:

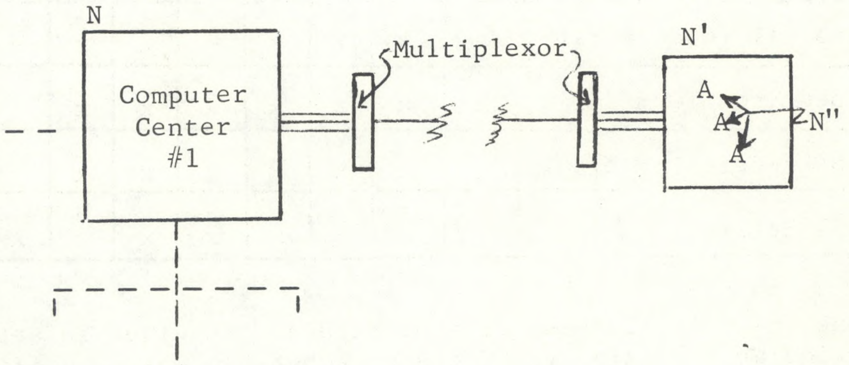


Figure 1 - Potential Request/Reply Network

In the program
N = number of computer centers
N' = number of grid squares served
N" = % of airports to be served in each grid square
A = airports at which terminals are to be placed

The request/reply technique connects terminals at each airfield within the selected computer center's grid squares through a multiplexor communications connection from the computer center to each grid square. In the cost component, the cost of the request/reply technique is determined as an accumulation of the costs associated with each computer center. These latter costs include terminal costs, communication costs, and computer costs.

The total demand served in all grid squares by the computer center is divided by the number of airfields within the grid squares to reflect the average demand served at an airfield. This demand is employed in queuing analysis to determine the average airfield requirement for terminals. The total number of terminals is then computed and used in determining all terminal costs.

This number also represents the total required connections to the computer. It is divided by the number of grid squares to determine the requirements for multiplexors and Wide Area Telephone Service (WATS) circuits, which represent the communications costs. The number or capacity of the computers required at the center and their associated operating cost is determined from the total residual demand to be served.

The analyst designates the grid square locations of computer centers for request/reply dissemination as a model input. The facility component measures the distance between a given grid square (starting with largest demand) to each computer center, then assigns the grid square to the least distant center. In the demand component the demand to be served by request/reply in an assigned grid square is determined by:

1. Allocating demand to each technique serving the grid square in a procedure which compares the relative efficiency of each of these techniques (based on the product of accessibility and usefulness factors for each support function), and

2. Reducing demand to be served by request/reply to the percentage of airfields for which the analyst specified installation.

The result of 1 above will be a percentage of total grid square demand. In 2 above, a national relationship between number of airfields and numbers of aircraft, converted into a relationship between cumulative percentages of demand, is entered to determine the necessary modification to the result obtained in 1.

These relationships are arrived at from a previously established relationship between Standard Metropolitan Statistical Areas (SMSAs) and general aviation aircraft shown on the next page.

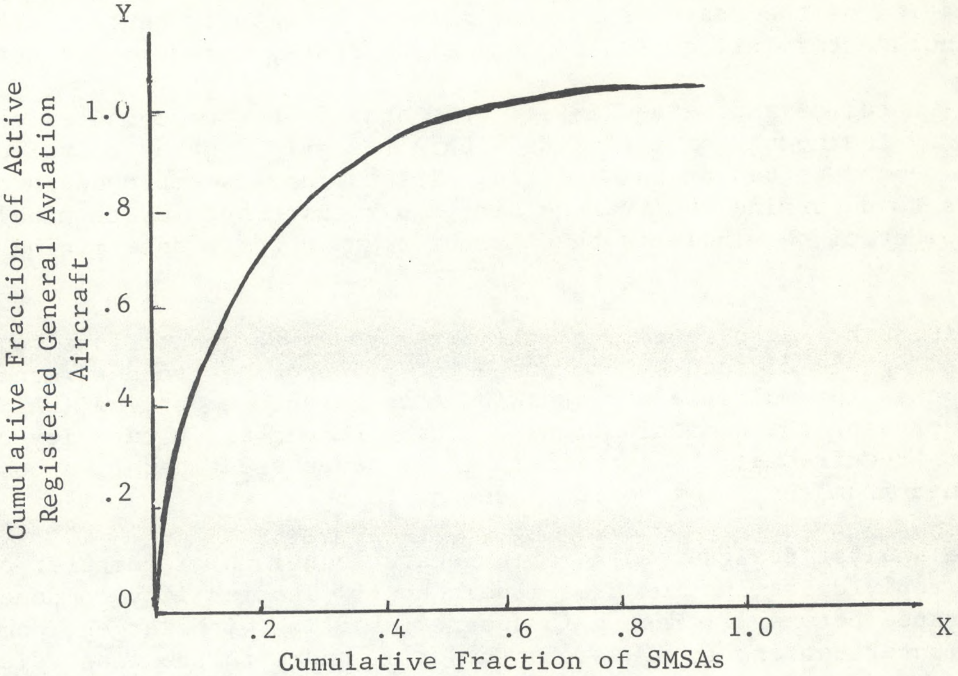


Figure 2 - Distribution of Registered Aircraft Among SMSAs

3.2 MULTIPLE TECHNIQUE DEMAND ALLOCATION

In a typical configuration there will be three or four dissemination techniques. Some grid squares will be served by one or two techniques, while others may be covered by all. This section gives an example of how demand is divided among techniques.

Prior to the division of demand among techniques in the demand component, the model's facility component allocates facilities to those locations where the most residual demand would be served. These allocations are controlled by the weights given to the support functions discussed earlier. The order of the techniques during data input is important in this stage of the computations because the weights are applied sequentially to the residual demand. For example, with two techniques having a weight of .8 each, the first will absorb 80% of the load while the second will absorb 80% of the remainder, or 16% (80% of 20%). The demand employed for purposes of allocating facilities (such as radio transmitters, phone installations, etc.) will not really reflect the load serviced by the facility because no provision is made to consider other facilities serving a particular location at this point in the model's computation. (See Table 6 for an outline of the model's structure.) Hence, the facility component allocates facilities for a given technique on the basis of gross estimates of demand, rather than examining an individual location and deciding what techniques to assign there.

