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FEASIBILITY STUDY OF USING SATELLITES FOR A DISASTER WARNING SYSTEM

(R-3015-1-2)

SECOND PROGRESS REPORT
(29 SEPTEMBER - 26 OCTOBER 1973)

Prepared for
NASA-LEWIS RESEARCH CENTER
Cleveland, Ohio 44135

Under
Contract No. NAS3-17795

26 NOVEMBER 1973

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6565 Arlington Boulevard

Falls Church, Virginia 22046

Major Offices and Facilities Throughout the World

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SECTION 1 - INTRODUCTION

The major objective in October was to complete Task 1, the development of a conceptual traffic flow and an assessment of the adequacy of the Disaster Warning System (DWS) requirements. Since the remaining efforts of this contract are heavily dependent upon the results of Task 1, and there is a need to maintain a close coordination with NOAA on this effort, an unusually detailed discussion of this effort is provided in this progress report.

Additionally, efforts are continuing on Task 2. The primary effort has been the identification of possible communications modes, both terrestrial and space, that may be applicable to the DWS.

SECTION 2 - TECHNICAL PROGRESS SUMMARY

2.1 TASK 1

2.1.1 Introduction

The primary objective of Task 1 is to develop a set of system requirements for the Disaster Warning System (DWS). To accomplish this objective, it is necessary to understand the functioning of that portion of the National Weather Service (NWS) which impacts upon the DWS. Furthermore, since the warning function is a part of and dependent upon other functions of the NWS, it is neither functionally nor economically effective to consider the DWS separately from the other NWS functions. Since the DWS is basically a communication system, it is necessary to establish a conceptual traffic flow of the present and, more importantly, the future (~1985) NWS.

There are two warning systems approaching the fully operational status that will impact the DWS and; hence, these systems are treated individually. Additionally, a satellite system is soon to be launched that will have a data collection capability specially designed for automatic collection of meteorological data from remote terrestrial platforms. If the DWS is to utilize satellites, this data collection function is a prime candidate to be integrated with the DWS. Therefore, the system is addressed individually.

Of more direct concern is an estimate of the number of warning messages. Based upon data during the last several years, future traffic estimates are made as well as queueing waiting times as a function of the number channels of a single satellite.

A set of requirements were generated by NOAA for a DWS utilizing satellites. These requirements are assessed with the aid of the conceptual traffic flow.

2.1.2 Traffic Flow

2.1.2.1 Functional Flow

2.1.2.1.1 Present

The NWS facilities which are of concern to the DWS and the information flow between them are conceptually illustrated in Figure 2-1. Individual facilities are discussed in more detail in Appendices A and B, but their functions will also be briefly stated here.

Data is most often acquired by observing stations which include FAA and Coast Guard stations as well as Weather Service Meteorological Observatories (WSMOs). Some of the data gathered includes surface observations of temperature, barometric pressure, temperatures/dew point spread, cloud coverage and heights of clouds, wind speed and direction, and precipitation. There are also remote radar facilities which aid in the detection of thunderstorm and tornado activity. Atmospheric data (including wind and temperature profiles) is gathered uding Radio Wind soundings (RAWINSONDES) balloons which carry radio equipment aloft, inactive balloons (PIBALS) which are merely observed from the ground, and ground-based sounding equipment.

Generally, the data is transmitted to Weather Service Offices (WSOs) which use it in the preparation of chart information and local reports. The semiprocessed data is then passed upwards to the appropriate Weather Service Forecast Office (WSFO); there are 47 WSFOs in the United States. Each WSFO further processes the data and utilizes it for local forecasting. The data is then transmitted to the National Meteorological Center (NMC) which combines data from the entire country to prepare prognosis charts and other graphics which are then sent back to individual WSFOs to aid in the preparation of their forecasts (and warnings). The forecast information is transmitted by the WSFOs for adaptation and dissemination to the public in a variety of ways. In other words, the data flow is principally towards higher level facilities while the forecast information travels in the opposite direction. Four WSFOs act as Regional Warning Coordination Centers (RWCCs) for larger regions. The RWCCs will monitor and coordinate warnings of all hazardous weather and issue warning bulletins for severe winter storms.

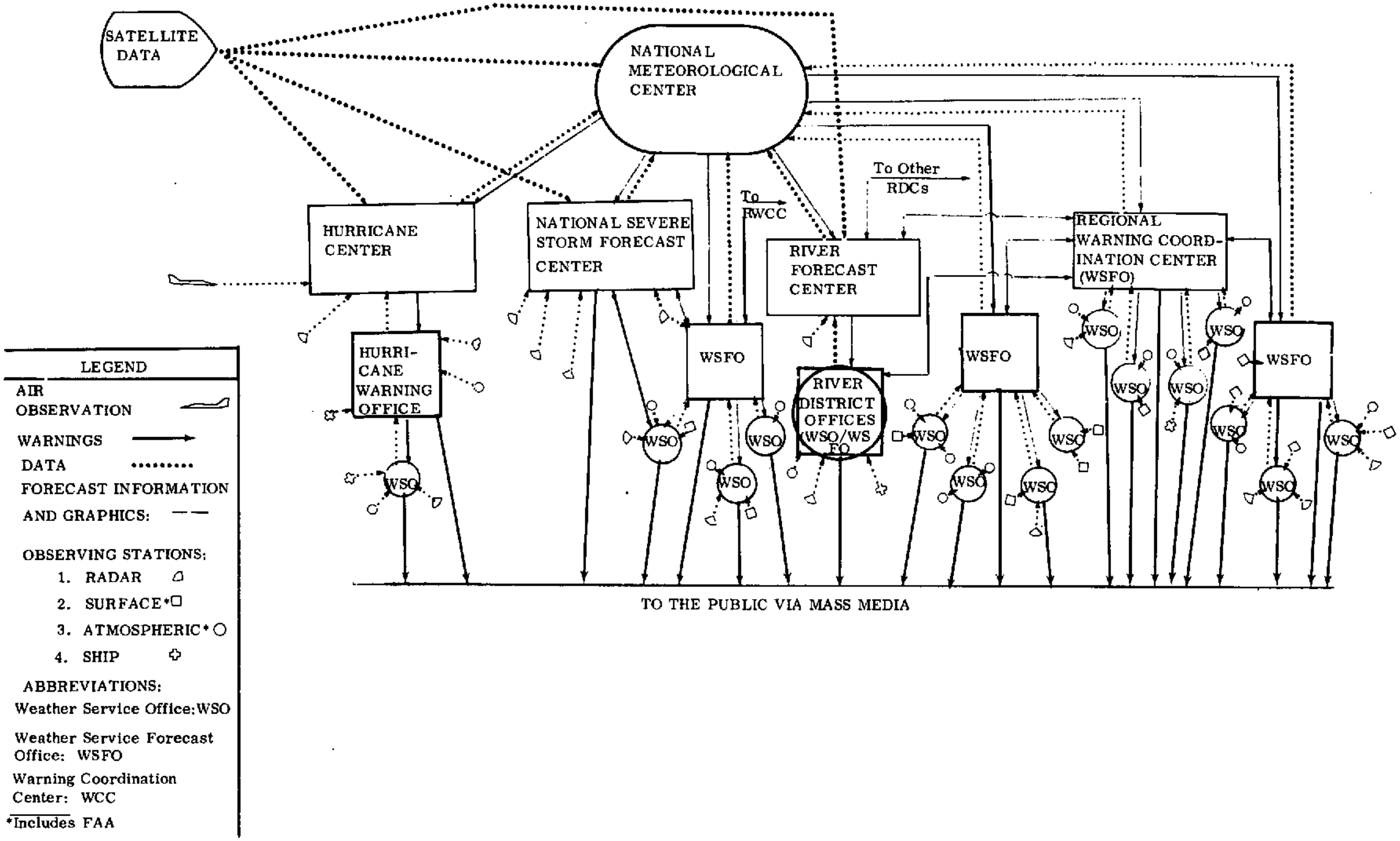


Figure 2-1. Representative Traffic Flow

The facilities which are principally concerned with emergencies are the three Hurricane Centers (The National Hurricane Center in Miami, Florida, and those in Honolulu and San Francisco) and the subsidiary Hurricane Warning Offices, the National Severe Storms Forecast Center, and the 12 River Forecast Centers (RFCs) with their subsidiary River District Offices (RDOs).

The Cooperative Hurricane Warning Network (CHURN) reports the development and movement of any tropical storm; observers in this program include Coast Guard stations, Coast Guard and commercial ships, and military aerial reconnaissance. The aerial data is transmitted directly to the Hurricane Center (unlike most other types of data). It is the responsibility of the Hurricane Warning Offices (and the WSFOs and WSOs) to disseminate warnings to the public.

The National Severe Storms Forecast Center (NSSFC) in Kansas City, Missouri is responsible for prediction of severe thunderstorm and tornado weather and for monitoring the development and motion of such disturbances. This facility is also responsible for the prediction of any weather conditions hazardous to aviation. The aviation weather warnings are issued as bulletins called AIRMETS and SIGMETS by FAA facilities and FAA transcribed broadcasts.

The 12 RFCs and their subsidiary RDOs are responsible for predicting flood conditions for their geographic areas of responsibility. RFCs, sometimes co-located with WSFOs, prepare warnings which are disseminated to the public principally through the RDOs. Data, on the other hand, is primarily gathered by the RDOs from observing stations and spotter networks and transmitted to the RFCs to enable them to prepare forecasts. The RFCs then prepare their forecasts and warnings which are transmitted to downstream RFCs as well as to RDOs.

Satellite data will be available to NMC, the Hurricane and River Forecast Centers, and the NSSFC. There will also be processed satellite data available through NMC via Forecast Office Facsimile (FOFAX) and other circuits.

The generalizations concerning traffic flow which are useful for its analyses are:

- Data is usually collected by lower echelon facilities (WSOs) and transmitted upwards.
- NMC prepares nationwide forecasts and graphics material which is transmitted to lower echelon facilities (first, the WSFOs) for preparation of area forecasts. Forecasts (and warnings) are then relayed to WSOs.
- Warnings may be disseminated to the public via mass media from several echelons; however, the responsibility for dissemination of warnings rests principally with the WSO.
- There is a great deal of collocation of facilities (e.g., the RDOs can be either WSOs or WSFOs.)

These generalizations are particularly useful when one considers the implementation of planned systems such as the Automation of Field Operations and Services (AFOS). The projected impact of AFOS on the traffic flow is described briefly in the following paragraphs.

2.1.2.1.2 Future

Planning the DWS necessitates certain assumptions about the form of the future NWS. The most important aspect of the future configuration of NWS involves the implementation of AFOS. Appendix C contains a brief description of AFOS. The simplest assumption can be made concerning this implementation is that the AFOS system will perform as it is now projected to perform; the following discussion of the DWS is based on this assumption.

The synoptic data which is transmitted to the NMC by WSFOs will be carried by the National Digital Circuit (NDC), a closed loop configuration connecting the WSFOs, the National Centers and the RFCs. The NDC will replace the FAA Services A and C circuits which presently perform this function; however, the FAA will still transmit airport observations on their own circuits. NDC will replace the Services A and C only as far as the NWS is concerned. Pictorial data and other graphics will still be carried by the facsimile circuits such as FOFAX due to the constraints on quantity and rate of data to be transmitted on NDC. Data transmitted to the WSFOs from the WSOs will also be via an automated link; this is termed AFOS Stage B. The WSFO/WSO links are merely spurs; there are no closed loops. There also will be some automation of the delivery of data to WSOs from observing stations; in fact, this process has already begun.

The principal function envisioned for the DWS is the delivery of urgent data (that which does not have time to traverse the NDC) such as observations concerning flash floods and tornadoes, and the alerting and warning of the public through the home receivers (see Figure 2-2).
types of platform data (as from data buoys) and the continuous broadcasting of routine weather forecasts to be received by the home receiver. The "urgent data" DWS may carry includes observations from spotter networks previously alerted (either through DWS or by other means). This data is relayed to the relevant WSO which then accesses the DWS to broadcast a warning if necessary. The WSFOs and RFCs would also have the ability to access the DWS for the purpose of issuing warnings as well as the WSOs, RDOs, HWOs, and the NSSFC.

Interactions between the (future) NWS and DWS are illustrated in Figure 2-2. The DWS functions may include:

- Relay of platform data to NMC
- Alerting spotter networks
- Delivery of urgent data to WSOs
- Delivery of warnings to public
- Broadcast of routine weather information

It is worth noting that the DWS also provides the capability for the WSFO to alert the WSO regarding the existence of hazardous weather. This capability may seldom be needed but it is not difficult to imagine situations in which it would be useful.

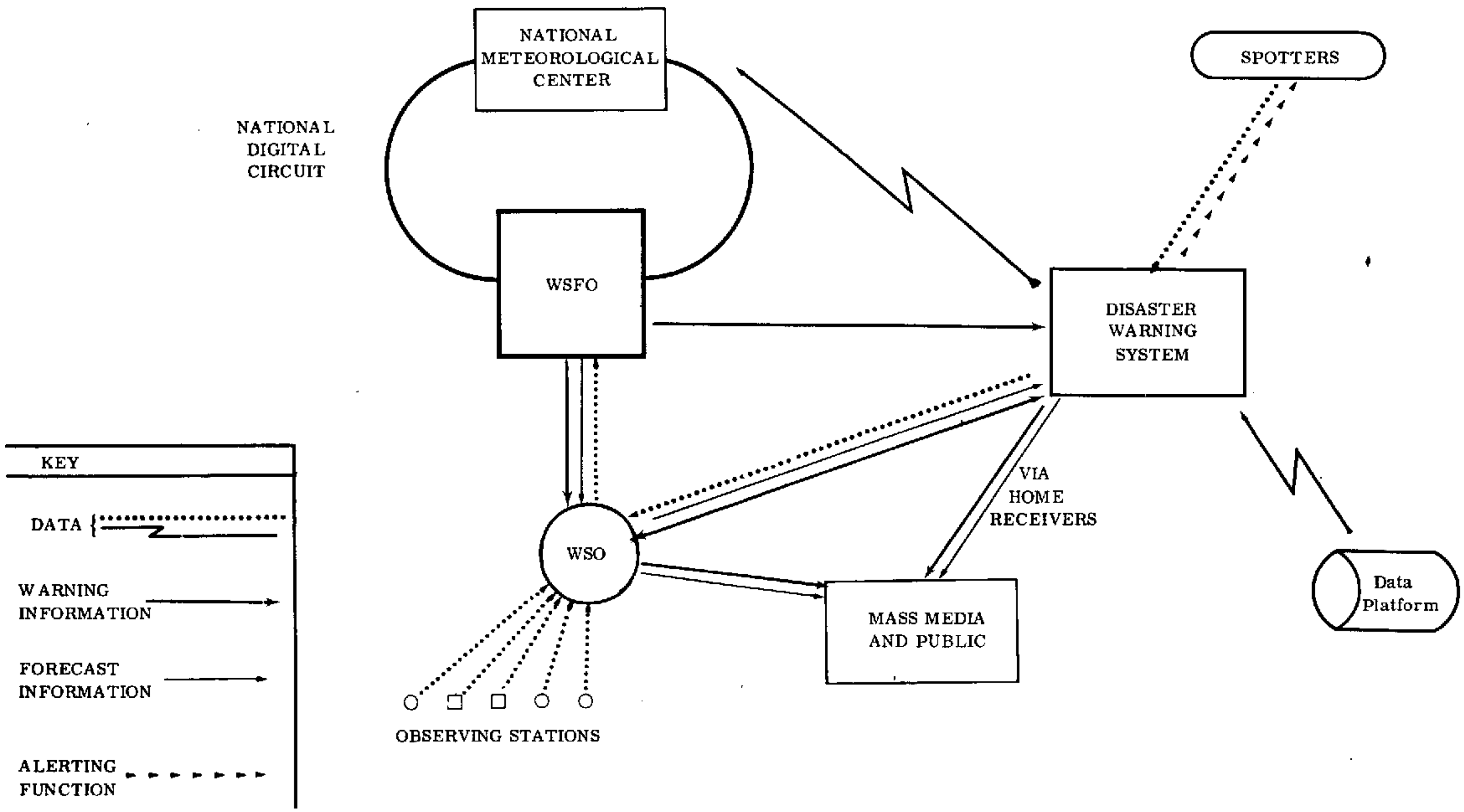


Figure 2-2. Implementation of DWS With AFOS

2.1.2.2 Planned Warning Systems

2.1.2.2.1 NOAA VHF-FM Broadcasts

There are presently 65 VHF broadcasting facilities located near large urban areas and coastal areas. Approximately 40 percent of the population is within the nominal coverage area of 40 to 50 mile radius from these transmitters. Each of these transmitters, operating at either 162.40 or 162.55 MHz, is controlled by a local NWS Office (typically a WSFO or WSO) which supplies a local forecast. This forecast is continously sent 24-hours a day with the taped messages being repeated every 4 to 6 minutes. The forecasts are updated as required, typically every 2 to 3 hours.