As the model proceeds into the demand component, and following the computation of the product of the accessibility (A) and usefulness (U) factors, the model sorts the values and takes the lowest and divides it by the number of techniques, as shown, for each support function. This is the step which divides the demand among techniques competing for demand in a particular square.

	AxU
Radio (RAD)	.8
Phone (PHO)	.6
Request/Reply (R/R)	.3

	SF 1	(Support Function one)	SF 2 ...
(R/R)	.3	.3/3 techniques = .1	.
(PHO)	.6		.
(RAD)	.8		.

This value (.1) is then allocated to each technique and represents a share of the total demand. Next, the model subtracts the first value from the second (.6 - .3) and divides the remainder by the number of techniques remaining (.3 ÷ 2). This amount is then added to the .1, resulting in:

(R/R)	.3	.1
(PHO)	.6	.1 + .15
(RAD)	.8	.1 + .15

Repeating this step and subtracting (.6 from .18) results in .2 (divided by the one remaining technique), or .2 added to RAD.

(R/R)	.3	.1	= .1
(PHO)	.6	.1 + .15	= .25
(RAD)	.8	.1 + .15 + .2	= .45

Therefore, the total demand is shared in the following proportions: Radio .45, Phone .25, Request/Reply .10, for a total of .8 of all the demand.

4.0 THE MODEL

The model structure was developed to provide a cost/effectiveness analysis of any mix of dissemination techniques which might be employed in providing weather information to general aviation. A general summary of what the model consists is shown on the next page. The model can be viewed as a mathematical representation of a highly complex, irregularly distributed queuing system in which nonstationary random demands can be satisfied by a limited mix of dissemination techniques.

4.1 MODEL INPUT

The input data used falls into two parts. One consists of a "configuration description record" (CDR), which is simply the specification of a particular mix of techniques and their attributes (which techniques, how many facilities, how much demand to serve, message length, etc.), while the other part of the input data consists of basic information concerning the general aviation weather service user environment, including a variety of FAA statistics concerning expected growth in general aviation during the coming decade.

In addition, there are a number of factors which have been incorporated into the model, including the accessibility, usefulness, and presentation factors (discussed earlier) which can be varied with each exercise of the model. Also, the costs of various equipment and facilities is included.

With the foregoing as input, the model then proceeds through four components in the order shown in Table 6. Summaries are provided at the end of each component (if desired), with an overall system summary at the end of the cost component. For a comparison of two or more systems, the evaluation component can be used. In addition, graphic output is provided giving location of facilities on a three page printout with which a plastic overlay map (approximating a mercator projection) is used.

The model converts basic data files into matrix estimates of grid block demand, employs these estimates in selecting the most effective grid block for installation of the facilities of the various dissemination techniques, and computes the distances to be employed in determining communications costs of the dissemination techniques. This latter feature is used most prominently in the telephone and request/reply techniques.

4.2 MODEL USE

To use this model as a design tool for a particular system configuration, one can specify such design variables as:

- Various sets of dissemination techniques (e.g., one set might consist of radio, phone, personal briefers, and self-briefing facilities, while a second set could consist of radio, television, phone and request/reply).

- Separation between facilities (in nautical miles).

- Varying resources geographically (e.g., facilities, personnel)

Table 6

Evaluation Model

INPUT DATA	CONFIGURATION DESCRIPTION RECORD	TECHNIQUE(S); NUMBER OF PRIMARY AND SLAVE FACILITIES: SEPARATION DISTANCE; RADIUS OF COVERAGE; MESSAGE LENGTH; % AIRPORTS SERVED; WEIGHTED SUPPORT FUNCTIONS (7); PRIORITY
	AVN WX SERVICE ENVIRONMENT	GRID SQUARE IDENTIFICATION; NUMBER OF G/A AIRCRAFT AND AIRPORTS PER 1° GRID SQUARE; FAA/NWS REGION IN WHICH LOCATED; FSS/WSFO/WSO LOCATIONS AND GRID SQUARES SERVED; EN ROUTE WEATHER FLIGHT SERVICES
PROGRAM VARIABLES		DEMAND FACTORS: QUEUING ANALYSIS, LINE CHARGES, FACILITY (EQUIPMENT) COSTS OTHER FACTORS: ACCESSIBILITY, USEFULNESS, PRESENTATION
COMPONENTS	FACILITY	Allocates facilities via "allocation rules" defined for each (mass dissemination) technique, by number of primary and slave facilities, area covered, and separation distance; for other point dissemination techniques such as teletype drops, allocates facilities according to number of primary grid blocks and/or percentage of airports served; this component computes distances between primary and slave locations; generates demand matrices for demand component from weighted support functions.
	DEMAND	Computes demand satisfied based on accessibility and usefulness factors as well as order/priority of the technique within a configuration; computes number of personal briefers required in a particular configuration.
	COST	Determines cost associated with each technique (capital, operating, and personnel); computes cost per demand served; provides cost output by S&E, FEC, R&D categories.
	EVALUATION	Ranks configurations according to system cost, cost per demand, and percent demand satisfied (related to presentation factor); determines percentage of total potential demand satisfied, and percentage of support provided for local, medium, and long range flights.

- Level of service factors (e.g., frequency of busy signal).
- Message lengths in support of particular segments of the user population (e.g., local flying vs. long range).

With these design variables, the model can output information on:

- Location of facilities assigned for each technique (alphanumeric or graphic).
- Distribution of demand captured and coverage (ratio of captured demand to total potential demand for each technique and for the total system).
- Initial cost and annual operating cost associated with each technique and the total system.

By changing the design variables and repeatedly applying the model, information can be generated on the best set of variables to achieve a given cost, demand served, or cost-demand ratio.

The major features of this computerized model include:

- Flexibility in defining a dissemination system configuration.
- Incorporation of geographical variation in demand.
- Incorporation of both existing and planned NWS and FAA facilities and service.
- Allowing for forecasts of growth in general aviation during the coming decade.

5.0 ANALYTICAL RESULTS

Since a considerable amount of the limited resources available for this project were consumed converting the model from one computer system to another, the amount of output from the model was somewhat restricted. However, the following sections give more detailed results of some of the model exercises using various sets of dissemination techniques, design variables, and time periods.

5.1 PRESENT SYSTEM

As a first choice for analysis it was decided that a configuration representing the present dissemination system would be best. This configuration was chosen in order to have a baseline or reference against which other configurations or alternatives could be compared. The specific information desired was the cost of the present system and its elements, and an indication of the amount of demand it satisfies. Once the basic output is obtained, variations of the present system can be evaluated. Defining the present system required some judgment since it was desired to include all the present means and sources general aviation pilots have for weather information. The table below lists the elements of the present system (in the 48 states) as they were used in the initial model exercises.

Table 7

Present FAA and NWS Dissemination System

Technique	Number
Radio (TWEB)*	92 L/MF Transmitters
Phone (PATWAS)**	44 Installations
Briefer (FAA & NWS)	5000 People
Self Briefing (FAA & NWS)	500 Locations

*Transcribed Weather Broadcast
**Pilots Automatic Telephone Weather Answering Service

These exercises showed that the present dissemination system as constituted in the preceding table costs a computed $70,000,000 annually. This includes all personnel and operating costs, and all capital costs for the existing system amortized over five years. According to the model, the system satisfies 80% of all the computed demand for weather information by general aviation, at a cost of 96 cents per demand. The individual cost per demand breakdown among the techniques is as follows:

Table 8

Present System Cost Per Demand

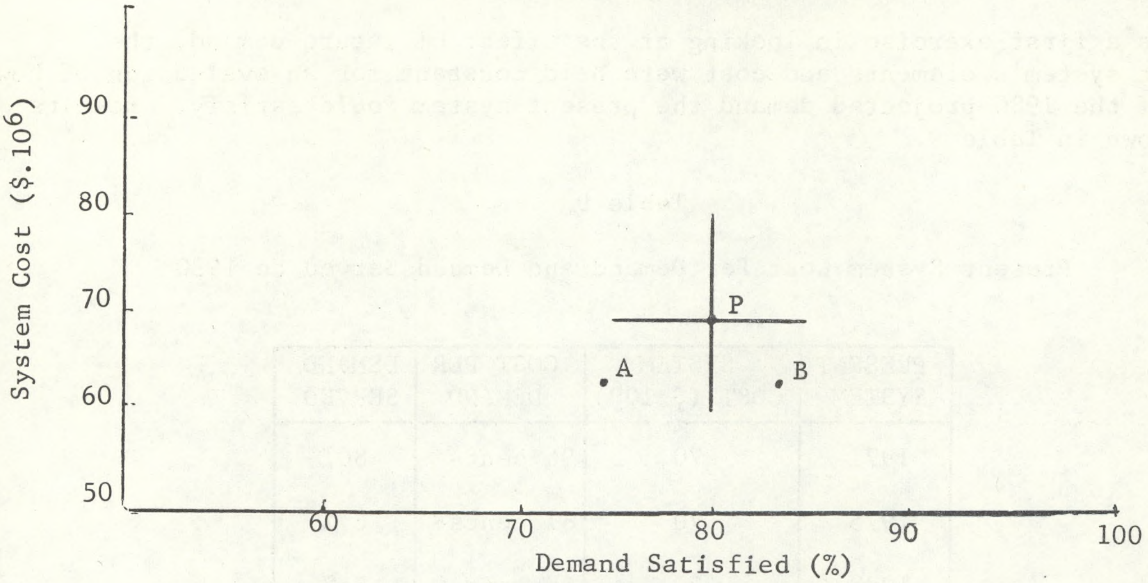
TECHNIQUE	COST ($)
RADIO (TWEB)	.03
PHONE (PATWAS)	.08
SELF BRIEFING	1.89
PERSONAL BRIEFER	1.66

See Appendix A for examples of graphic output showing where the model locates facilities of the four techniques comprising the present dissemination system. These locations tend to closely approximate the sites of present facilities.

Subsequently, some variations of the present system were evaluated. The objective of these exercises was to determine the change in costs and demand served in a system which reduces the number of briefers by 10%, while substituting television or request/reply.

In the first of these two model exercises, the elements of the present system were used as shown in Table 7, but with 4500 instead of 5000 briefers, and the addition of five computer centers for handling request/reply briefings (via teletypewriter terminals) at 500 of the busiest airports. This particular system (Configuration A) resulted in a total cost of $65,000,000 with 74% of the demand satisfied at a cost of 96 cents per demand.

The next exercise again used the elements of the present system as shown in Table 7, but with 4500 instead of 5000 briefers, and the addition of 50 television outlets providing a TWEB (transcribed weather broadcast) type product. This particular system (configuration B) resulted in a total cost of $65,000,000 with 83% of the demand satisfied at a cost of 85 cents per demand. Figure 3 presents a summary and comparison of these initial model exercises, all of which are based on 1971 demand.



CONFIGURATION	COST PER DEMAND	SYSTEM COST
A - REQUEST REPLY	96 cents	$65,000,000
B - TELEVISION	85 cents	65,000,000
P - PRESENT SYSTEM	96 cents	70,000,000

Figure 3 - Summary of Initial Alternatives

In the next section, results of further exercises are presented which show the change in demand satisfied and cost per demand in the face of projected increases in general aviation activity from the present to 1980. Throughout all these exercises the accessibility and usefulness factors discussed earlier were held constant, as were the weighted supported functions.

5.2 FUTURE SYSTEM

In structuring an alternative or different set of dissemination techniques to meet the anticipated growth in general aviation, a number of points must be considered. Among these are:

- Does the system reduce the burden on manpower?
- Are advances in computer and communications technology being fully utilized?
- Is the system in the National Weather Service interest from the standpoint of its overall service commitments?

As a first exercise in looking at the effect of future demand, the present system's elements and cost were held constant for an evaluation of how much of the 1980 projected demand the present system could satisfy. Results are shown in Table 9.