This system also has the capability to demute specially designed receivers by sending the proper tone, thus, providing a positive alert to warn of hazardous conditions. This alerting function is being used primarily to alert schools, hospitals, and other places of assembly, public utility units, emergency forces, and news media. General public use of this alerting function is expected as receivers containing this capability become more readily available

This system is presently being expanded and approximately 175 transmitters are planned by 1978. A total of approximately 280 transmitters are required to provide coverage to 90 percent of the population.

2.1.2.2.2 Decision Information Distribution System

The Decision Information Distribution System (DIDS) is being developed by the Defense Civil Preparedness Agency (DCPA) to provide a capability for simultaneous nationwide issuance of attack warnings. Since this is an attack warning system, reliability and survivability (particularly against an EMP threat) are emphasized rather than factors such as broadcast area selectivity and high data rates. The system concept is to utilize a few low frequency broadcasting terminals providing nationwide coverage and a 24-hour a day capability to demute receivers and deliver warning by voice, teletypewriter, and remote siren control. The primary users will probably be located at national, state, and local emergency operating centers, Federal and State agencies, national and local warning points, State adjutant and military headquarters locations, and broadcast radio and television stations. Additionally, inexpensive DIDS receivers are expected to be available for purchase by the general public.

The presently planned DIDS will consist of three National Warning Centers (NWCs) connected via leased wire services to two high power (200 kW) low frequency (61.15 kHz) control transmitters. A distribution system consisting of ten medium power (50 kW) low frequency (each transmitter at a unique frequency ranging from 160 to 190 kHz) transmitters which provide coverage to 99 percent for siren control and 96 percent for voice messages of the Continental United States (CONUS) population. Geographic selectivity can be achieved by utilizing the available code in the demuting signal.

Under the Disaster Relief Act of 1970, the use of the DCPA warning system is authorized for the additional purpose of providing warnings of natural disasters. Under this authorization, a configuration by which the NWS could access the DIDS has been formulated. This concept has a control point (under NWS operation) at the WSFO closest to each of ten DIDS distribution transmitters. The other NWS warning facilities (247 facilities consisting of most of the remaining WSFOs and WSOs) have access to the DIDS through these control points. The number of accesses into each control point varies from 10 to 35. Whenever a NWS facility initiates a warning message, a header record, in addition to the warning message, is sent to the appropriate control point. The header will contain an originator ID code, destination address code, priority code, and a code to specify whether the warning message is voice or teletype. Upon receipt of the message at the control point, the header code will be authenticated, formatted for transmission on DIDS, and either sent to the DIDS transmitter via a dedicated leased line or taped for transmission at a later time if a queue exists.

2.1.2.3 Geostationary Operational Environmental Satellite

The collection of meteorological data from a large number of remote (unmanned) ground platforms is one of the prime additional functions of a potential disaster warning satellite. This data collection function is presently planned to be performed by the soon to be launched Geostationary Operational Environmental Satellite (GOES). The basic (in terms of impact upon the satellite design) purpose of the GOES is to provide earth imaging, both visual and infrared, from synchronous altitude. Since a large number (perhaps up to tens of thousands) of data collection platforms (DCPs) will be implemented for use with GOES, any new satellite data collection capability would most likely have to be compatible with these DCPs that are presently to be deployed.

The DCPs' communication characteristics are given in Table 2-1. To meet to interrogation signal requirements, a satellite EIRP of 16 dBW is required with an additional 6 dB for DCPs with low elevation angles. A satellite G/T of -21.5 dB/^{o}K is required to satisfy the data uplink requirements. The satellite multiple access is accomplished by a combination of time and frequency multiple access.

DCPs are assigned frequency channels and time slots (either in response to interrogation or self-timing). Thus, the satellite must have a receiver bandwidth of 300 Hz. In the GOES the UHF signals are cross-strapped to an S-Band transponder for the link to the control station located at Wallops Island, Virginia. The link to a control station is not constrained by the GOES configuration; however, use should be made of the baseband equipment and control techniques that have been developed for GOES.

Table 2-1. Data Collection Platform Communication Characteristics

Characteristics	Interrogation Signal from Satellite	DCP Signal to Satellite (Interrogated DCPs only)	DCP Signal to Satellite (Self-Timed DCPs only)
Frequency (MHz)	468.825	401.850 to 402	401.700 to 401.850
Number of Channels	1	100	50
Channel Spacings (kHz)	N/A	1.5	3.0
Modulation	$\pm 70^{\circ}$ PSK, Manchester Coded	$\pm 70^{\circ}$ PSK, Manchester Coded	$\pm 70^{\circ}$ PSK, Manchester Coded
Band Rate	100	110	110
Message Duration (seconds)	0.5	60	60
Error Rate	10^{-6}	10^{-6}	10^{-6}
Emergency Requirements	Time Slots Reserved for Priority Interrupt	Frequency Channels Reserved to respond to emergency commands and data that exceeds preset threshold	Frequency Channels Reserved to respond to data that exceeds preset threshold

2.1.2.4 Projected Warning Traffic

2.1.2.4.1 Introduction

Disaster warning traffic is estimated for 1985, the approximate operational time of the DWS. Based upon this projection, an analysis, based upon classical study state queueing theory, is used to determine the number of Disaster Warning Satellite System (DWSS) communication channels required to relay the warnings. Two types of queueing "service discipline" are considered: first-come-first-served and nonpreemptive priority. A constant single service rate is assumed for all priority classes. Poisson inputs are used for arrivals and an exponential distribution is used for service.

With the first-come-first-serve discipline, the number of channels necessary to relay a specified percentage of all warning messages within a specified delay time interval is determined. The reduction of queueing delay time by means of nonpreemptive priority discipline is then investigated, and the total information is used to arrive at a decision as to the number of communication channels required by DWSS.

2.1.2.4.2 Summary, Conclusions and Recommendations

Based upon the projected natural disaster warning traffic for 1985, at least four independent communication channels would be required for a single DWSS. The optimum number of channels is not yet determined.

With four communication channels, nearly 99.8 percent of all warning traffic satisfies the time requirement to get on-line to the general public. The addition of more channels improves the queueing performance at an increased expense. Therefore, a tradeoff study of benefit to cost should be performed to determine the optimum number of channels required for a DWSS.

Although the assignment of priorities to different types of warnings messages results in only moderate improvement in queue delay time (6 to 20 percent for four channels), this routing procedure is recommended. Warning messages concerning natural disasters such as tornadoes and flash floods require a maximum of 1 minute to get on-line to the public. Priority service discipline expedites the dissemination of these critical messages without adversely affecting the dissemination of less critical (time) messages. Additionally, if the actual traffic exceeds the estimates, priority discipline will still ensure that critical warning messages will get on-line to the public in the most expeditious manner.

The study was confined to the area of accessibility of warning messages to communication channels. Routing disaster warnings to the general public is only one function of the natural DWS. Some of the other potential functions are:

1. Provide disaster communications among national, regional, and local weather service office and affected areas.
2. Provide environmental information to the general public.
3. Provide a system for collecting decision information for warning to the public.

Whenever a communication channel assigned for natural disaster warning messages is idle it can be used to route other less critical communications. If a procedure is implemented whereby a warning message can preempt a nonwarning message then the time to get a warning on-line to the public will not be significantly affected by the additional traffic load. Otherwise, additional communication channels may be required.

Further studies concerning DWSS routing of disaster warning should be pursued in the following areas:

1. Obtaining data as suggested for more refined estimation of disaster warning traffic.
2. Estimating warning traffic on a regional basis where the regions are determined by satellite antenna coverage.
3. Control and command procedures and requirements for assigning communication channels and controlling their transmission power (to be done in Tasks 2 and 3).

2.1.2.4.3 Traffic Estimations

At the present time, it is difficult to determine accurately an upper bound for the disaster warning traffic for the year 1985. Perhaps the best method of estimating the traffic for 1985 is to monitor the warning traffic issues by a warning office (WFSO or WSO) situated in a disaster prone region and having a large number of manned and automated reporting stations. The monitoring operation would yield the average as well as the busy time (peak) traffic per unit time per unit station. Knowing the number of offices issuing warnings, this data could be then used to yield an upper bound for the disaster warning traffic. The advantage of such a method of estimating traffic is that it takes into account future NOAA plans and improvements for monitoring and reporting disasters. This type of data is not presently available and therefore cannot be used to estimate disaster warning traffic for 1985.

Future plans for improving monitoring and reporting disasters are described in References 4 and 5. However, it is doubtful whether this information alone can be used with confidence to estimate future warning traffic since the relation between quantity and/or quality of monitoring and reporting stations and number of warning messages is not known. Therefore, in view of the limitations, 1985 disaster warning traffic is estimated by extrapolation using available warning messages data from year 1966 to 1973. The method of estimating the warning traffic is described in the following paragraphs.

Two types of warning data were analyzed: weather warning messages and river warning messages. Weather warning data were provided for 87 months from January 1966 to March 1973. River warning data were provided for 74 months from January 1967 to February 1973. The weather warning data included: tornadoes and severe storms; hurricanes; small craft and gales; winter storms; and others. Forecasts for inland lakes, although included in the data, were not considered as warnings and therefore were not included in the traffic estimate.

A linear regression analysis was performed on the aggregate and each category of the weather warning data (excluding hurricane warning) and the river warning data to determine trends and seasonal variations. Hurricane warning traffic was estimated using the same procedure described in Reference 2. The upper 95 percent prediction interval (see Reference 1) was used as a conservative upper bound for traffic estimations for the aggregate weather and river warnings as well as each category of weather warning data. The correlation coefficients of the regressions were also calculated to obtain quantitative information about the linear growth with time of warning traffic. The following is a description of the formulations used in estimating the natural disaster warning traffic.

Given M time units, the regression line is given by:

$$\tilde{y}_i = E\{y_i | x_i\} = a + bx_i$$

where $E\{y_i | x_i\}$ is the mean of the random variable y_i (warning messages per unit time) where the time units, x_i, are viewed as constants. The constants b and a are given by:

$$b = \frac{\sum_{i=1}^{M} (x_i - \bar{x}) y_i}{\sum_{i=1}^{M} (x_i - \bar{x})}$$

$$a = \bar{y} - b\bar{x}$$

where

$$\bar{x} = \frac{1}{M} \sum_{i=1}^{M} x_i$$

and

$$\bar{y} = \frac{1}{M} \sum_{i=1}^{M} y_i$$

The correlation coefficient ρ is given by:

$$\rho = \sqrt{1 - \frac{\sum_{i=1}^{M} (y_i - \tilde{y}_i)^2}{\sum_{i=1}^{M} (y_i - \bar{y})^2}}$$

If the variance σ^2 of the number of messages is a constant independent of the time unit x_i, then the unbiased estimate of σ^2 is given by S^2y/x where

$$S^2_{y/x} = \frac{1}{M-2} \sum_{i=1}^{M} (y_i - \tilde{y}_i)$$

The upper prediction interval bound is given by:

$$a + bx_+ + t_{\alpha/2;n-2} \, S_{y/x} \sqrt{1 + \frac{1}{n} + \frac{(x_+ - \bar{x})^2}{\sum_{i=1}^{M} (x_i - \bar{x})^2}}$$

where

x_+ = time unit for which prediction interval is desired

$t_{\alpha/2};n-2$ = 100 $\alpha/2$ percentage point of the t distribution with n-2 degrees of freedom.

Figures 2-3 through 2-8 depict the yearly warning traffic, the regression line, and the 95 percent upper prediction bound for the aggregate weather warning traffic, river flood warning traffic and each category of weather warning. Table 2-2 presents the regression coefficient, the expression for the regression line and the 1985 95 percent upper prediction bound for each type of warning data. The values of the regression coefficients seems to validate the linear growth of warning traffic with time. Table 2-3 presents the regression coefficient, regression formula and 1985 traffic estimate for each category of weather warning message. In Table 3-3 small craft warning (SCW) traffic increases at the fastest rate whereas tornadoes and severe storm warning (TSSW) traffic increases at the slowest rate. The relatively low value of regression coefficient for winter storm warning (WSW) and TSSW indicate that for these categories of warning the assumption of linear growth may not be valid. Since the trends of the different categories are different, the sum of these categories is not the same as the predicted value based upon the aggregate weather warnings.

Seasonal variations for river and each category of weather warning were estimated on a monthly basis. Using the available warning data the monthly fraction of the total yearly traffic were estimated for each month. The results were applied to 1985 traffic and are shown in Table 2-4. The peak 1985 monthly traffic load occurs at December as a result of seasonal contribution from WSW and SCW. The lowest traffic load occurs at August. Figure 2-9 provides a comparison of monthly warning traffic between the 1985 estimate and average traffic based upon the warning data. The warning messages shown in Figure 2-9 combine the following: river warning (RW), TSSW, WSW, SCW and other warning (OW).