Table 9

Present System Cost Per Demand and Demand Served to 1980

PRESENT SYSTEM	SYSTEM COST ($.$10^6$)	COST PER DEMAND	DEMAND SERVED
1971	70	96 cents	80%
1975	70	81 cents*	67%
1980	70	65 cents*	55%

*Cost per demand declines because more demand is being satisfied in 1975 and 1980. However, as reflected in the demand served column, the potential demand to be served grows at a much faster rate.

Another way of viewing this output is portrayed in the following graph which shows the decline in demand served with time, if the present dissemination system remains unchanged.

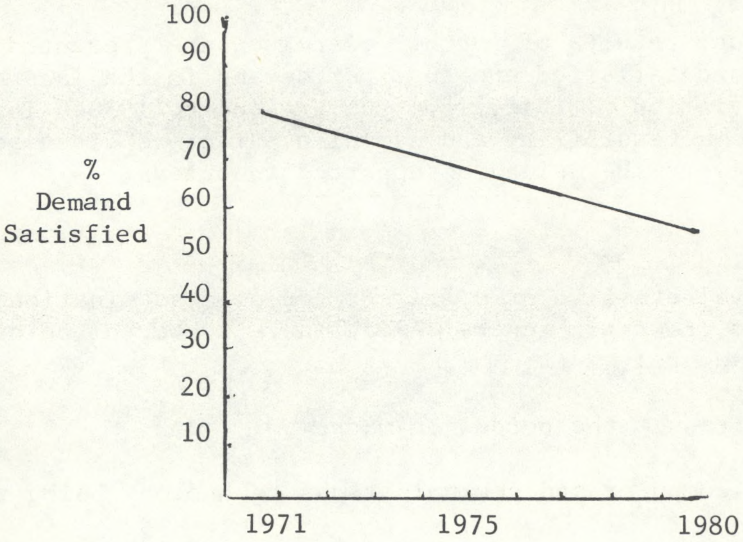


Figure 4 - Present System 1971-1980

Next, alternatives A and B (section 5.1) were used for an evaluation of how much of the demand projected out to 1980 they could satisfy. Results indicate that the relative position of each alternative remains unchanged. However, alternative B remains more cost/effective with time due to the considerable demand which television can potentially satisfy. Table 10 summarizes the relationship between the two alternatives for the three time periods evaluated.

Table 10

Future Systems Evaluation Summary

ALTERNATIVE	A			B		
YEAR	1971	1975	1980	1971	1975	1980
SYSTEM COST ($$10^6$)	65	65	65	65	65	65
COST PER DEMAND ($)	.96	.82	.65	.85	.71	.56
% DEMAND SATISFIED	74	63	52	83	72	60

5.3 OTHER SYSTEMS

Alternative systems also can be derived by using cost limits and constraints on numbers of people, or type and location of facilities. For example, a cost limit could be the cost of the present system. One type of constraint might be the total number of people in the system, or the distribution of facilities such as the allocation of one computer center per FAA or NWS Region for request/reply purposes.

In addition, heretofore unknown or little-used dissemination techniques can be incorporated into the model. These might include such techniques as picturephone, radiotelephone, and data banks with automatic acoustic reply via touch tone telephone.

6.0 CONCLUSIONS

In discussing any conclusions, it must be recognized that the results to date are based on limited model exercises, and should be viewed accordingly. Results thus far have also been limited by a lack of sensitivity testing. Finally, distinctions need to be made in discussing conclusions about the model vs. conclusions about the results, since so much is dependent on how the initial design variables are specified.

Although there has not been sufficient exercising of the model to warrant a wide range of conclusions, it can be said that the model functions in the manner intended and inspires confidence in its results.

One conclusion which perhaps emerges from the results presented in Section 5 is that "point" dissemination techniques such as request/reply (interrogating a computer via a teletypewriter) cannot effectively compete with mass dissemination techniques such as radio or television on a cost/effectiveness basis. Therefore, "point" dissemination techniques should be used to supplement the mass techniques in the design of a future dissemination system.

6.1 PROBLEM AREAS

The design problems for any future system will be not only in determining which techniques should be used, but particularly the role each should play in the total system. Specifically, what proportion of the total demand should one technique attempt to serve in relation to other techniques, is a question that must be resolved. It is likely that optimizing a particular alternative will require considerable experimentation with the model.

The model also needs to be refined in order to make the results more precise and easy to understand. Additionally, a substantial effort is required for updating much of the initial cost data used as well as the data base for aircraft distribution and total flight services.

As mentioned previously, the accessibility and usefulness factors and weighted support functions have been held constant in the exercises presented in this report. The necessity for determining the impact of varying these factors and functions (sensitivity testing) is well recognized and will be a part of any future work with this model.

6.2 FUTURE POSSIBILITIES

Among a number of future possibilities for further work with the model are the following:

- Expand the data base to more accurately reflect the user population.
- Survey the user population and identify problem areas.
- Update all of the data base, particularly cost data.
- Streamline the program to make it more efficient.

- Provide more graphic output.
- Modify the program so that it can be used to evaluate dissemination techniques for other types of weather service, such as agriculture, marine, and public.
- Investigate other model applications.
- Attempt to optimize a total system.

APPENDIX A

GRAPHIC OUTPUT

The following series of figures shows where the model locates facilities of the four dissemination techniques comprising the present system.

The matrix covering the 48 states is scanned by the model from left to right in 1° strips. The numbers shown indicate the sequence of facility location as well as the total number of facilities placed up to a particular point. For example, in Figure A-1, with a total of 92 sites throughout the 48 states, number 30 happens to be located at Salt Lake City.

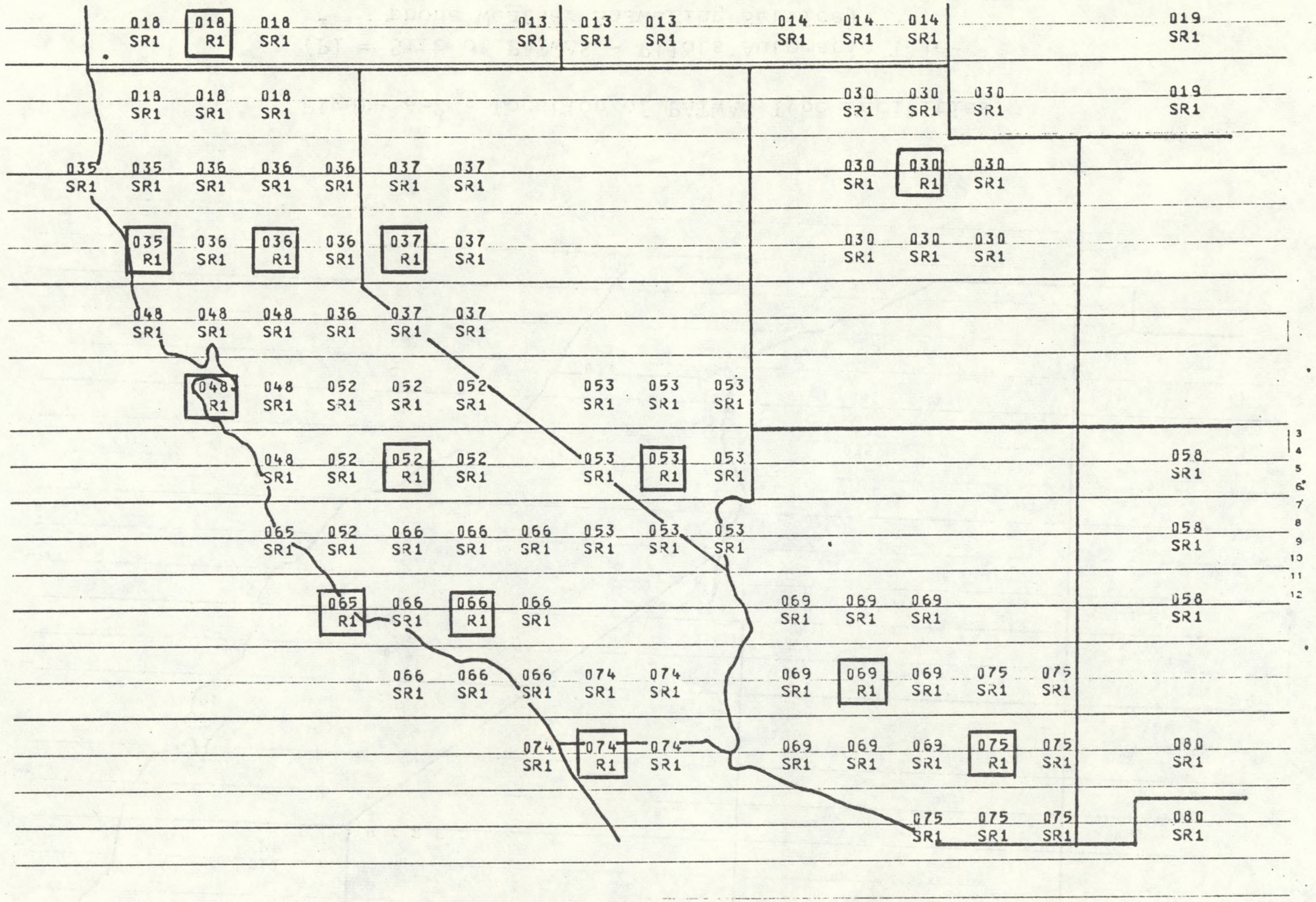


Figure A-1 - Location of Radio Facilities

(R1 = Site of transmitters for transcribed weather broadcast)
(SR1 = Slave (satellite) grid square which is within range of the transmitter in the correspondingly numbered square.)