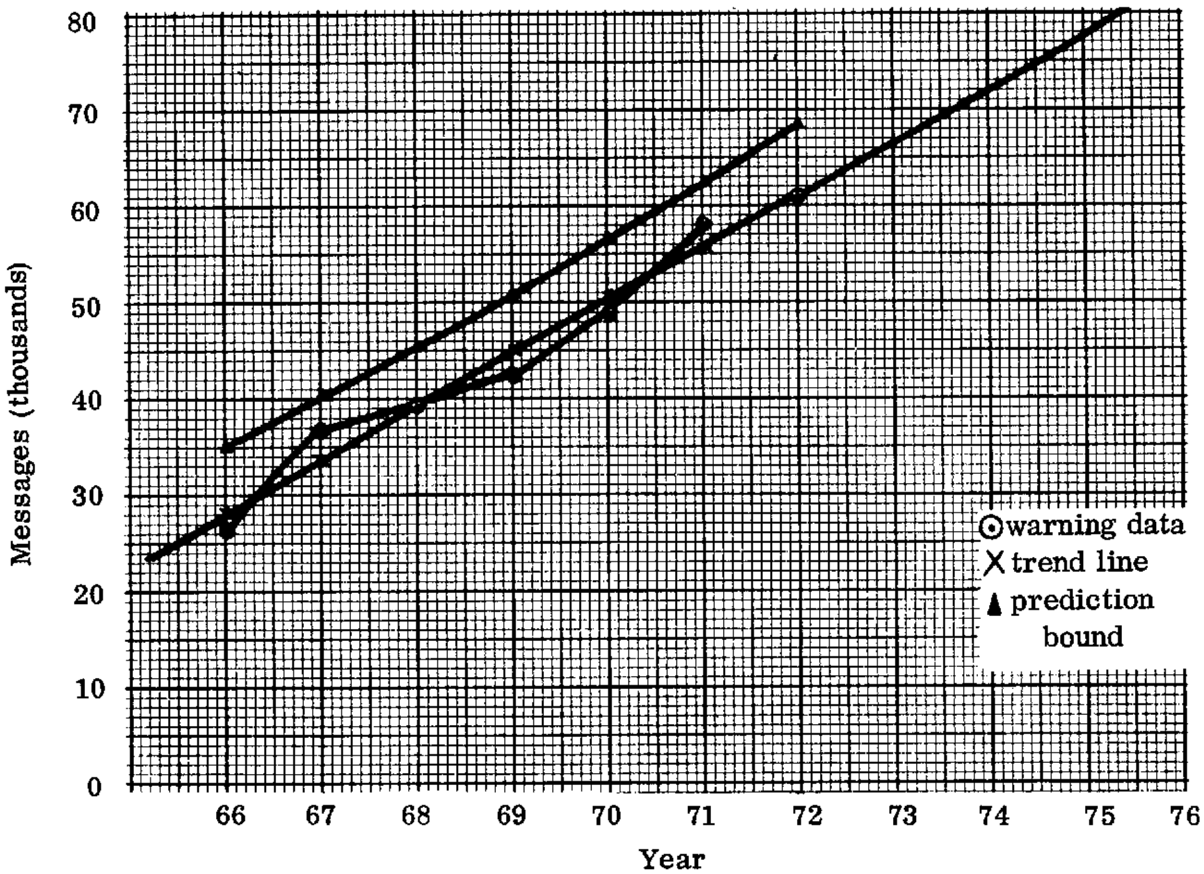


Figure 2-3. Total Weather Warning Traffic

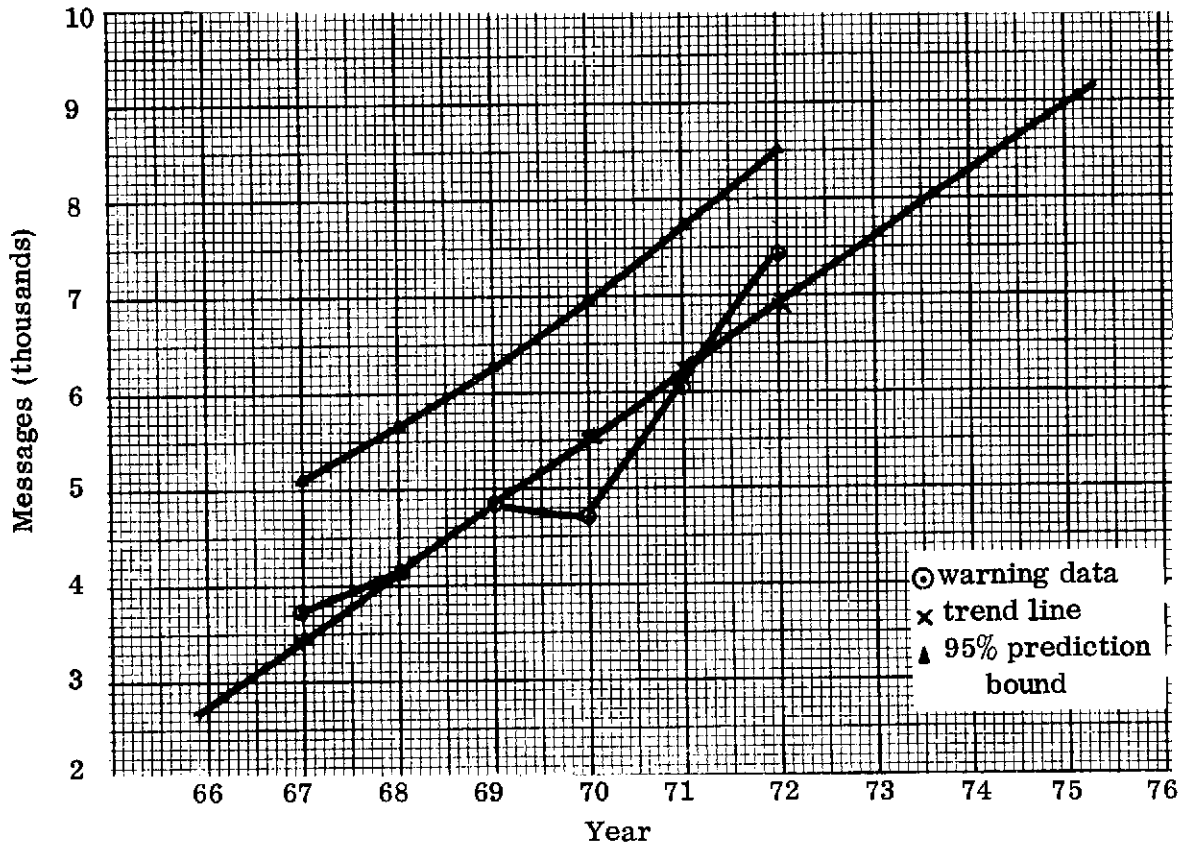


Figure 2-4. River Warning Traffic

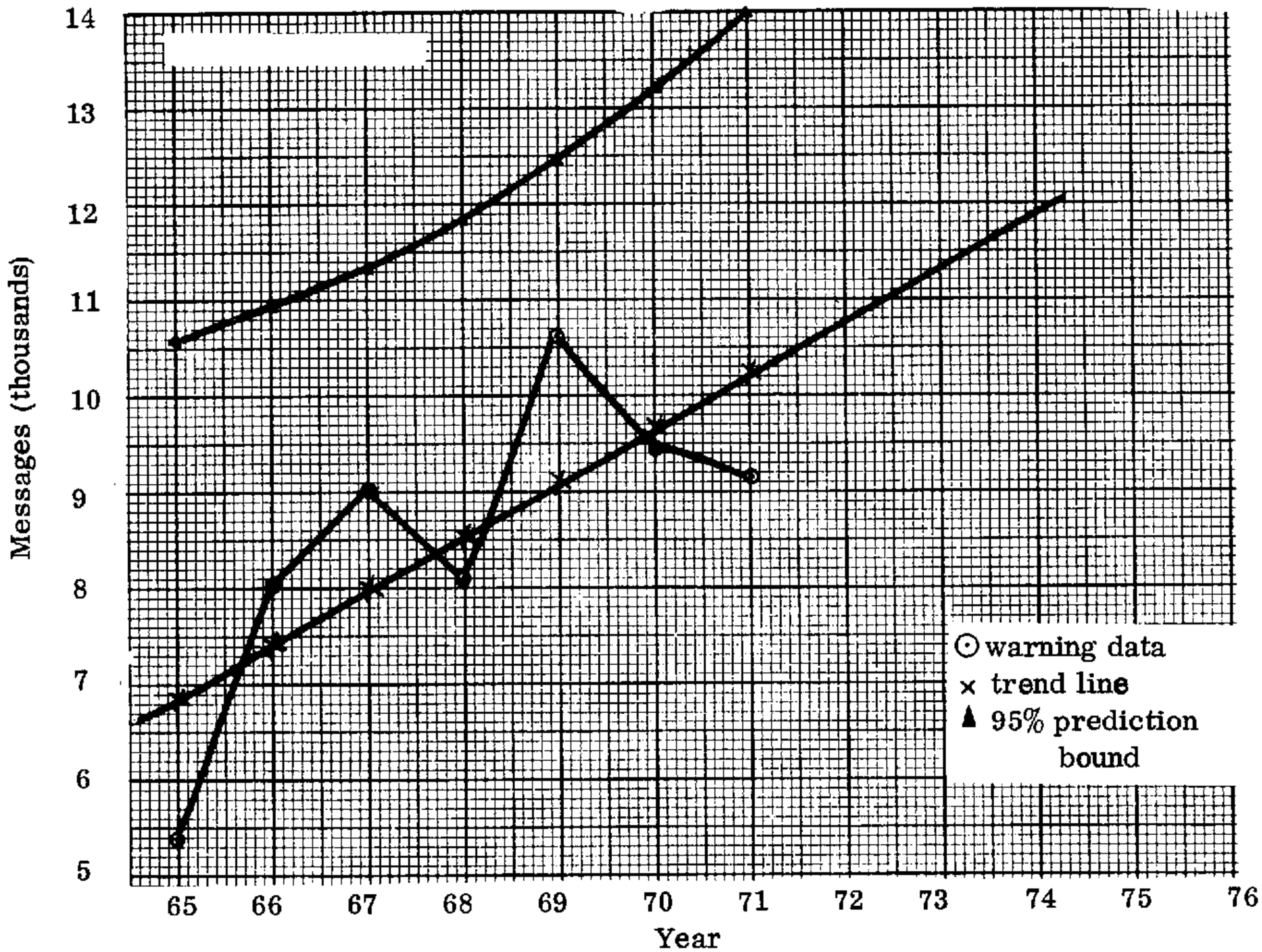


Figure 2-5. TSSW Traffic

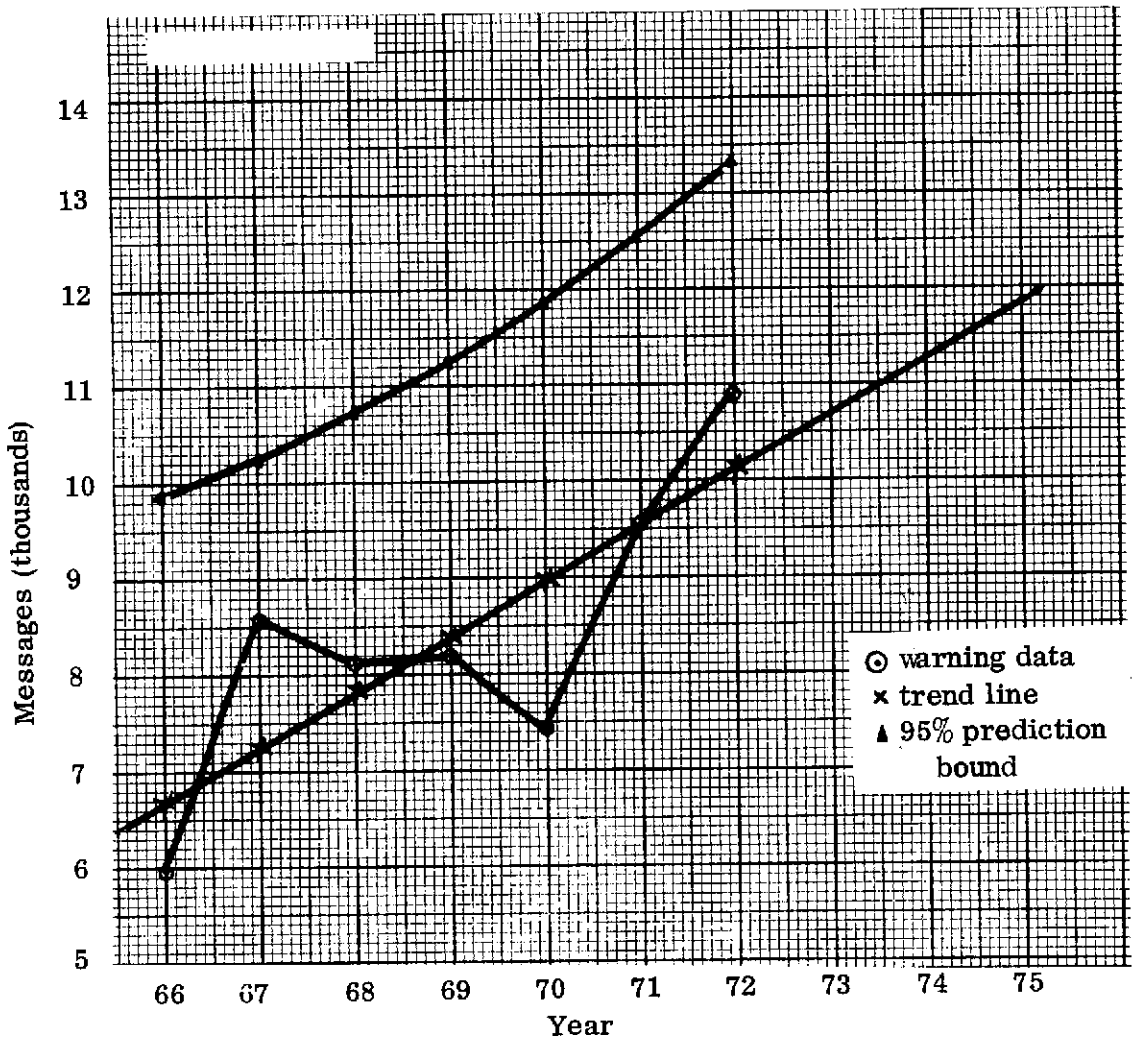


Figure 2-6. WSW Traffic

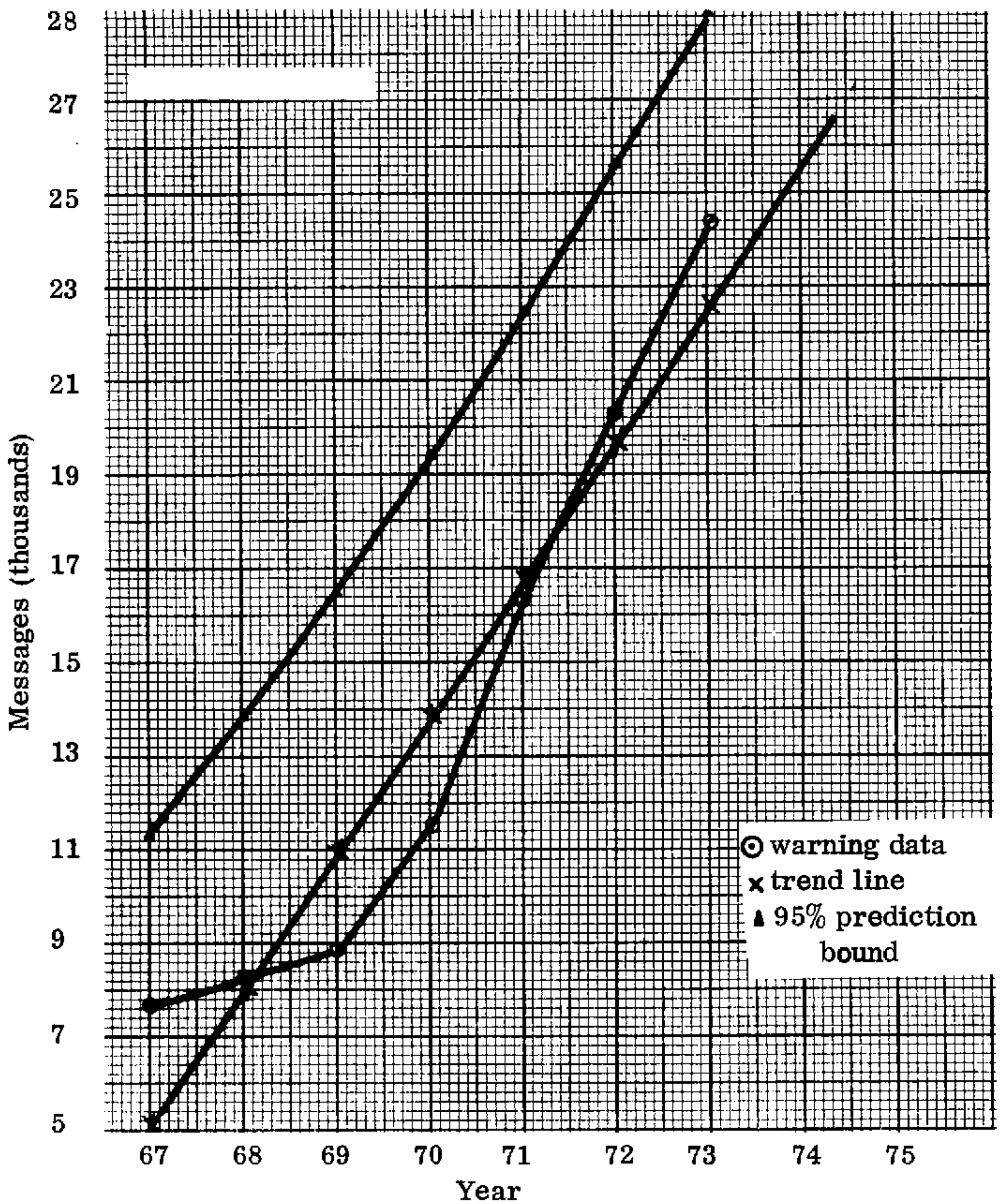


Figure 2-7. SCW Traffic

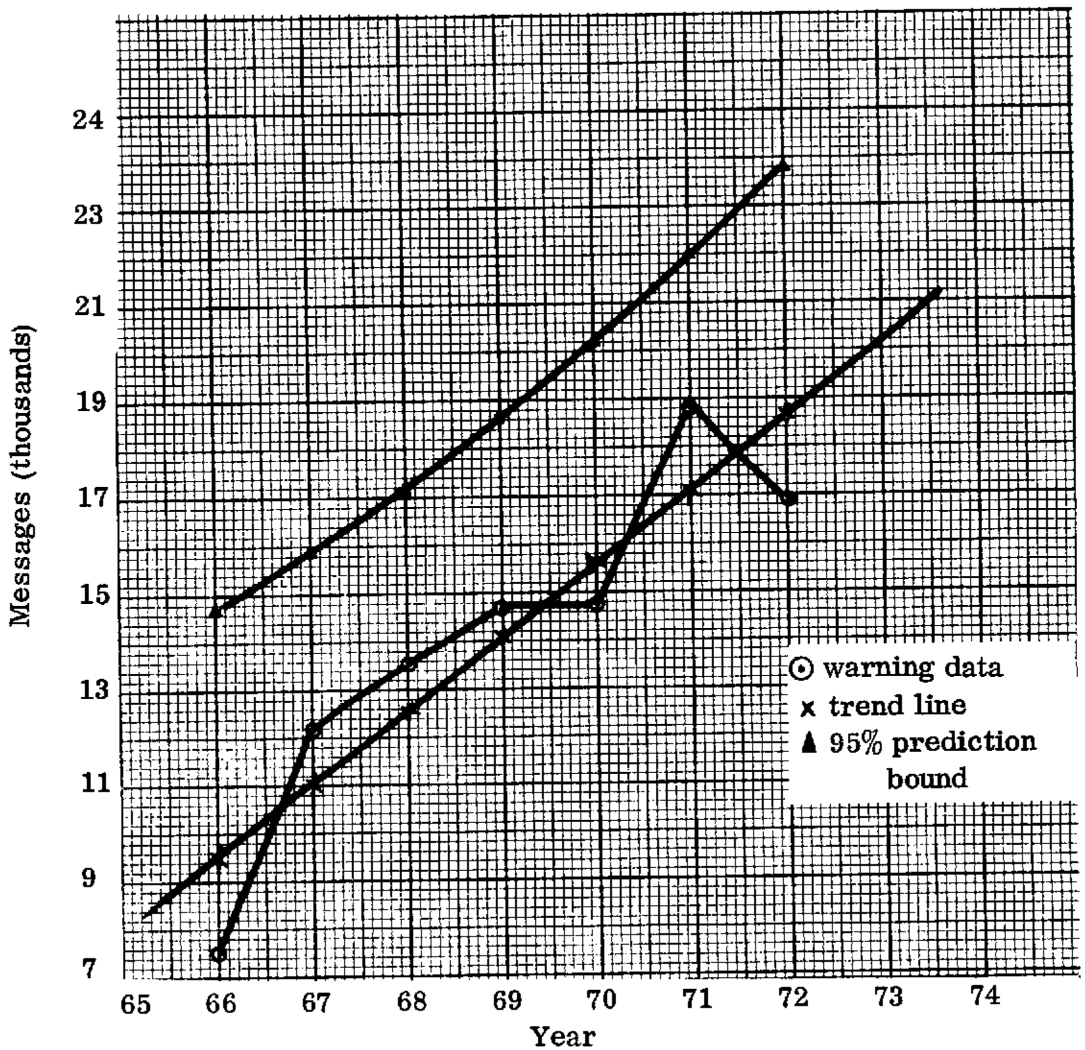


Figure 2-8. OW Traffic

Table 2-2. Weather and River Warning Estimate

Warning Type	Regression Coefficient	*Regression Line Formula (yearly traffic	95% Upper Prediction Bound (1985)
Weather	.986	$22683.6 + 5581.6x_1$	152,668.7
River	.947	$2765.3+689.4x_2$	21,106.

*x_1 = 1, 2, 3..... starting with 1966

x_2 = 1, 2, 3.....starting with 1967

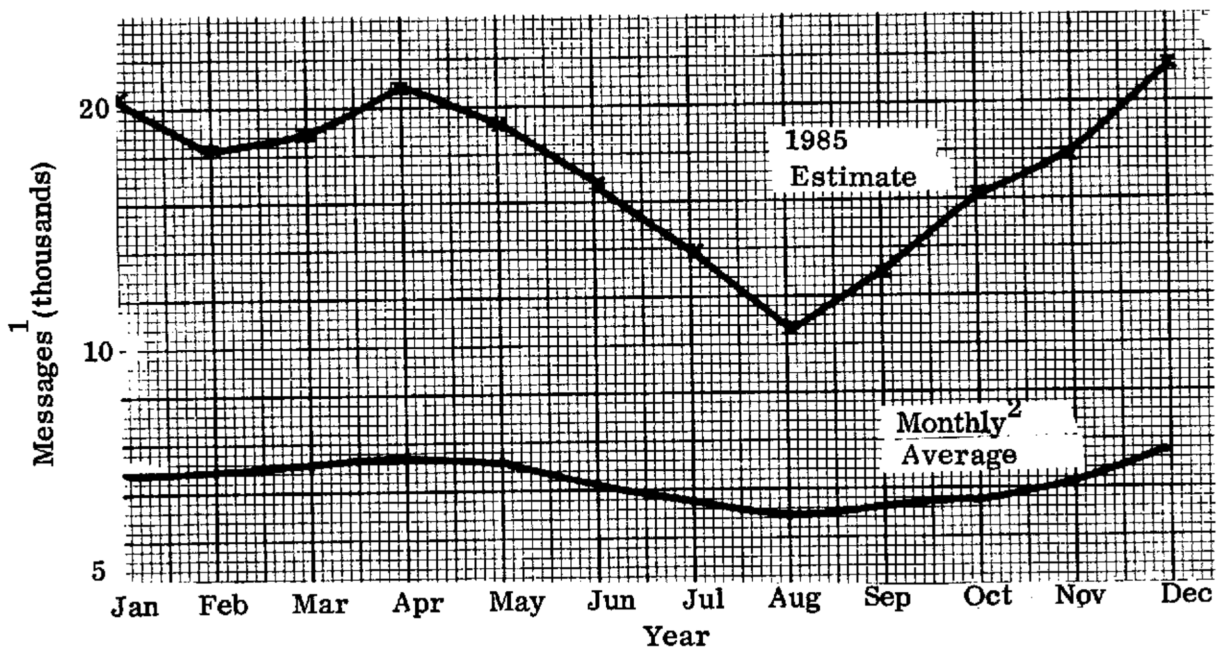
Table 2-3. Estimate of Weather Warning Categories

Weather Warning Category	Regression Coefficient	* Regression Line Formula (yearly traffic	95% Upper Prediction Bound (1985)
WSW	.797	6106. + 575.6x	26,116.3
TSSW	.738	6300.7 + 562.7x	27,576.3
SCW	.960	2214.6 + 2922.4x	77,193.6
OW	.908	8062.3 + 1521.x	52,115.8

* x = 1, 2, 3..... starting with 1966

Table 2-4. Estimated Monthly Load of Disaster Warnings for 1985

	RW	TSSW	WSW	SCW	OW	TOTAL
Jan	1535	308	6376	6220	5544	19983
Feb	1535	662	4286	6809	4243	17535
Mar	1535	1440	3508	7503	4412	18401
Apr	2139	4543	1977	7451	4241	20351
May	3017	5980	343	5360	4198	18898
Jun	2371	6420	36	4378	3563	16768
Jul	1795	3527	4	4409	3748	13483
Aug	1339	1940	45	3881	3979	11184
Sep	1250	1028	262	6069	4206	12815
Oct	1502	811	1391	7949	4398	16051
Nov	1480	363	2365	8434	4619	17261
Dec	1608	551	5523	8731	4965	21378
Total Year	21,106	27,576	26,116	77,194	52,116	204,108



1 - Warning messages include RW, TSSW, WSW, SCW and OW.

2 - Based upon weather and river warning data.

Figure 2-9. Comparison of Monthly Traffic From Data And 1985 Estimates

2.1.2.4.4 Queueing Analysis

This paragraph contains the steady-state queueing equations for multiple-service (channel) models with Poisson arrival and exponential service distribution. Results for both first-come-first-serve and nonpreemptive priority service disciplines are given. References 1 and 2 give extensive descriptions as well as detailed derivations for the former service disciplines whereas the queueing equations for the other service disciplines are derived in Reference 3. The particular queueing model considered is one having a single waiting line with one or more servers, as shown in Figure 2-10.

The following is a listing of the standard notation and terminology used in the queueing equations:

Line Length = number of calling units (messages) in the queueing system.

Queue Length = number of calling units (messages) waiting for service (communication channel.)

P_n = probability that exactly n messages are in the queueing system.

s = number of servers or parallel service channels (communication channels) in the queueing system.

λn = mean arrival rate (expected number of message arrivals per unit time) of new calling units when n units are in the system. When λn is constant for all n, this constant is denoted by λ.

μn = mean service rate (expected number of units completing service per unit time) when n units are in the system. When the mean service rate per busy server is a constant for all $n \geq 1$, this constant is denoted by μ.

L = expected line length.

L_q = expected queue length.

W = expected waiting time in system (includes service time).

W_q = expected waiting time in queue (excludes service time).

ρ = utilization factor for service facility, that is, the expected fraction of time the servers are busy, for the case considered here of constant λ and μ, $\rho = \frac{\lambda}{s\mu}$.

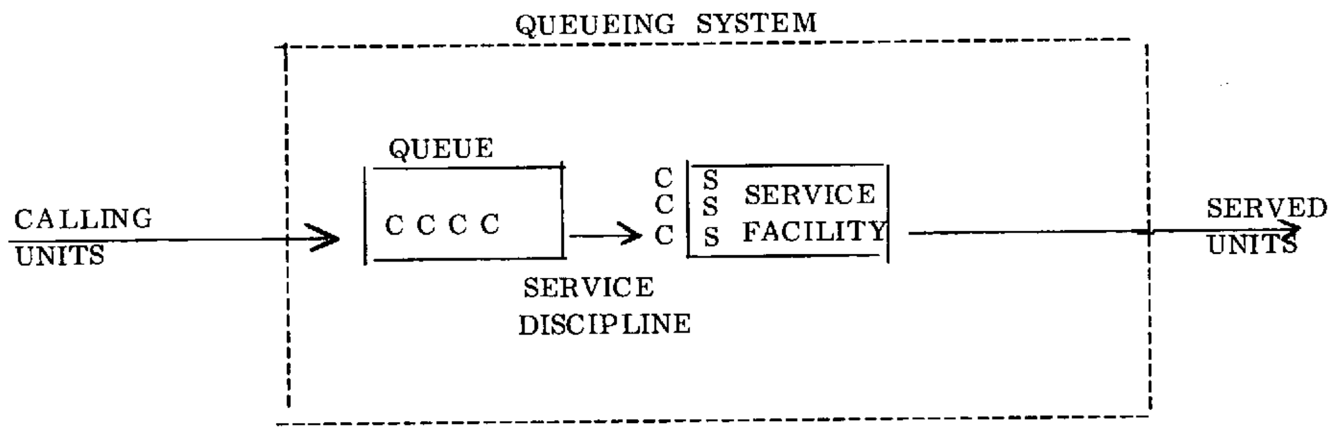


Figure 2-10. Queueing Model

When λ_n is a constant, λ, for all n, it has been proven that in the steady-state queueing process,

$$L = \lambda W$$

under essentially general conditions. Furthermore, the same proof shows that

$$L_q = \lambda W_q$$

Also, for a constant $\mu_n = \mu$

$$W = W_q + \frac{1}{\mu}$$

The following equations are applicable for multiple-server model with first-come-first-serve priority discipline having arrivals occur according to a Poisson input with parameter λ and exponentially distributed service time with mean $1/\mu$:

$$P_o = \frac{1}{\sum_{n=0}^{s-1} \frac{\left(\frac{\lambda}{\mu}\right)^n}{n!} + \frac{\left(\frac{\lambda}{\mu}\right)^s}{s!} \sum_{n=s}^{\infty} \rho^{n-s}}$$

or