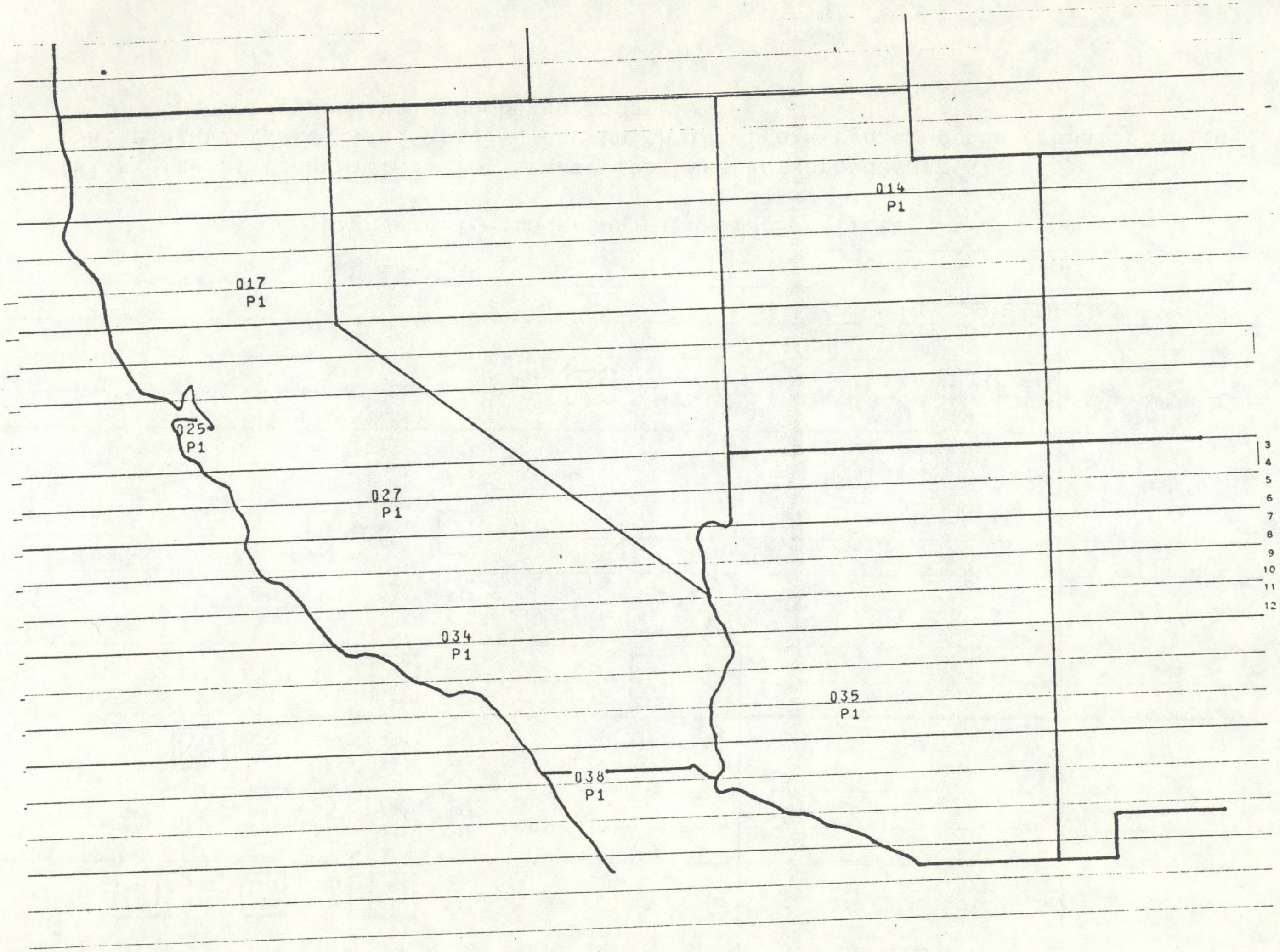


Figure A-2 - Location of PATWAS Type Facilities

(P1 = Site of PATWAS - Pilots Automatic Telephone Weather Answering Service)

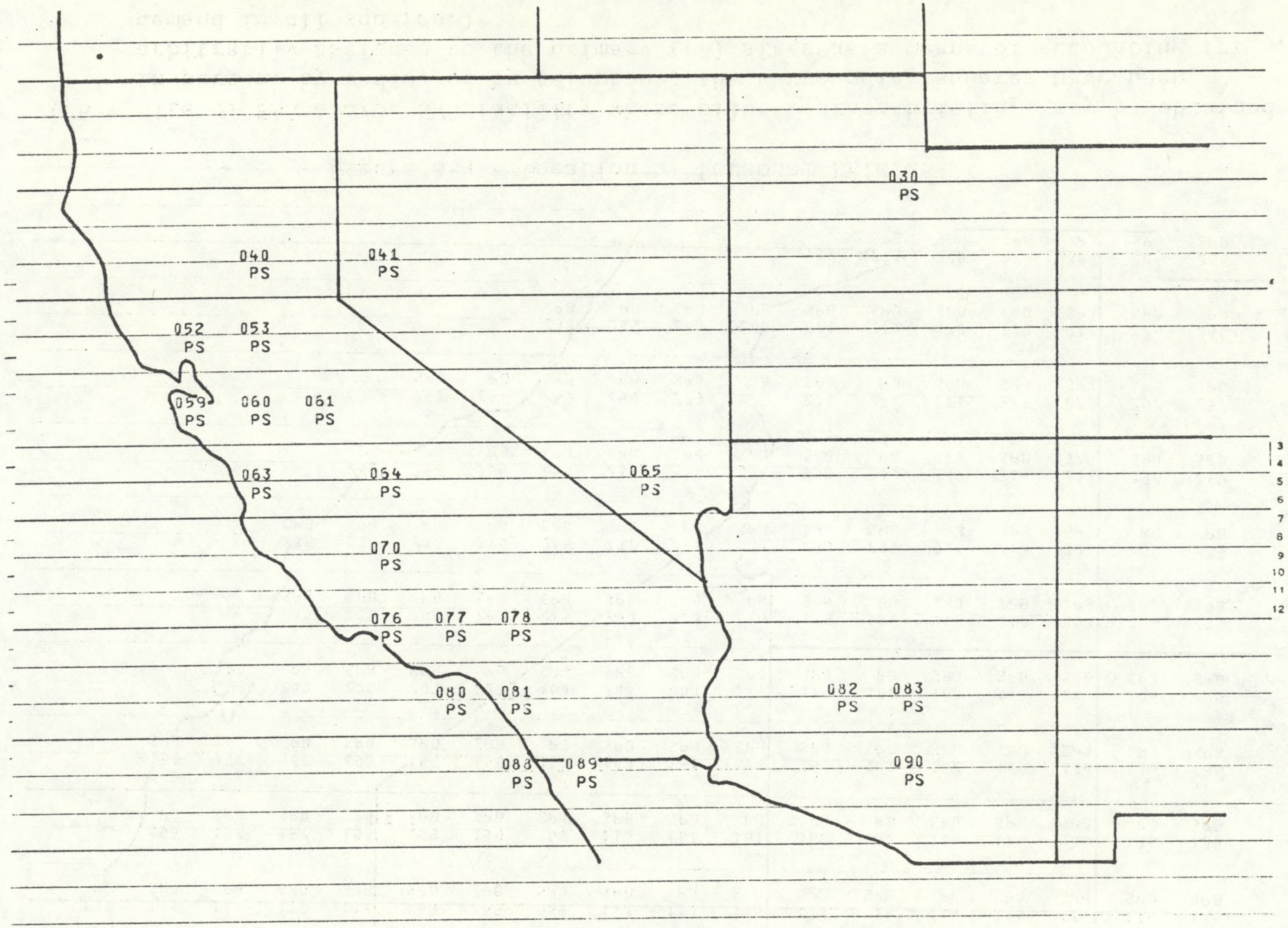


Figure A-3 - Location of Self-Briefing Facilities

(PS = Site of FAA and/or NWS pilot self briefing display)