$$P_o = \frac{1}{\sum_{n=o}^{s-1} \left[\frac{\left(\frac{\lambda}{\mu}\right)^n}{n!}\right] + \frac{\left(\frac{\lambda}{\mu}\right)^s}{s!} \frac{1}{1-\rho}} \qquad \text{for } \rho < 1$$

$$P_n = \begin{cases} \dfrac{\left(\frac{\lambda}{\mu}\right)^n}{n!} P_o & \text{if } 0 \le n \le s \\[2ex] \dfrac{\left(\frac{\lambda}{\mu}\right)^n}{s!\, s^{n-s}} P_o & \text{if } n \ge s \end{cases}$$

$$L_q = \frac{P_o \left(\frac{\lambda}{\mu}\right)^s \rho}{s!\,(1-\rho)^2}$$

$$W_q = \frac{L_q}{\lambda}$$

$$W = W_q - \frac{1}{\mu}$$

$$L = L_q - \frac{\lambda}{\mu}$$

The probability of waiting in a queue (excluding service time) is given by:

$$P(>0) = \sum_{n=s}^{\infty} P_n = \frac{P_o \left(\frac{\lambda}{\mu}\right)^s}{s!\,(1-\rho)}$$

If the probability of waiting in the queue, more than t time units is desired, it could be calculated using the following formula:

$$P\left\{ > t\right\} = e^{-s\mu t(1-\rho)} P\left\{ > 0\right\}$$

The probability of waiting more than t time units in the queueing system (including service time) is given by

$$P\left\{T > t\right\} = e^{-\mu t}\left\{1 + \frac{P_o\left(\frac{\lambda}{\mu}\right)^s}{S!\ (1-\rho)}\left[\frac{1 - e^{-\mu t(s-1-\frac{\lambda}{\mu})}}{s-1-\frac{\lambda}{\mu}}\right]\right\}$$

Since the DWS requirements call for different maximum warning time to get messages on-line to the general public, a queueing service discipline using priorities is also considered. The model assumes that there are r priority classes (class 1 has the highest priority and class r the lowest), and that the members of the highest priority class represented in the queue would be selected on a first-come-first-served basis. Service is nonpreemptive, i.e., units being served cannot be ejected back into the queue if a higher priority unit enters the queueing system.

A Poisson input process and exponential service times are assumed for each priority class. The model also makes the somewhat restrictive assumption that the mean service time is the same for all priority classes. However, it does permit the mean arrival rate to differ among the priority classes. Based upon the derivations given in Reference 3, the waiting time in a queue for a member of priority class p is given by:

$$W_{q_p} = \frac{E\left\{T_o\right\}}{\left[1-\left(\frac{1}{s\mu}\right)\sum_{k=1}^{p-1}\lambda_k\right]\left[1-\left(\frac{1}{s\mu}\right)\sum_{k=1}^{p}\lambda_k\right]}$$

where $E\{T_o\}$ is the expected time required to finish an item already in service and is given by:

$$E\{T_o\} = \frac{(s\rho)^s/s\mu}{s!\,(1-\rho)\left[\sum_{j=o}^{s-1}\left[(s\rho)^j/j!\right]+\sum_{j=o}^{\infty} s^s\,\rho^j/s!\right]}$$

$$E\{T_o\} = \frac{(s\rho)^s/s\mu}{s!(1-\rho)\left[\sum_{j=o}^{s-1}\left[(s\rho)^j/j!\right]+\frac{s^s}{s!}\,\frac{\rho^s}{1-\rho}\right]}$$

where

$$\rho = \lambda/s\mu \text{ and } \lambda = \sum_{k=1}^{r} \lambda_k$$

2.1.2.4.5 DWSS-Channel Requirements

Based upon the formulations described in the previous paragraph, a computer program, QUEUE, was written to compute various queueing parameters as a function of the number of communication channels using first-come-first-serve service discipline. Included in the inputs to the program are mean arrival (warning traffic),rate (messages/minute) and mean service rate (messages/minute). The mean arrival rate for the year 1985 is:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rate (Messages per Minute)	.4633	.4057	.4257	.4709	.4373	.3879	.3120	.2586	.2964	.3713	.3994	.4955

The peak warning traffic load which occurs in the month of December was used as input to the program. A nominal mean service rate of 1.008 messages per minute was used. This number was calculated (Reference 2) by considering the average length of 21 types of weather service warning and assuming a speaking rate of 137 words per minute.

QUEUE yields the following outputs:

Mean time in system	=	Expected waiting time in minutes for a message including service time.
Mean time in QUEUE	=	Expected waiting time in minutes before a message acquires a communication channel.
Mean QUEUE number	=	Expected number of messages waiting to be served.
Utilization factor	=	Expected time each communication channel is utilized per unit time.
Prob >0 in QUEUE	=	Probability of a warning message having to wait in queue.
Prob >T in QUEUE	=	Probability of a warning message having to wait more than T minutes in queue.
Prob >T in system	=	Probability of a warning message having to wait more than T minutes in queue.(service included).

Table 2-5 presents the output generated by QUEUE for an expected arrival rate of .4955 message per minute and an expected service rate of 1.008 messages per minute. The results indicate that with three channels more than 98 percent of all warning messages will have an immediate access to a channel. Nearly 99.9 percent of all warning traffic will not be delayed more than 1 minute. With four channels, only .1697 percent of all the warning traffic will be delayed. Only .0049 percent of the warning traffic will be delayed for more than 1 minute.

Of course, as the number of total channels increases, the probability of waiting in a queue decreases. Table 2-6 presents the output generated by QUEUE for expected arrival rate of .4955 message per minute and expected service rate of .625 message per minute. Here almost 5 percent of the warning traffic will be delayed if three channels are used. The percentage of total traffic delayed for more than 1 minute is 1.28 percent. With four channels, .9287 percent of the traffic is delayed and .1251 percent is delayed for more than 1 minute.

The requirements for DWSS (Reference 6) specify the maximum time for a warning message to get on-line to the general public and the smallest areas to be warned.

Table 2-5. Queueing Parameters Versus Number of Channels

Mean arrival rate (messages per min.) .4955
Mean service rate (messages per min.) 1.0080

No. of Chan.	Mean Time in Sys.	Mean Time in Que	Mean Que. No.	Util. Fctr.	Prob. >0 in Que.	Prob. >T in Que. T=1 min	Prob. >T in Que. T=5 min	Prob. >T in Sys T=1 min	Prob. >T in Sys. T=5 min.
1	1.951	.959	.475	.491567	.491567	.294447	.037906	.598996	.077112
2	1.056	.064	.032	.245784	.096983	.021201	.000048	.392863	.007613
3	.998	.006	.003	.163856	.014472	.001155	.000000	.367684	.006536
4	.993	.000	.000	.122892	.001697	.000049	.000000	.364949	.006474
5	.992	.000	.000	.098313	.000162	.000002	.000000	.364949	.006474
6	.992	.000	.000	.081928	.000013	.000000	.000000	.364949	.006474

Table 2-6. Queueing Parameters Versus Number of Channels

Mean arrival rate (messages per min.) .4955
Mean service rate (messages per min.) .6250

No. of Chan.	Mean time in Sys.	Mean time in Que.	Mean Que. No.	Util. Fctr.	Prob. >0 in Que.	Prob. >T in Que. T=1 min.	Prob. >T in Que T=5 min.	Prob. >T in Sys. T=1 min.	Prob. >T in Sys. T=5 min.
1	7.722	6.122	3.033	.792800	.792800	.696502	.414914	.878535	.523352
2	1.898	.298	.148	.396400	.225054	.105831	.005175	.605880	.066684
3	1.637	.037	.018	.264267	.050848	.012799	.000051	.547205	.045745
4	1.605	.005	.002	.198200	.009287	.001251	.000000	.536947	.044122
5	1.601	.001	.000	.158560	.001404	.000101	.000000	.535464	.043956
6	1.600	.000	.000	.132133	.000180	.000007	.000000	.535283	.043939

A copy of the requirements is presented in Table 2-7. All disaster warnings other than RW, TSSW, WSW and SCW were assumed to be consolidated in the category of other warnings (OW). Ten percent of all OW were assumed to require a maximum queueing time of 1 to 5 minutes (examples: flash flood, earthquake, etc.) whereas the remaining 90 percent of all OW were assumed to require a maximum queueing time of 15 minutes or more (examples: storm tide, air pollution, etc.).

Based upon the requirement for maximum queueing time two distinct priority classes were designated in the analysis. The first priority class (Class I) includes Hurricane Warning (HW), TSSW, and 10 percent of all OW with a required maximum queueing time of 1 minute. The second priority class (Class II) includes WSW, SCW, RW and 90 percent of all OW with a required maximum queueing time of 15 minutes. Tables 2-8 and 2-9 summarize the monthly warning traffic rate (messages/minute) as estimated for the year 1985 for the priority classes. The monthly ratios of Class I to Class II priority rate are:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Class I / Class II	.0449	.0659	.114	.3228	.5121	.6785	.6580	.2639	.127	.1399	.05	.0531

Results for nonpreemptive priority service discipline were generated by a computer program, PRIOR. Only two priorities classes (Class I - high priority, Class II - low priority) were considered. The following parameters were calculated with the aid of PRIOR:

Expected waiting time in the system - (SYS. TIME)

Expected waiting time in the queue - (QUE. TIME)

Expected line length - (SYS. LNGT)

Expected queue length - (QUE. LNGT)

The same parameters were computed for first-come-fitst-serve service discipline with no priorities. Two extreme cases of traffic loads were input to the program. These were the December and the June traffic loads (see Tables 2-8 and 2-9). The former represents the peak total traffic load, whereas the latter represents the peak traffic load of Class I messages. The results are shown in Tables 2-10 through 2-13. for expected service rate of 1.008 and .625 messages per minute. The percentage

Table 2-7. Disasters-Maximum Warning Time To Get Message On-Line To General Public and Smallest Areas To Be Warned

	Disasters	Time	Area*
1.	Severe Local Storms:		
	a. Tornadoes	1 min	Part of County
	b. Severe Thunderstorms	1-5 min	Part of County
2.	Flash Flood	1 min	Part of County (Flood Plain)
3.	Lake Seiche	1-5 min	Segment of Lake Coastline
4.	Tsunami	1-5 min	Segment of Coastline
5.	Earthquake	1-5 min	Part of County (Segment of State)
6.	Volcanoes	1-5 min	Part of County
7.	Landslides and Avalanches	1-5 min	Part of County
8.	Oil Spills	1-5 min	Segment of Coastline
9.	Accidents (e.g., Chlorine Barge)	1-5 min	Part of County
10.	Hurricane (Tropical Storms)	1-15 min	Segment of Coast line
11.	Forest and Grass Fires	5-15 min	Part of County
12.	Winter Storms (blizzard, heavy snow, ice storm, freeze or frost, cold-wave, high winds)	15 min - 1 hr	Portion of State
13.	Storm Tides	15 min - 1 hr	Segment of Coastline
14.	River Flooding	15 min - 1 hr	Part of State (Flood Plain)
15.	Air Pollution	1 - 6 hrs	Metropolitan Area
16.	Civil Disturbances Riots, Attack Warnings--Not an NOAA requirement		

*Coastal Area - 50 mi off coast--length variable
County = 20 x 20 mi (400 sq mi)--average
Segment of Coastline = Up to 10 mi in-land, length is variable

Table 2-8. 1985 Traffic Rate (Messages/Minute) For Priority Class I

	HW	TSSW	10% of OW	Total
Jan		.007	.0128	.0199
Feb		.0152	.0098	.0251
Mar		.0333	.0102	.0435
Apr		.1051	.0098	.1149
May		.1384	.0097	.1481
Jun		.1485	.0083	.1568
Jul	.057	.0816	.0086	.1472
Aug		.0448	.0092	.054
Sep		.0237	.0097	.0334
Oct	.019	.0187	.0102	.0479
Nov		.0083	.0107	.019
Dec		.0135	.0115	.025

Table 2-9. 1985 Traffic Rate (Messages/Minute) For Priority Class II

	RW	WSW	SCW	90% of OW	Total
Jan	.0355	.1475	.1439	.1155	.4424
Feb	.0355	.0992	.1575	.0884	.3806
Mar	.0355	.0812	.1736	.0919	.3822
Apr	.0495	.0458	.1724	.0883	.356
May	.0698	.0079	.1240	.0875	.2892
Jun	.0549	.0008	.1012	.0742	.2311
Jul	.0415	.0000	.1020	.0781	.2216
Aug	.0310	.001	.0897	.0829	.2046
Sep	.0289	.0061	.1404	.0876	.263
Oct	.0347	.0322	.1839	.0916	.3424
Nov	.0342	.0547	.1951	.0962	.3802
Dec	.0372	.1278	.2020	.1035	.4705

Table 2-10. December 1985 Traffic (μ = 1.008)

	Chan.	Prior	Sys. Time	Queue Time	Sys. Lngt.	Queue Length
No priority μ = 1.008 λ = .4955						
	1	1	1.951220	.959156	.966829	.475262
	2	1	1.055847	.063783	.523172	.03160
	3	1	.997787	.005723	.494403	.002836
	4	1	.992543	.000480	.491805	.000238
	5	1	.992099	.000036	.491585	.000018
	6	1	.992006	.000002	.491569	.000001
Two Priority Classes μ = 1.008 λ_I = .025 λ_{II} = .4705	1	1	1.492132	.500069	.037303	.012502
	1	2	1.975613	.983550	.929526	.462760
	2	1	1.040774	.048710	.026019	.001218
	2	2	1.056648	.064584	.497153	.030387
	3	1	.996889	.004825	.024922	.000121
	4	1	.992487	.000423	.024812	.000011
	4	2	.992546	.000483	.466993	.000227
	5	1	.992096	.000032	.024802	.000001
	5	2	.992099	.000036	.466783	.000017
	6	1	.992066	.000002	.024802	.000000
	6	2	.992066	.000002	.466767	.000001

Table 2-11. December 1985 Traffic (μ = .625)

	Chan.	Prior	Sys. Time	Queue Time	Sys. Lngt.	Queue Length
No priority μ = .625 λ = .4955						
	1	1	7.722008	6.122008	3.826255	3.033455
	2	1	1.898283	.298283	.940599	.147799
	3	1	1.636860	.036860	.811064	.018264
	4	1	1.604633	.004633	.795096	.002296
	5	1	1.600534	.000534	.793065	.000265
	6	1	1.600055	.000055	.792027	.000027
Two priority Classes μ = .625 λ_I = .025 λ_{II} = .4705						
	1	1	2.921333	1.321333	.073033	.033033
	1	2	7.977091	6.377091	3.753221	3.000421
	2	1	1.783718	.183718	.044593	.004593
	2	2	1.904370	.304370	.896006	.143206
	3	1	1.627486	.027486	.040687	.000687
	3	2	1.637358	.037358	.770377	.017577
	4	1	1.603752	.003752	.040094	.000094
	4	2	1.604680	.004680	.755002	.002202
	5	1	1.600453	.000453	.040011	.000011
	5	2	1.600538	.000538	.753053	.000253
	6	1	1.600048	.000048	.840001	.000001
	6	2	1.600056	.000056	.752826	.000026

Table 2-12. June 1985 Traffic (μ = 1.008)

	Chan.	Prior	Sys. Time	Queue Time	Sys. Lngt.	Queue Length
No priority μ = 1.008 λ = .3879						
	1	1	1.612643	.620580	.625544	.240723
	2	1	1.030204	.038140	.399616	.014795
	3	1	.994876	.002812	.385912	.001091
	4	1	.992252	.000189	.384895	.000074
	5	1	.992075	.000011	.384826	.000004
	6	1	.992064	.000001	.384822	.000000
Two priority Classes μ = 1.008 λ_I = .1568 λ_{II} = .2311						
	1	1	1.444156	.452093	.226444	.070888
	1	2	1.726960	.734897	.399101	.169835
	2	1	1.025463	.033399	.160793	.005237
	2	2	1.033420	.041357	.238823	.009558
	3	1	.994649	.002585	.155961	.000405
	3	2	.995029	.002966	.229951	.000685
	4	1	.992241	.000178	.155583	.000028
	4	2	.992260	.000196	.229311	.000045
	5	1	.992074	.000011	.155557	.000002
	5	2	.992075	.000012	.229269	.000003
	6	1	.992064	.000001	.155556	.000000
	6	2	.992064	.000001	.229266	.000000

Table 2-13. June 1985 Traffic (μ = .625)

	Chan.	Prior	Sys. Time	Queue Time	Sys. Lngt.	Queue Length
No priority μ = .625 λ = .3879	1	1	4.217638	2.617630	1.636019	1.015379
	2	1	1.770496	.170496	.686775	.066135
	3	1	1.618129	.018129	.627672	.007032
	4	1	1.601862	.001862	.621362	.000722
	5	1	1.600172	.000172	.620707	.000067
	6	1	1.600014	.000014	.620645	.000005
Two priority classes μ = .625 λ_I = .1568 λ_{II} =.2311						
	1	1	2.925587	1.325587	.458732	.207852
	1	2	5.094273	3.494273	1.177286	.807526
	2	1	1.734454	.134454	.271962	.021082
	2	2	1.794951	.194951	.414813	.045053
	3	1	1.615690	.015690	.253340	.002460
	3	2	1.619783	.019783	.374332	.004572
	4	1	1.601679	.001679	.251143	.000263
	4	2	1.601987	.370219	.370219	.000453
	5	1	1.600159	.000159	.250905	.000025
	5	2	1.600181	.000181	.369802	.000042
	6	1	1.600013	.000013	.250882	.000002
	6	2	1.600015	.000015	.369763	.000003

improvement in queue delay time over the no priority case for Class I messages is presented in Table 2-14. It is apparent from the table 2-14 that expected queue time improvement diminishes as the number of channels increases. The improvement, however, increases with reduced service rate because the larger queues that are formed do not affect the high priority class. It is also apparent from the table that the improvement decreases as as the ratio of Class I messages to the total traffic increases.

For comparison, an analysis was carried out for a alternate message routing procedure whereby each of the two priority classes is relayed through a separate dedicated set of channels. This contrasts the previous routing cases where all messages are relayed through the same set of communicating channels. The results are shown in Table 2-15. Assuming three channels dedicated to Class I priority messages and one channel dedicated to Class II priority messages, under the worst traffic and service conditions, 99.956 percent of Class I and 92.6 percent of Class II messages will satisfy transmission time requirements. With no priority and assuming four channels, 99.87 percent (see Table 2-6) of all traffic satisfies the transmission time requirement. This suggests that for a given total number of channels the alternate routing procedure discussed may be inferior with respect to transmission time requirements.

Table 2-14. % Improvement In Expected Queue Time for Class I Messages

Mean Service Rate (messages/min)	Number of Channels	% Improvement for June traffic	% Improvement for Dec traffic
1.008	1	27	47.86
	2	12.4	23.63
	3	8	15.69
	4	5.8	11.87
	5		11.1
.625	1	49.3	78.4
	2	21.1	38.4
	3	13.4	25.4
	4	9.8	19.0
	5	7.5	15.1

Table 2-15. Probability Of Waiting Time For Dedicated Channels

Expected Service Rate (msg/min.)	Expected Traffic Rate (msg/min) Class I June	Class II Dec.	Number of Channels	Probability of Waiting more than T min. in Queue T=0	T=1	T=15
1.008		.4705	1	.466766		.000147
			2	.088322		.000000
			3	.012578		.000000
			4	.001404		
			5	.000128		
			6	.000010		
.625		.4705	1	.7528		.074166
			2	.205866		.000002
			3	.044542		.000000
			5			
			6			
1.008	.1568		1	.155556	.066407	
			2	.011226	.001749	
			3	.000566	.000032	
			4	.000022	.000000	
			5	.000001	.000000	
			6	.000000	.000000	
.625	.1568		1	.25088	.157083	
			2	.027963	.009371	
			3	.002235	.000401	
			4	.000137	.000013	
			5	.000007	.000000	
			6	.000000	.000000	

2.1.2.5 Summary

The conceptual traffic flow of the future (~ 1985) NWS is illustrated in Figure 2-11. The three major types of traffic are: data collection, forecast materials, and forecasts and warnings. Meteorological data traffic flows from the lower echelons up to the NMC, forecast material originates at the NMC and flows to the lower echelons, and the forecasts and warnings originate at the middle and lower echelons and are passed to the general public.

The primary communication configuration consists of a full access network together with the lower echelon facilities connected to nodes of the larger network. The full access network (AFOS, Stage A), illustrated as circles connected in a loop in Figure 2-11. connects all the WSFOs, RFCs, and National Centers and all traffic is accessible to all facilities. In Figure 2-11, two loops are illustrated; however, in the actual implementation, one network will carry all the illustrated traffic.

The lower echelon and facilities (e.g., WSOs), illustrated as triangles in Figure 2-11, are connected to their parent facility. Data generally flows from these facilities and some of this data is then entered into the complete access network. Some of the forecast material is passed down to the lower echelons along with the localized forecasts. One of the basic functions of the lower echelon facilities is to provide forecasts and warnings to the general public. This information is passed to the via the mass media using facilities such as the NOAA Weather Wire Service (NWWS) and a DWS directly to home receivers. This dissemination is illustrated by the hexagons in Figure 2-11.