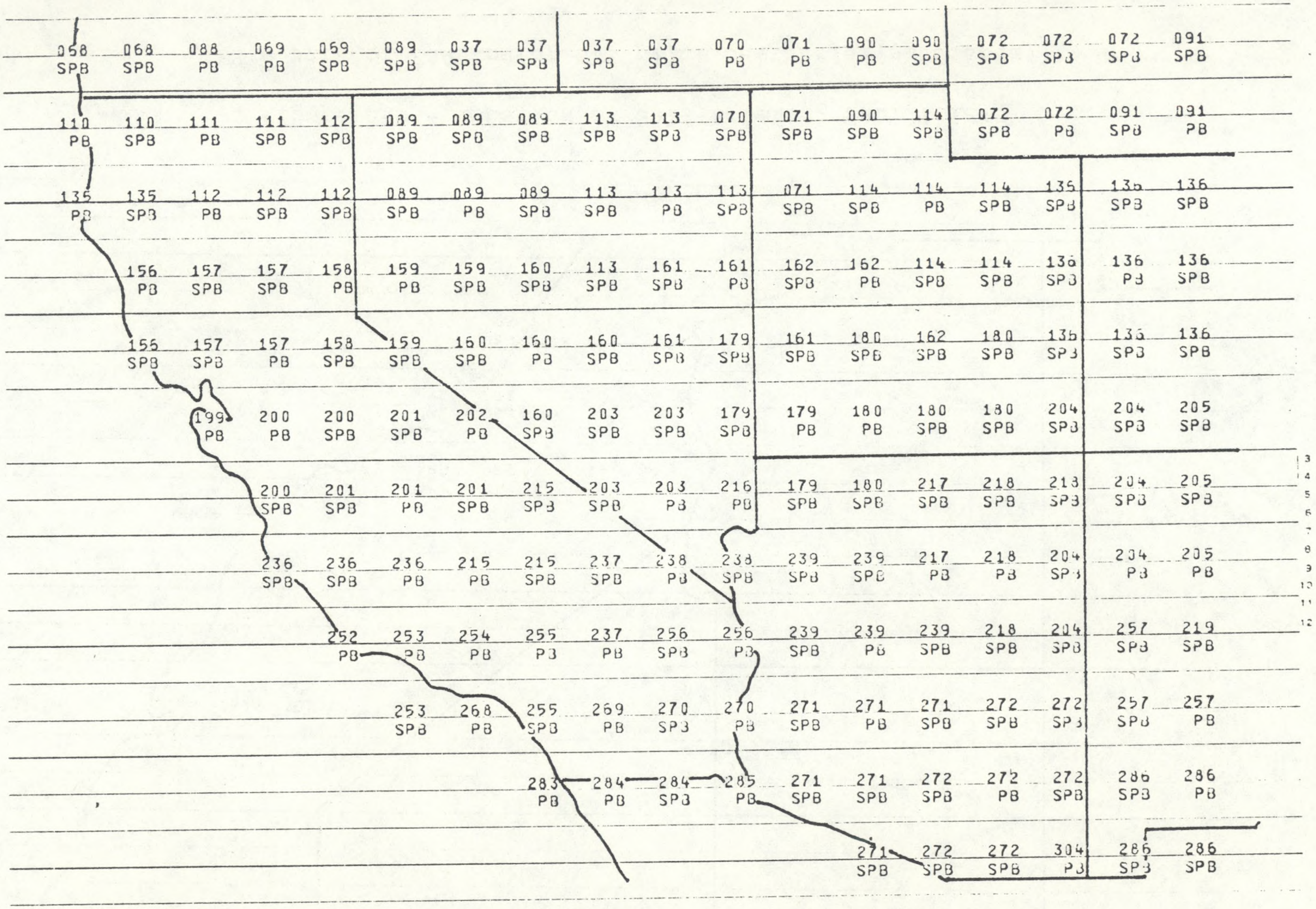


Figure A-4 - Location of Personal Briefers

(PB = Site of FAA and/or NWS facility where pilot weather briefings may be obtained in person, by radio, or by telephone; the surrounding squares have been arbitrarily assigned to the primary (PB) sites as a means of accounting for demand in all squares.)