Generalizations can be made concerning the traffic in the full access network; but not for the networks connecting the lower echelons to their parent facilities. Each facility must be treated individually since they are tailored to the particular locale. Furthermore, all traffic within a particular spur network is not necessarily received by all nodes of that network. For example, data may be preprocessed or only used locally to adopt and refine forecasts received from the parent facility.

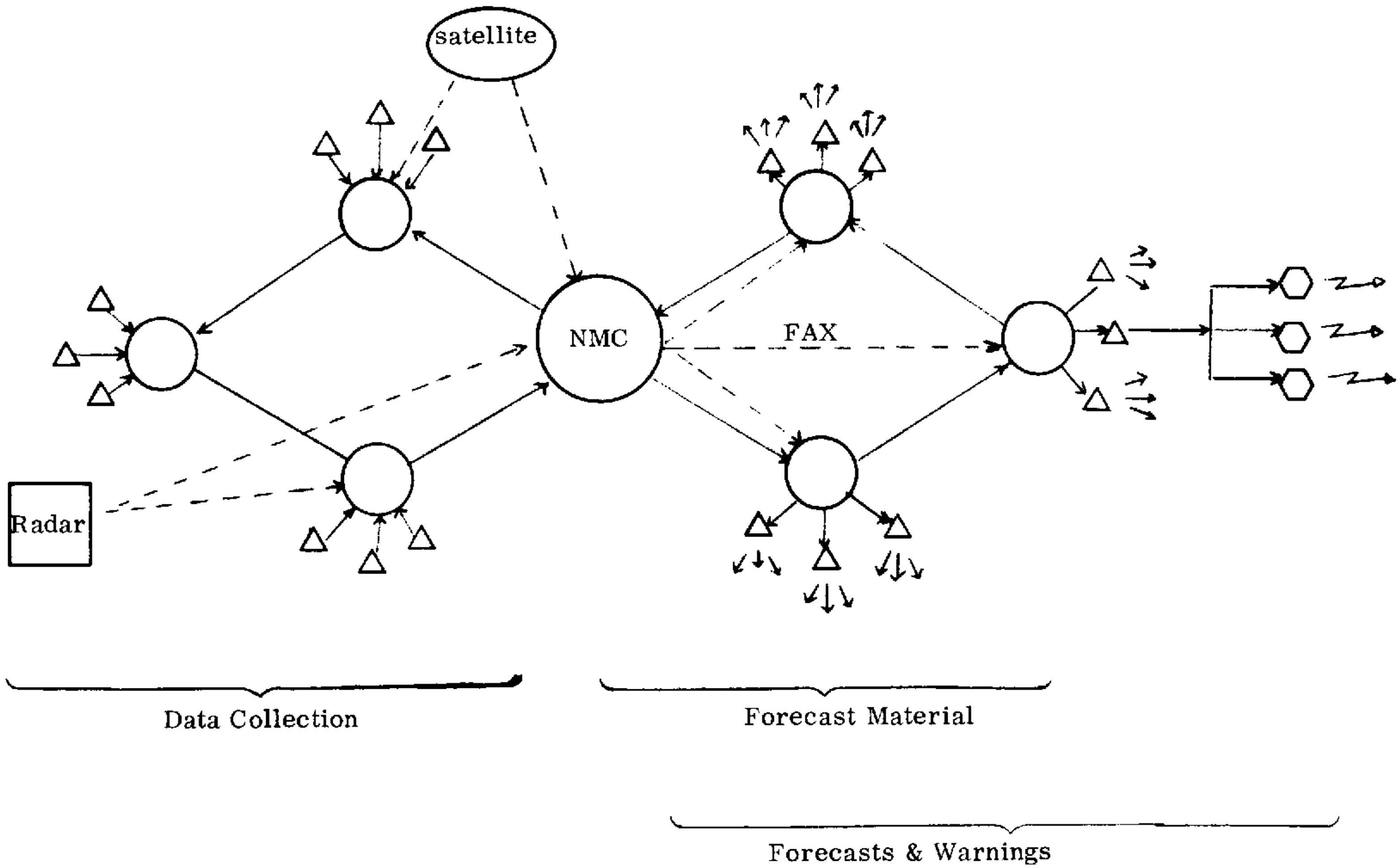


Figure 2-11. Conceptual Traffic Flow of Future NWS

Some auxiliary traffic is also illustrated in Figure 2-11. Satellites will be used to obtain meteorological data such as earth and cloud coverage images and data from remote platforms. This data will go directly to the NMC; however, some of the data may also be received directly from the satellite at some special facilities. The high resolution imagery will be sent over facsimile networks via the Satellite Field Services Station to the WSFOs, RFCs, and the National Centers. Also, the RAWARC network will continue to provide radar data to selected facilities.

Summarized in Table 2-16 is the estimated traffic loading of the future NWS illustrated in Figure 2-11. Other than the warning and satellite imagery traffic, the estimates are from the AFOS (Stage A) requirements. No estimates were made of the (nonwarning) traffic to and from the lower echelons since each facility must be considered individually. The amount of traffic is most likely bounded by the values presented for the AFOS (Stage A) and the average is probably approximately 1/50 of those values. It is possible, though not considered probable, that it may be necessary to obtain more accurate estimates of the traffic loading at the lower echelons. If necessary, the types of functions of each facility can be obtained (Reference 4) and individual traffic estimates made.

The estimated satellite imagery traffic is based upon 19 sectors of either visual or IR images plus four sectors of IR images being transmitted every 30 minutes. The images are transmitted using analog signals which requires approximately 20 minutes to transmit a single image over C5 conditioned land lines.

The estimated warning traffic is based upon the results of Paragraph 2.1.2.4.3. Each warning message was estimated to be one minute long sent at a rate of 150 words per minute. The effects of this traffic load upon a DWS was discussed in detail in Paragraph 2.1.2.4.4 and will not be repeated here.

Rough estimates were made of the amount of scheduled and unscheduled traffic. Since this has a strong effect upon the applicable multiple access techniques, this information is required for the synthesizing of alternative systems. If the selected alternatives are very sensitive to the amount of scheduled and unscheduled traffic, a more precise estimation will be made.

Table 2-16. NWS Traffic Loading

	Number of Messages/day	Amount of Data/day	Daily Scheduled*	Daily Unscheduled*
Data Collection				
Surface	15,912	795,600 Characters	600,000 Characters	195,600 Characters
Synoptic & Radar	2,424	244,400 Characters	244,400 Characters	-
Forecasts				
FT-1, FT-2	2,268	203,840 Characters	203,840 Characters	-
Winds Aloft	582	146,000 Characters	30,000 Characters	116,000 Characters
State, Zone & Local	2,800	1,167,500 Characters	671,250 Characters	496,250 Characters
Special	990	832,000 Characters	492,000 Characters	340,000 Characters
Forecast Material				
Graphics	225	3,870,000 bits	3,870,000 bits	-
Satellite Imagery	1,104	368 hrs. on C5 line	368 hrs. on CS line	-
Warnings**				
HW	82	12,300 words	-	12,300 words
RW	101	15,150 words	-	15,150 words
TSSW	214	32,100 words	-	32,100 words
WSW	212	31,800 words	-	31,800 words
SCW	291	43,650 words	-	43,650 words
OW	185	27,750 words	-	27,750 words

* Estimated from available data.

** Worst case month

2.1.3 Disaster Warning System Requirements

2.1.3.1 Introduction

The DWS is not considered to necessarily be a communication system separate from others of the NWS; but rather the DWS ensures, either by utilizing existing communications or establishing new ones, the availability of functions necessary for the timely and accurate disaster warning dissemination to the public. Additionally, if a separate communication system is required to meet some or all of the DWS requirements, there may well exist excess communication capabilities that may be applicable to provide either primary, alternative, or backup capacity for other functions of the NWS.

In the following paragraphs the required communications is divided into three categories:

- Broadcasting to home receivers
- Data collection
- Coordination

The parameters used to specify a communication system are somewhat dependent upon the particular system; however, there are some parameters that are generally applicable. Coverage is one of the fundamental parameters which defines the physical relationship between the transmitters and receivers. Whenever multiple transmitters are using a common link, which is typical with satellite systems, the applicability of various multiple access techniques arises and is highly dependent upon other parameters such as coverage, message format, and time response. The message format, which limits applicable modulation types, its associated performance requirement, and time response are the fundamental parameters that size a communication system. Also, any limitations such as receiver sensitivity and antenna gains have significant effects upon the system.

In the following discussion of the DWS requirements whenever there is a difference from the requirements in Reference 6, the difference will be noted and reasons discussed. One overall difference is that the requirements in Reference 6 are for a satellite system whereas the requirements in this paragraph are not constrained to a satellite system.

2.1.3.2 Broadcasting to Home Receivers

The most fundamental requirement, which is not explicitly stated in Reference 6, is that the DWS shall be designed so that an inexpensive home receiver (including a modest antenna at most) can receive the warning messages. Also, there shall be a capability to demute the receiver using the broadcast and there shall be at least three addresses for each receiver. The receiver shall have the capability to automatically switch to its own internal power source in the event of a power outage, and there shall be a home owner option of "ON" and "OFF".

The coverage requirement contained in Reference 6 for distribution of disaster information is 100 percent of the geographic area within 35°W longitude to 180° meridian and 0° to 50°N latitude plus Alaska. Additionally, there is a requirement for a population coverage of 99 percent within the geographic area served during disaster time and a relaxation to 90 percent within the area served during nondisaster times. The geographic coverage is directed toward a satellite system and would be difficult to meet using a terrestrial system. It would appear as if a coverage based only upon serving a percentage of the population would be more appropriate. It is not certain which population is to be served. The population in the 50 states is included, but other areas where the NWS operates, such as in the Caribbean and Pacific, may need to be served as well. The percentage of the population served is interpreted as the population percentage of a particular area that is being warned. Also, what constitutes serving a particular receiver must be defined. This definition would most likely be expressed as a probability of achieving a minimum signal-to-noise ratio.

The number of transmitting stations to be designated by NOAA may include (Reference 6) any of the WSFOs, WSOs, or National Centers.* Additionally, any WSFO, WSO, or National Center has the authority to transmit warnings without further approval. The capability of a NWS facility to transmit a warning is interpreted to include transmission at a remote site.

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*In Reference 6, National Warning Center is used and is interpreted to be the National Centers as opposed to the National Warning Centers of the NAWAS.

Stated in Reference 6 is the requirement for the DWS to have minimum capability of transmitting ten messages (consisting of disaster warning and/or disaster information) simultaneously. Based upon the results contained in Paragraph 2.1.2.4.4, ten simultaneous messages appears to be high. The significance of requiring ten simultaneous messages will be determined when sensitivity analyses are done for different alternative systems. Nevertheless, consideration should be given to the probability of simultaneously needing to transmit ten urgent (1 minute delivery time) messages. Furthermore, consideration should be given to the geographical coverage in which a maximum number, say ten, simultaneous messages must be transmitted. This is important if there exists several DWS transmitters since it is necessary to know how many simultaneous messages each of the transmitters must send.

There are four types of messages for the general public that are required (Reference 6) to be sent during disaster times. They are:

Watch bulletins

Preparedness information and safety rules

Disaster warning

Evacuation information.

These four types of messages will be considered jointly in the following discussion, but the warning message is the most important and generally will have the more stringent requirements in terms of minimum response time and percentage of the population served. Also, the wake-up (demuting) capability may be limited to disaster warnings or the home-owner may have an option as to which type of messages will initiate a wake-up alarm. The system is to have the capability (Reference 6) of activating receivers within 15 seconds. The time constraint is interpreted to be from the time the message broadcast begins.

A potentially significant requirement (Reference 6) is that all these messages are to be voice messages. These messages provide two functions: alerting and information concerning the nature of the alert. The alerting function is the most important and should meet the most stringent requirements. The two questions regarding the information are how much information needs to be transmitted and in what form.

The most reliable means of ensuring that the information content of a broadcasted message is received is to provide a hard copy. This is particularly true whenever an urgent warning message is sent during those times when the recipient is asleep. It is unlikely that an alarm followed by a single voice message would be totally comprehended by a sufficiently large percentage of the intended recipients. Typically, it is necessary to sequentially repeat the voice message several (like three) times following an alerting alarm to ensure that the message is received, comprehended, and retained. Even though rather substantial advances have been made and are expected to be made in inexpensive teleprinters, hardcopy written messages are not expected to be economically feasible for home receiver by 1985. However, it is economically feasible to consider simple display techniques such as coded lights or numerics. The applicability of such hard copy display is primarily dependent upon the quantity of information which must be displayed.

If an individual is given only an alert, based upon the historical occurrences of natural disasters and his own observation, there exists a reasonable probability that he will deduce the appropriate action to be taken. How much more information is necessary to increase the probability of correct response? Additionally, if sufficient preparedness is taken, it may be possible to reduce the possible messages into a finite set of canned messages that only require the insertion of key element such as time. If so, a code, such as a number, could be transmitted, the corresponding canned message looked up in a code book, and the key elements inserted.

The necessity of considering other than voice messages is dependent upon the sensitivity of the DWS design to the voice requirements. Alternatively, a combination of voice and display may be appropriate with the coverage requirement on the voice message relaxed to minimize its impact upon the system design.

A mandatory requirement (Reference 6) for information during normal times includes voice messages for "education for what to do when a disaster strikes". The required duty cycle is continuous, as required. It is not clear how many simultaneous voice messages are to be sent nor for what time duration. However, it presently appears as though this requirement may have a strong impact upon the design of the DWS. More importantly, the public interest in such a service is questionable.

2.1.3.3 Data Collection

The three sources of required data collection (Reference 6) are:

Information from spotter networks during disaster times

Data from hurricane reconnaissance aircraft to Miami (NHC) during disaster times

Data from the automatic Data Collection Platforms (DCPs) during both disaster and nondisaster times

The duty cycle requirement (Reference 6) for the hurricane reconnaissance aircraft is one sample per 10 seconds for 5 hours at seven bits per sample. There may be up to 5 aircraft simultaneously on station. It is questionable whether it is necessary to maintain this high duty cycle with the very low amount of data per sample. If this data could be stored and sent less frequently, the communication channel could be used more efficiently.

The information from the spotter networks is to be provided by voice (Reference 6). This seems to be unduly restrictive since conceptual man operated devices to digitize the observations seems feasible. Additionally, digital data would probably be more applicable to the AFOS concept.

The multiple access requirements (Reference 6) for the spotter networks state that spotter information can be transmitted for any one of 100,000 points, and the system shall have the capability of transmitting 50 of these messages simultaneously. It is not stated whether these 50 messages could be from one given area, or, if several communication links are utilized, whether each link must be able to handle 50 simultaneous messages. More importantly, the multiple access technique should be constrained by a minimum time by which spotter information must reach its destination given some worst case spotter network activity.

Data from the DCR is to be collected both during disaster and nondisaster periods. During nondisaster periods, most of the data is synoptic where all (or most of the) 20,000 DCPs are interrogated (or self-timed). Thus, the requirement for the capability of transmitting 200 messages simultaneously (Reference 6) is reasonably based upon the present GOES concept. However, there would be added flexibility if the requirement was stated in terms of a minimum time to receive all synoptic data.

The requirement for the capability of transmitting 200 messages simultaneously during disaster times is not adequate. During disaster times in addition to receiving data from some DCPs in response to interrogation, data would be received from DCPs that responds to meteorological observations which exceed preset thresholds. Thus, the requirement should include the capability to receive unscheduled data. Also, the requirements for nondisaster and disaster times would not be expected to be the same. Again, a requirement to be able to receive a certain number of unscheduled messages within a given time would appear to be more applicable.

2.1.3.4 Coordination

The remaining traffic was included under coordination traffic which consists of preparatory and auxiliary functions to the primary functions of issuing warnings to the general public. This coordination traffic (Reference 6) is categorized and summarized in Table 2-17. This categorization is done according to the origin (four of the five originate at NWS facilities) and destination of the messages. The first three categories appear to duplicate the functions of existing or planned systems: NWWS, AFOS, and NAWAS. However, the DWS requirements are almost entirely associated with natural disasters, many applicable only during disaster times. Nevertheless, if these existing or planned systems can satisfy the DWS requirements, they shall be considered for that task.

However, there are two points that must be resolved before these systems can be considered candidates to satisfy some of the DWS requirements. First, no required response time (duty cycle is given) is stated. Second, all messages require at least a voice message; whereas, neither the NWWS nor AFOS have a voice capability.