APPENDIX B

SYSTEM FLOW CHART

WITH

DATA KEY

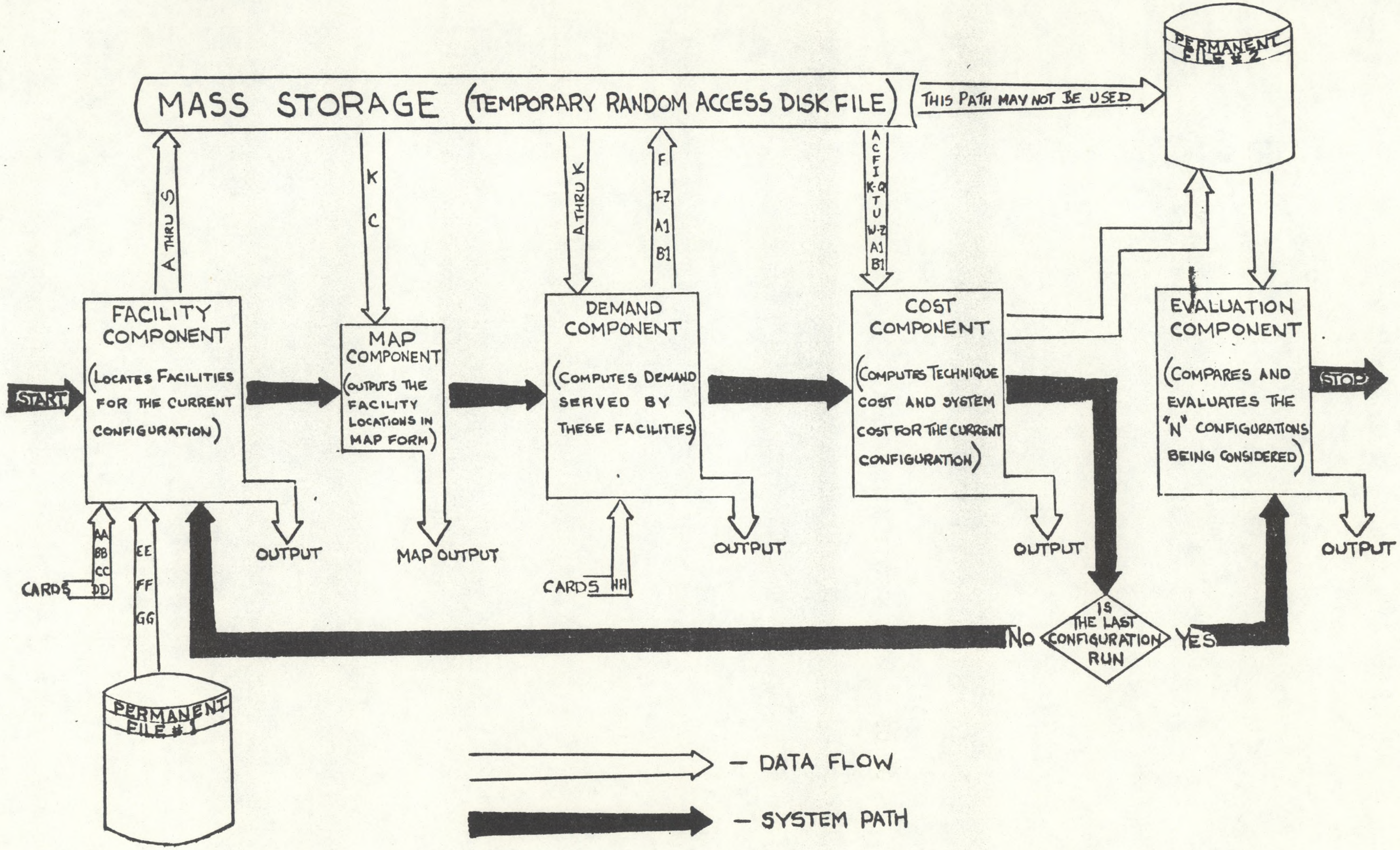


Figure B-1 - System Flow Chart

(See Data Key next page.)

DATA KEY

A. - (IONE, JONE, IXMAX, JMAX) 1ST/LAST MATRIX GRID SQUARES

B. - (XM1(26,60,7)) TOTAL AVAILABLE DEMAND/GRD.SQR. BY SUPPORT FUNCTION

C. - (FACFL1 & FACFL2(10,26,60)) GRID SQR. LOCATIONS OF TECHNIQUES

D. - (SFAC8 & SFAC9(26,60)) FSS, WSFO OR WSO LOCATION MATRICES

E. - (IPRIOR (10)) PRIORITY LENGTH FOR EACH TECHNIQUE/USED IN DEMAND COMPONENT

F. - (MSGL (10)) MESSAGE LENGTH FOR EACH TECHNIQUE

G. - (FAC (10)) NO. OF FACILITIES LOCATED FOR EACH TECHNIQUE

H. - (WBF (26,60)) LOCATION MATRIX FOR FSS'S, WSFO'S & WSO'S

I. - (AXNPR2(10)) NO. OF SLAVES

J. - (NCDR OR KCT) NO. OF TECHNIQUES IN THE CONFIGURATION

K. - (KTN(10)) THE CONFIGURATION TECHNIQUE NUMBER

L. - (TNDIS1 & TNDIS2 (3,26,60)) PHONE/CABLE TV LINE LENGTHS/COST COMPONENT

M. - (ILAM) LEVEL OF SERVICE FOR TECHNIQUES

N. - (XSLAV) NO. OF SLAVES FOR A PARTICULAR TECHNIQUE

O. - (AXN,ARR,ASD,AXNPRI) NO. OF PRIMARIES (OR % COVERAGE), RADIUS OF COVERAGE, SEPARATION DISTANCE AND NO. OF SLAVES (OR % COVERAGE)

P. - (EFAC(10)) NO. OF EXISTING RADIO FACILITIES

Q. - (OFAC(2)) NO. OF CO-LOCATED RADIOS, TYPE 1 & 2

R. - (XM(I,J,1)) MATRIX OF NO. OF AIRPORTS PER GRID SQR.

S. - (ICOMP) NO. OF COMPUTERS IN REQUEST/REPLY SYSTEM

T. - (DEMAND (7,26,60)) RESIDUAL DEMAND BY SUPPORT FUNCTION, FOR EACH GRID SQUARE

U. - (DMAND1 (10,26,60)) DEMAND SERVED BY TECHNIQUES SERVING EACH GRID SQUARE

V. - (DMAND2(10,26,60)) TOTAL DEMAND SERVED BY A PRIMARY IN ANY GRID SQUARE

W. - (DMDSUP(7)) TOTAL DEMAND SATISFIED BY ALL TECHNIQUES FOR EACH SUPPORT FUNCTION

X. - (B(10)) SAME AS FAC(10)

Y. - (TOTPER(1)) NO. OF PERSONAL BRIEFERS IN THE SYSTEM

Z. - (TOTDMD(10,7)) DEMAND SERVED BY TECHNIQUE & SUPPORT FUNCTION

A1. - (DMDSPS) TOTAL PERSONAL BRIEFER DEMAND

B1. - (PBR) PERSONAL BRIEFER

AA - TIME PERIOD (1971, 1975 or 1980)

BB - COMPUTER DATA (NO. & LOCATION) FOR REQUEST/REPLY

CC - CONFIGURATION DATA - PERIOD, NO. OF TECHNIQUES, 1ST/LAST GRID SQUARES OR MATRIX AND LEVEL OF SERVICE

DD - TECHNIQUE DATA - TECHNIQUE NO., NO. OF PRIMARIES (OR % COVERAGE), RADIUS OF COVERAGE, SEPARATION DISTANCE, NO. OF SLAVES, % COVERAGE OF SLAVES, % AIRPORTS TO SERVE, NO. OF PERSONAL BRIEFERS, WEIGHTED SUPPORT FUNCTIONS, PRIORITY, MESSAGE LENGTH.

EE - AIRCRAFT CONTACTS/GRID SQR. (TO BE CONVERTED TO EN ROUTE DEMAND)

FF - NO. AIRCRAFT AND NO. AIRPORTS PER GRID SQUARE

GG - LOCATIONS OF GRID SQUARES WITH FSS'S, WSFO'S OR WSO'S AND GRID SQUARES ASSIGNED TO EACH

HH - USEFULNESS AND ACCESSIBILITY FACTORS FOR EACH TECHNIQUE