Table 2-17. Categorization of Coordination Communications

Origin	Destination	Message Type	Format
1. NWS Facilities	News Media	Watch Bulletins Preparedness Information Disaster Warning* Radar Information** Educational Routine Forecasts	Voice plus graphics for TV
2. NWS Facilities	NWS Facilities	Watch Bulletins* Radar Information** Coordination Planning*	Voice
3. NWS Facilities	Public Officials	Watch Bulletins* Radar Information	Voice
4. NWS Facilities	Spotter Networks	Alert Spotter Networks Radar Information	Voice
5. Any one of 100,000 police, fire, civil defense and local authorities	State Officials and National Organizations NWS Facilities	Communications for rescue and relief and damage assessment	Voice

* Additional hard copy required.

** Additional digital/graphics required.

In fact, the first two categories in Table 2-17 appear to be voice network equivalents to NWWS and AFOS. For the same or similar reasons given in Paragraph 2.1.3.2, the voice requirements seem unduly restrictive and perhaps less desirable than hard copy.

2.2 POTENTIAL COMMUNICATION MODES (TASK 2)

The continuing task of identifying alternative communication modes is described under the subheadings "Terrestrial Communication", Paragraph 2.2.1 and "Satellite Communications", Paragraph 2.2.2. Alternatives based on terrestrial communications will employ existing or planned facilities techniques and equipments. Therefore, information has been gathered to provide the needed data base. Summaries of these subheadings define (1) telecommunications common carriers, (2) types of services, (3) tariffs, (4) data transmission speeds, and (5) reliability. This is followed by a brief description of the parameters that impact on the critical satellite downlink where reception is by special home receiver. Frequency choices and EIRP values are indicated and the impact of building attenuation and rain are delineated.

2.2.1 Terrestrial Communications

2.2.1.1 Telecommunications Common Carriers

American Telephone and Telegraph Company (AT&T) provides approximately 85 percent of the domestic telecommunications voice services. Its operating companies are franchised to operate in areas of one or more states which regulate the rates for services provided within their respective state boundaries. Interstate service is provided by the Long Lines Department of AT&T and is regulated by the Federal Communications Commission (FCC).

Those areas not franchised to AT&T are served by over 400 independent telephone companies, e.g., General Telephone Company, Continental Telephone Company, Union Telephone Company. They generally operate only within state boundaries (intra-state) and, like the AT&T operating companies, are regulated by the individual state's regulatory commissions.

Western Union (WU) is the primary provider of teletypewriter circuits and provides both inter- and intra-state services. WU is also regulated by the state or FCC according to the boundaries within which the service is provided.

In July 1971, the FCC issued a precedent-setting decision authorizing the establishment of a new class of communications common carriers. This decision, which will alter long-established patterns in the U. S. telecommunications industry, basically permits the operation of two types of specialized carrier:

1. Carriers offering private line business communications service for voice, data, and facsimile.

2. Carriers offering only switched digital data transmission services.

One of the main advantages that the new specialized common carriers offer is a digital broadband switching system. This is a significant advancement which could be applicable to DWS.

Communication satellite systems will be both an important element of certain specialized carrier networks and an important resource available to users in establishing their own communication network. A satellite permits the use of a network concept in which all terminals can broadcast directly to each other through the satellite, as contrasted with the point-to-point multi-hop relay used in ordinary ground transmission systems. There are now four to six companies planning to enter this domestic satellite communications field. Published costs for leasing use of their satellites are significantly lower than the charges for comparable ground transmission systems.

The demand for remote terminals and the level of sophistication in their use have greatly increased. Usage is growing rapidly for both special purpose terminals and general purpose devices with build-in intelligence that allow them to be tailored to specific applications and to perform several different types of functions.

In addition to increasing logic power, other trends in terminals include:

1. Decreasing prices, particularly for those terminals with a high electronics content as opposed to predominantly electromechanical devices.

2. Greater availability of peripheral options such as cassette drives, small discs, varying printer, and line speeds.

3. Greater use of programmable controllers to allow them to be tailored to specific applications.

The FCC in an historic administrative order in June 1968 made possible the creation of a new industry which has become known as Interconnect. This emerging industry provides privately owned telephone systems interconnected with the telephone company networks. The primary market segments targeted by Interconnect companies include business, institutional, and Government users whose equipment requirements are in excess of ten telephone locations. Within these market segments, user-customers are generally categorized by one of three switching equipment requirements:

1. Key Station Systems utilized for systems of up to 30 telephone lines.

2. Private Automatic Branch Exchange (PABX) systems utilized for systems requiring more than 30 lines.

3. Centrex PABX Systems utilized by businesses requiring more than 1000 lines.

Some of the factors which characterize Interconnect systems as an attractive alternative to telephone company equipment and programs are:

1. Interconnect companies have developed a broad line of modularly expandable PABX systems which have additional features not found on standard Bell equipment, and knowledgeable Interconnect companies can provide a system tailored to each customer's specific needs.

2. Interconnect equipment is being adapted to encompass the entire range of communication requirements including data and facsimile transmission.

3. Using Interconnect systems equipment, the customer replaces fixed recurring costs, which are subject to increase, with an investment, thus stabilizing his communication costs while availing him of the advantage of depreciation and applicable investment tax credits.

4. Through specialization, Interconnect companies can normally react more rapidly and completely than telephone companies.

2.2.1.2 Type of Communications Service

The more prevalent types of available communications services are discussed in the following paragraphs.

A. Voice Communications Services

1. Long Distance (DDD). The most commonly used voice communications service is the commercial direct distance dialing (DDD) network. Each call placed is individually billed on the basis of duration, time of call placement, and destination.

2. Short Period Service. Short Period Service is a long distance call which is contracted during a specified time of each day to a particular destination for a specified time duration. It can be contracted for 1 to 7 days a week and for periods as short as 10 minutes. If the conversation lasts longer than that contracted for overtime charges are incurred at normal long distance rates.

3. Wide Area Telephone Service (WATS). WATS is designed for users who make or receive many long distance calls to or from many points. It is purchased as a special "access" line connected to the nationwide DDD network. Each line optionally provides either inward or outward service (capability for receiving or originating calls), but not both over the same line. WATS provides for calls to or from six selected service areas. The customer, rather than being charged for each individual call, is billed at a flat monthly rate based on the service area purchased. WATS may be purchased as a full-time service, 24 hours a day, or for 10 hours of service per month with additional charges for each hour of overtime usage.

4. Tie Lines. Tie lines are dedicated circuits between two specified users. Equipment at the two user locations can be either PBXs (switchboards) or telephone handsets. This type of service is normally provided between two users whose calling volumes are sufficient to justify dedicated circuits rather than DDD or other types of communications services. Similar to full-time WATS, this service is provided 24 hours a day, 7 days a week. Charges for the service are based on mileages between the two user locations and a terminal connection charge for the PBX, handset, or other equipment.

5. Foreign Exchange Service. Foreign Exchange (FX) service is provided between two locations and is similar to a tie line except that one location will be terminated in a local telephone company central office and assigned a local telephone number. The subscriber end of the circuit is normally terminated in a PBX/switchboard or handset. This type of service is normally used when one user has need to communicate with a variety of different users in a distant localized area. As with tie lines, charges for this service are based on the mileage between the two user locations, a terminal charge for the PBX or handset termination and the normal monthly charge for a telephone exchange number at the distant end of the circuit.

6. Common Control Switching Arrangement (CCSA) - Switched Network. A Common Control Switching Arrangement is normally provided to serve the communications requirements of a large number of geographically separated users with significantly large volumes of communications. Examples of such dedicated networks include the United States Military Automatic Voice Network (AUTOVON), The General Services Administration (GSA), and the Federal Telecommunications System (FTS).

Combinations of the services are used to provide the total voice communications requirements of commercial and Government users.

B. Data Systems

Data Systems are typically divided into high-speed and low-speed analog and digital systems. For example, a high-speed analog data service is television; a high-speed analog data service would be facsimile; and a low-speed digital data service is teletype. The most commonly used data services are described in the following paragraphs.

1. Analog Data Services

a. Facsimile. Facsimile service, which is normally considered low-speed, transmits fixed images (e.g., engineering drawings, sketches, or weather maps) as analog signals. A specialized form of facsimile called "photofax" is commonly used for transmission of pictures.

b. Television. Two commonly used television services are commercial television and educational television (ETV). Commercial television is commonly used by the major broadcast networks and other commercial television broadcasters. Commercial television transmission services are provided with a high degree of redundancy in equipment and transmission facilities to assure reliability and continuity in the transmission. Commercial television services are provided on a scheduled basis for periods as short as 1 hour per day or up to 24 hours a day, 7 days a week. ETV is similar to commercial television except the high degree of redundancy to assure reliability and continuity of transmission is not provided. As implied by its name, ETV is normally used where economy is required, as for educational purposes, and high reliability is not required. Common carrier transmission rates for ETV are approximately one-half those for commercial TV.

c. Electrically Transmitted Handwriting. While not as prevalent today as in the past, another low-speed analog data service involves the transmission of handwritten messages. Basically, the device used for this are electromechanical, transmitting and reproducing handwriting on a real-time basis to another point. Most applications of this service are for very short distances, such as a handwritten order placement in a sales showroom to a storage point near the sales location. These services are considered low-speed analog data and normally require a normal voice bandwidth (4 kHz) circuit provided by commercial communications carriers.

2. Digital Services

a. TELEX/TWX. This low-speed digital service is similar to voice DDD previously described except that it is for record copy. As with DDD, billing is based on destination and duration of the call and is billed on an individual call basis. This service is normally used where there is a relatively low volume requirement to communicate with a large number of users, i.e., no concentrated communications requirement to one or more users. Under a recent agreement between Western Union and AT&T, TWX service was purchased from AT&T and the combined TELEX/TWX service is now provided solely by Western Union.

b. Dedicated Lines. Dedicated lines, comparable to tie lines for voice communication, are available for either low-speed (teletypewriter) or high-speed (computer) applications. Bandwidth of the dedicated lines is based on the data transfer rate requirements. Charges for this service are based on bandwidth requirements, mileages between the serviced user locations and any special terminal equipment requirements. Dedicated lines can be provided as either point-to-point or multipoint (party line) services for a number of users.

c. Switched Data Networks. This type of data is normally either low-speed teletype or high-speed computer networks. The networks are comparable to the voice CCSA (switched network) previously described. A variety of switched data networks is provided for various types of applications, e.g., the Military Automatic Digital Network (AUTODIN), the GSA Automatic Record Service (ARS), commercial airlines, large manufacturing firms.

Various types of high-speed computer networks are now evolving. Examples of these are the recently implemented Applied Research Project Agency (ARPA) computer network and the yet to be implemented Worldwide Military Command and Control System (WWMCCS) computer network. It appears that several of these types of computer networks will evolve in the future.

2.2.1.3 Tariffs

All telecommunications common carriers are required to file tariffs specifying the costs for their inter-state service offerings with the FCC. Likewise, intra-state offering tariffs are filed with the individual State regulatory commissions. Almost without exception, inter-state communications services cost less than the comparable intra-state services. Details on tariffs/costs are now being obtained.

2.2.1.4 Data Transmission Speeds

Dedicated data links are currently provided by AT&T and Western Union. The Government is able to lease voice (type 3002) circuits using TELPAK (cheaper by the dozen) pricing. An unconditioned 3002 voice circuit is capable of transmitting data at 1200 bps. Line conditioning increases the data transmission handling capability of a 3002 line. The following table provides a comparison of the types of 3002 line conditioning and their nominal bps data rate capability.

Conditioning	Nominal Data Rate (bps)
C-0	1200
C-1	1400
C-2	2400
C-4	4800

The data rate is dependent on the modem used on the circuit. A modem is required to convert digital data output of a computer or a data terminal to an analog signal for transmission on the common carrier's predominantly analog transmission facilities. It must be recognized that the common carriers do not guarantee minimum error rates for data transmission; they provide circuit conditioning in terms of loss and distortion with no reference to data rates or expected error rates. Therefore, the foregoing rates are based on nominal ranges claimed by various modem manufacturers. One modem is claimed to be capable of transmitting from 1800 to 10,800 bps depending on the type of network on which it is used and the type of input data to the modem. In addition to the circuit and conditioning charges, there are charges for each terminal's local access to the circuit.

2.2.1.5 Reliability

Generally, terrestrial communications systems reliability can be affected by sabotage or enemy attack and severe weather conditions, electronic equipment failure, and power failures. Common carrier protections against these factors are summarized as follows:

The various terrestrial communications systems are engineered with differing degrees of reliability. Long-haul cable systems such as L-3 and L-4 installed since the early 1960s are generally buried underground and located to avoid target areas. These systems have varying degrees of hardness and blast protection which causes these systems to be more reliable and survivable during natural disaster. Other terrestrial systems, such as microwave relay radio and the older cable (C and K carrier) systems, are generally above ground and therefore less reliable/survivable during disasters and extremely bad weather. It is not uncommon for these cables to fall to the ground and become inoperative during heavy icing conditions or wind storms.

Some microwave relay radio systems such as TH, TL, TM are subject to fading (loss of signal or "noisy" circuit conditions) during heavy fog and temperature inversions. Therefore, the common carriers will not use these systems where these bad weather conditions frequently prevail. Generally, these types of bad weather conditions only occur to a severe enough degree in the Southeastern portion of the United States along the Gulf of Mexico coastal regions.

Automatic broadband switching is used in most of the long-haul terrestrial communications systems to significantly increase reliability. This automatic switching occurs in a few milliseconds and is undetectable in voice communications and causes only a minor hit (loss of a few bits) in data communications. Broadband switching is also employed on microwave relay radio systems, i.e., one spare broadband radio channel of five is reserved to be automatically switched into the system if a working channel becomes inoperative or noisy.

Automatic broadband switching is not effective to increase system reliability in the event of a total system failure. A total system failure can occur if a microwave tower is blown over in a severe hurricane or a cable system is severed by accident. In this case, the common carriers have comprehensive broadband restoration plans which must be manually implemented. Once a total system failure is detected it may take anywhere from a few minutes to several hours to completely restore all affected circuits in the failed system.

The common carriers communications equipment is normally served by commercial power sources. However, if commercial power fails there is generally a standby battery supply with a minimum of 8 to 24 hours of reserve power. This standby power is automatically switched into the system immediately upon the loss of commercial power. In addition to the standby battery supply, most major terrestrial communications systems also have diesel engine generators which automatically start when commercial power fails. Normally there is a 7-day supply of fuel for these generators. The basis for this 7-day supply is that it is felt that additional fuel can be provided if the commercial power outage lasts more than the 7-days. Diesel generators are normally provided on all L and radio carrier transmission systems. Locations which have only battery reserve power are equipped so that a transportable diesel generator can be brought to the site to supply power prior to the battery reserve being exhausted.

2.2.2 Satellite Communications

Various alternatives for implementing disaster warning communications via satellite are being investigated. The downlink is the critical link and is examined first. The satellite broadcasts will be either (1) directly to special home receivers or (2) to receiving terminals which would then rebroadcast the warning messages to existing (or presently proposed) receivers. The first approach implies the use of very low-cost (low performance) equipment since millions of special receivers would be required, at home owners expense. This in turn requires high EIRP satellites. The second, or rebroadcast, approach could employ relatively expensive receiving terminals since the number required would be small. The result is a reduced satellite EIRP (cost).

The initial effort was directed toward generating downlink power budgets when using the special home receivers. The results are for rough sizing of the DWS and for providing a basis for frequency choice. The three WARC-approved satellite broadcasting frequency bands are considered for evaluation, although other frequencies have not been ruled out at this time. A discussion with FCC confirmed that other bands such as the 1.6 and 0.47 GHz regions are also possibilities depending on bandwidth requirements, flux density level, etc.

Satellite EIRP was calculated at the WARC frequency bands for two types of receiving antennas. The first provides a constant 40^{o} beamwidth regardless of frequency, hence the size of the receiving antenna decreases with increasing frequency. This antenna has a gain of 12 dB and its beam is broad enough that antenna orientation is not a problem. The size is relatively compact at all but the lower frequency bands for outdoor use at

790 MHz and for outdoor or indoor use at 2.6 and 12.2 GHz. At 790 MHz, a dipole antenna is assumed for indoor use.

The antenna and receiver noise temperature for consumer quality equipment were calculated as follows:

Frequency	Receiver Temperature	Antenna Temperature
790 MHz	$625^{o}K$	$3930^{o}K$
790 MHz	$625^{o}K$	$1379^{o}K$ (Horizontal dipole)
2.6 GHz	$1160^{o}K$	$334^{o}K$
12.2 GHz	$2610^{o}K$	$350^{o}K$

The antenna temperatures are applicable at low elevation angles and for (1) high humidity with heavy rain, (2) disturbed sun, and (3) urban man-made noise environment.

The satellite EIRP is the direction of a receiver required to provide minimal voice quality when operating at FM threshold is:

Frequency	EIRP
790 MHz	31.2 dBW
790 MHz	37.7 dBW (dipole)
2.69 GHz	37.1 dBW
12.2 GHz	53.2 dBW

The numbers do not include allowances for rain or building attenuation. A polarization loss of 3 dB is included for the dipole antenna. The EIRP at 12.2 GHz would have to be increased by 30 dB or more to provide the required reception reliability, i.e., essentially 100 percent during very heavy rain. This factor, when coupled with the higher equipment costs at 12.2 GHz, rule out this band for further consideration.

The tradeoff is not clear between the lower two frequency bands since both have certain advantages. The final choice depends on relative equipment costs, acceptable antenna sizes and building attenuations.

A significant factor is building attenuation which appears to increase with frequency.

An FCC study of television signal attentuation indicates that building attenuations of TV Channel 31 can be in excess of 28 dB for concrete structures and in excess of 17 dB for wooden structures. Therefore, significantly increased satellite EIRPs would be required with the use of indoor antennas.

The satellite configurations and weights associated with the stated values of EIRP have been initially sized. This information, along with further evaluations of receiver costs, antenna cost and size and building attenuation will be used in choosing between the two lower frequency bands.

SECTION 3 - CURRENT PROBLEMS

No problems that may impede performance on this project are currently contemplated.

SECTION 4 - WORK PLANNED

Task 1 has been essentially completed, but some additional efforts may be required in response to NOAA and NASA review of the results contained in this progress report. Following this review, a set of system requirements will be submitted for NASA review. Using a NASA approved set of system requirements and conceptual traffic flow, a set of technical parameters will be developed upon which the remaining tasks will be based.

The efforts in Task 2 will continue and some initial efforts started on Task 3. Specially, in the space systems, coverage and uplink considerations will be examined. One important aspect of uplink that will be addressed is the inherent multiple access problem. For the terrestrial systems, more details on the costing of commercial facilities will be acquired, and a general investigation of broadcasting systems will be initiated.

The mid-term presentation planned for mid December has been scheduled, with NASA approval, for 9 January 1974.

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APPENDIX A
PRESENT COMMUNICATION SYSTEMS

The basic communications for the NWS offices are provided by the FAA-operated, long-line teletypewriter networks; Services C and A. Service C is the "meteorological network" and carries most of the United States' surface synoptic and upper air data; marine and other forecasts and some warnings; river data; and special guidance material for professional meteorologist. Service A, often called the "aviation network", primarily is used in the collection and distribution of hourly surface observations. Exchange of meteorological information between the United States and foreign countries is provided by the Service O teletypewriter network and the International Exchange System.

In addition to these networks there are two other major teletypewriter networks; radar reporting and warning coordination (RAWARC) and NOAA weather wire service (NWWS). RAWARC, which terminates at the NSSFC in Kansas City and at NMC provides the means to collect and distribute radar reports and storm warning information. Secondarily, RAWARC is used to bypass Services A, C, and O whenever these circuits are busy. The purpose of the NWWS network is to distribute consumer-oriented weather warnings, forecasts, and data to the mass news media for relay to the public and specialized users. Both the RAWARC and NWWS networks are being expanded.

There are two major facsimile networks. The National Facsimile Network is the basic weather graphics network which serves approximately 250 WSOs as well as non-NWS users. The distribution to the WSFOs of forecast guidance materials prepared by the NMC and satellite products from the National Environmental Satellite Service is provided by the Forecast Office Facsimile System (FOFAX).

In addition to these major system, there are numerous local and specialized networks which provide coverage that has not been provided by the major systems or provides additional specialized services. For example, there are facsimile networks for Alaska and Honolulu, local public service loops where NWWS has not been implemented, networks for fire weather forecasts, warnings, and advisories, a "hot line" (telephone system) to connect those Hurricane Warning Offices in the eastern U.S., and circuits to provide radarscope images displayed at locations remote from the radar.

The National Warning System (NAWAS), operated by DCPA, is designed to provide warning of an actual attack upon the United States. By a joint agreement between DCPA and NSW, the use of NAWAS has been expanded to include the dissemination of warnings and other information concerning natural disasters. NAWAS is particularly useful for control of activity and status feedback during natural disasters. NAWAS is a nationwide telephone (two-way voice party line) network with a hierarchical structure consisting of three National Warning Centers (two serve as alternatives), eight regions, and state circuits. In each state, one primary (or control) point has been designated. The network is configured so that each state can function autonomously; however, the primary point monitors the nationwide network so that the state network can readily be reconnected. Of the 1867 NAWAS terminal points, approximately 230 are located in NWS offices. Expanded NWS use of NAWAS, particularly for intra-NSA coordination of disaster information, includes the installation in one NWS office in each state of a drop on the NASAW circuit in an adjoining state.

APPENDIX B

SUMMARY OF FACILITY RESPONSIBILITY

A conceptual traffic flow has been established for the present National Weather System and for the system as it is projected to develop with the implementation of AFOS. As an aid to evaluating the traffic flow requirements, a summary has been made of the responsibilities of the various types of facilities in the National Weather Service (NWS) with particular attention to the impact of these responsibilities on traffic flow. The data for this summary was obtained primarily from Reference 4. This summary is given in the following paragraphs.

B.1 NATIONAL METEOROLOGICAL CENTER (NMC)

Responsibility: NMC is responsible to NWS for preparation of forecasts (including long range) for the entire country. NMC is also responsible to the World Meteorological Organization; this responsibility notably includes tropical analysis for the southern hemisphere.

Traffic: Incoming traffic is largely composed of observational data in rather unprocessed form. This data includes cloud and temperature satellite data as well as routine observations. The daily distribution of incoming observations is 13,400 synoptic (1,400 from ships), 1,500 atmospheric sounding, 2,500 aircraft. Processed data in the form of graphics leaves NMC for the WSFO at the rate of 576 facsimile (weather charts) and 420 teletype transmissions per day; the latter category largely represent forecast information.

Communications: NMC presently utilizes the land line facilities run by the NWS and the FAA. These include Services A, C, and O, as well as RAWARC, FOFAX, and APT; the latter three are for facsimile transmission.

Relationship to Planned Systems: The NMC will be one of the principal modes of the AFOS system. It will probably not be one of the primary facilities to issue warnings via the DWS.

B.2 HURRICANE CENTERS

Responsibility: The National Hurricane Center (NHC) at Miami, Florida is charged with maintaining a watch for developing tropical disturbances. One part of NHC is the Regional Center for Tropical Meteorology (RCTM) which specifically analyzes the changes and movements of tropical storms; CHURN (the Cooperative Hurricane Reporting Network) aids in this task by frequent reporting of surface observations from the CHURN stations.

There are also Pacific Hurricane Centers located at San Francisco and Honolulu with responsibility for forecast and warning of tropical cyclone formations in their respective areas.

Traffic: The number of observations taken by CHURN stations is highly variable; at least one observation is taken daily, and at Coast Guard operated CHURN stations, readings are taken every 3 or 6 hours. In times of emergency, readings may be taken hourly. Forecast and warning information is transmitted to Hurricane Warning Offices (HWOs) and WSFOs for public dissemination. In particular, the severe weather outlook for 24 hours (including the same graphic analysis) is issued twice daily.

Communications: The HWOs are equipped with a "hot line" to converse with NHC (and each other). Hurricane Centers are also equipped with several facsimile circuits (notably the tropical regional analyses forecast circuit - NHC only). Service O and the International Exchange System (IES) are two of the principal means of communication to overseas from the Hurricane Centers.

Relationship to Planned Systems: The Hurricane Centers will be provided drops for AFOS and will probably only utilize the DWS for warning the public through the HWOs (as is done now) although a capability could be provided for direct access.

B.3 NATIONAL SEVERE STORMS FORECAST CENTER (NSSFC)

Responsibility: NSSFC maintains a watch for the development of severe weather conditions; as part of its function it releases the 24-hour Severe Weather Outlook Narrative and

24-hour Severe Weather Outlook Graphic twice daily. The Severe Local Storms (SELS) of NSSFC releases forecasts of conditions such as tornadoes or severe thunderstorms as often as needed; these are released in "watches" for public use and as SIGMETS or AIRMETS (warnings of severe weather) for aviation via the FAA Flight Service Stations and recorded announcements.

Traffic: The traffic is highly variable depending upon weather conditions. At least the 24-hour Severe Weather Outlook Narrative and Severe Weather Outlook Graphic are issued twice daily for dissemination by WSFOs and WSOs.

Communications: NSSFC is able to communicate via Services A, C, and O as well as the RAWARC circuit. It also has drops on the National and Aviation Meteorological Facsimile Networks as well as FOFAX. There is also a special line to Kansas City to provide data from the ATS satellites as part of the GOES program.

Relation to Planned Systems: The NSSFC will be part of the AFOS system. It will also have to have the ability to access the DWS.

B.4 RIVER FORECAST CENTER (RFC)

Responsibility: The dozen RFCs are responsible for preparation of forecasts of water supply, precipitation, and river condition for both short (less than 5 days) and long-term (up to 30 days and, in some instances, entire seasons). Each RFC transmits its forecast information to its subsidiary River District Offices (RDOs) for dissemination to the public.

Traffic: The amount of traffic for RFCs is not specifically stated in the references; it must be highly variable. It is stated that forecasts must be prepared for 2,200 points; if it is assumed that this is done once or twice daily, one has an indication of traffic. The incoming traffic is data which emanates directly from sensors or from subsidiary RDOs. Other WSOs participate in both data acquisition and warning dissemination. Outgoing traffic is largely composed of forecast information which goes to the subsidiary RDOs and downstream RFCs.

Communications: The RFCs will have communication capability using at least Service C and RAWARC facilities. They will also have drops for the National Facsimile Circuit and FOFAX. Since they are often collocated with WSFOs, one may expect the "typical" WSFO communications. RFCs will also receive data via teletype and telephone (automatically and manually.)

Relation to Planned Systems: RFCs will be a part of the AFOS network. They will probably be able to access the DWS to issue warnings.

B.5 RIVER DISTRICT OFFICE (RDO)

Responsibility: The RDOs are responsible for collection of data and transmission of partially processed data to the parent RFC. RDOs are also responsible for the dissemination of warnings to the public via the mass media.

Traffic and Communications: The traffic is highly variable with stressful situations. Normal traffic will follow the pattern of either a WSFO or WSO since the RDOs are always collocated with one of these two types of facilities. This is true also of the available communications. In addition, RDOs will have additional incoming communications for data specific to their RDO function; these are telephone or teletype and are sometimes automated.

Relation to Planned Systems: The RDOs are not a part of AFOS; they will be linked to parent RFCs by teletype. RDOs will necessarily be a part of DWS.

B.6 WEATHER SERVICE FORECAST OFFICES (WSFO)

Responsibility: There is approximately one WSFO for each state; its responsibility is to issue state weather forecasts for a 24- and 48-hour period each 6 or 12 hours prepared from global data sent by NMC and local data sent by the subsidiary WSOs. The WSFOs are also responsible for originating warning information of all types to be disseminated by the WSOs. Some WSFOs may have Marine Forecast Units attached to them with responsibility for Coastal Waters (or lakes) forecasting. Four WSFOs serve as Regional Warning Coordination Centers (RWCCs) for large regions. Some WSFOs may have direct data collection responsibility (such as radar remote data or data associated with RFC or RDO functions.)

Traffic: Incoming traffic includes data sent by the satellite WSOs as well as data accumulated directly. A large number of graphics (approximately 200) is sent to each WSFO by NMC each day. The WSFO takes the local data and processes it for transmission to NMC. The global NMC forecast data is modified before being retransmitted to the WSOs.

Communications: The communications capabilities will vary but each WSFO will have access to Service A and C circuits as well as RAWARC. Facsimile circuits available include FOFAX and the National Facsimile Circuits.

Relation to Planned Systems: WSFOs will be a part of AFOS. They will also probably have access to the DWS for warning dissemination.

B.7 WEATHER SERVICE OFFICE (WSO)

Responsibility: WSOs are responsible for modification and dissemination of forecasts and warnings which come to them from their parent WSFO. They must prepare the 48-hour local (typically county) forecast and contact appropriate media. WSOs are also responsible for a great deal of data collection (surface, atmospheric, and hydrologic) which must be amassed for transmission to the WSFO. Virtually all warning information must pass through WSOs including items such as fire weather.

Traffic: Depending upon the frequency of observations (every 3, 6, or 12 hours) and the size of the area of responsibility, traffic is variable. One expects at least several transmissions of forecast information to be received from the governing WSFO each day and probably a similar number of amassed data transmissions to the WSFO daily. Forecasts are issued to the media each 6- or 12-hour period and warnings would be issued irregularly.

Communications: The typical WSO has a teletype connection to its WSFO and local teletype service to the mass media. Data acquisition (possibly automated) teletype and telephone lines will also be present. Radar remoting capabilities are often available.

Relation to Planned Systems: The WSO is not a part of AFOS; it is linked to the WSFO (node) by teletype. WSOs will probably require the ability to access the DWS due to their warning responsibility.

B. 8 WEATHER SERVICE METEOROLOGICAL OBSERVATORY (WSMO)

Responsibility: The WSMO is responsible only for collection of data and the transmission of the data to the responsible WSO. The data may include temperature, precipitation, temperature/dewpoint spread, wind speed and direction, cloud coverage and heights, and temperature and wind data obtained from balloons or RAWINSONDES (radio-wind-sounding equipment carried aloft.) There are 312 National WSMOs (including the automated ones - AMOS), 300 FAA staffed stations and an additional 500 "supplementary" stations including supplementary aviation and Coast Guard stations.

Traffic: The traffic is variable with the responsibility of the station; aviation observations are taken hourly while synoptic or Coast Guard Stations generally take data every 3 or 6 hours.

Communications: Presently, there are local teletype and telephone lines from the to the WSOs.

Relation to Planned Systems: WSMOs will not be part of AFOS; it is planned to automate the taking of data to a greater extent in the future, however. WSMOs will probably also not be an integrated part of the DWS.

AUTOMATION OF FIELD OPERATIONS AND SERVICES

At NWS facilities such as WSFOs and WSOs, much activity is spent in the acquisition, handling, and dissemination of meteorological data; the reception, storage, retrieval, and utilization of synoptic guidance material; and the composition and dissemination of forecasts. Presently, most of this activity is done manually using hard copies of data and guidance material. The purpose of the Automation of Field Operations and Services (AFOS) is to automate these time consuming and menial tasks so that the meteorologists can more effectively perform their forecasting (and warning) functions. Based upon study results of the NWS operations, the use of decentralized automation was chosen to perform the collection and preprocessing of meteorological observations and storage, retrieval, display, and message composition support for the forecaster.

Conceptually, in the first stage (A) of AFOS, every WSFO, RFC, and National Center (node) will contain a minicomputer with random access mass storage discs driving a set of local interactive displays. A key AFOS concept is that each node will have access to all messages (observational data, forecasts, bulletins, graphics, etc.) between other nodes, and will store these messages that may be needed at their facility. One exception to this total access is whenever one facility requests data, that had previously been accessible but that it did not retain, from another facility.

The presently planned communication network for AFOS (stage A), the National Digital Circuit (NDC) consists of full duplex, voice grade land lines capable of carrying 2400 bits per seccond. The nodes will be serially connected and at each node the messages will be stored, checked for errors, acknowledge correct receipt or ask for retransmission, and then forwarded. For messages going to two or more nodes, the message is sent both directions on the serial loop and is terminated when received at a node from both directions. Messages sent to single node is sent via the shortest route. Since the NDC lines are voice quality, failure of a NDC link is circumvented by automatically dialing the commercial dial-up lines.

The second stage (B) of AFOS is the automation of the WSOs and their linkage to their parent WSFO. The degree of automation and the extent of communications will depend upon the particular WSO. But the WSO would be a spur from its WSFO rather than a part of the NDC loop.