NATIONAL AVIATION METEOROLOGICAL REQUIREMENTS
THROUGH 1975

This report has been approved for general distribution.

October 1961

FEDERAL AVIATION AGENCY
AVIATION RESEARCH AND DEVELOPMENT SERVICE

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It is difficult to conceive of a single area in aviation operations where more immediate benefits can be achieved than improved weather support. This document presents the requirements of aviation users for weather support through 1975; it also defines the areas in the aviation weather services where research, development, and testing are needed to reach an adequate level of service to users.

According to a Civil Aeronautics Board study during the five year period, 1953-1957, U. S. air transports, both domestic and international, were involved in 511 accidents. Of these, "weather" was a factor in 146, or 28.6 per cent. In the general aviation field, weather was stated as the cause for 1769 accidents during the years 1957 and 1958. During the same period, 9928 accidents were attributed to "pilot error", which was quite often the result of unexpected flight into adverse weather that the pilot was unable to handle. Many statistics point to the delays, diversions, and stacking of aircraft over airports during periods of bad weather, which are at least inconvenient and inefficient, if not hazardous.

Other statistics emphasize the fact that the growth of aviation operations and the problems of managing and controlling the air-space have far outreached the capabilities of our current aviation weather services. The curves in Figure 1 accent the disproportion

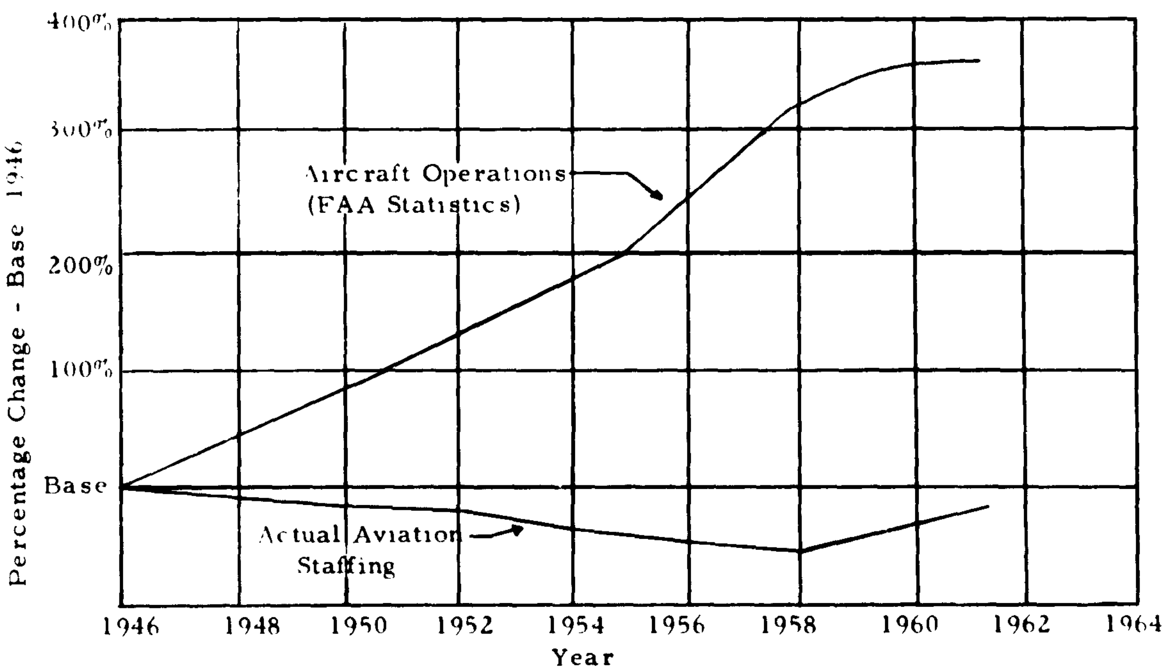

Figure 1 Aircraft Operations vs Staffing of Weather Bureau's Aviation Facilities (Reproduced with additional data from "Design for a Modern National Weather System", U. S. Weather Bureau, 1958)

between the growth in aviation operations and the staffing of the Weather Bureau's aviation weather service facilities through the period 1946 to 1961. Since the current aviation weather service is primarily manual, the staffing curve represents a slow decline in capability to satisfy aviation's demands for weather support.

The current aviation weather services developed during the last 35 years, as the aviation industry grew from infancy to a transportation giant. Continued growth, the expansion of operations to include supersonic transports and vertical take-off and landing craft, and the introduction of automated control systems to cope with increasing speeds and traffic densities are inevitable over the next 15 years. The disparity between aviation operations and the capability of the weather services, indicated in Figure 1, will tend to increase also.

As part of a comprehensive effort to insure the safe and efficient utilization of the national airspace, the Federal Aviation Agency conducted this requirements analysis. Its aims were to determine the weather information required by aviation operations through 1975, and to identify problem areas that exist in supplying this information. These goals were reached by the following process

- Identifying the weather information required to support air navigation and air traffic control and management operations through 1975.

- Determining the present capability of the aviation weather services to support current air navigation and air traffic control and management operations.

- Determining the areas in meteorological services that must be changed or developed to satisfy the operational requirements through 1975.

- Identifying those problem areas where "quick fix" improvements can be made and those needing research and development to meet operational requirements

For the purposes of this analysis, an operational information requirement was defined as any piece or group of meteorological information necessary for making decisions affecting aircraft utilization or airspace management

COMMON AVIATION WEATHER INFORMATION REQUIREMENTS THROUGH 1975

Users of meteorological information were divided into three major groups

- Airspace users
- Air traffic controllers
- Aviation meteorologists

The meteorological information they will require through 1975 is dependent upon the number and types of aircraft operating within this time period, the experience levels of pilots, the amount and complexity of air traffic control and the techniques employed by aviation meteorologists to generate operationally oriented forecasts and present them in an operational format.

REQUIREMENTS OF AIRSPACE USERS

It is not the affiliation of the pilot or his aircraft with general aviation, commercial-carrier or military aviation that determines their dependence on weather information, but the aircraft performance, the mission flown, the type of aircraft employed and the pilot's experience. Eight distinct types of aircraft use the available airspace Each type has typical performance characteristics that necessitate specific knowledge of meteorological conditions. The eight categories are defined in Table 1.

These categories of airspace users include not only the aircraft, but all aspects of its operation.

Table 1. Airspace User Categories

Category	Equipment and Use
A	Light, Single Engine Aircraft, visual flight rules (VFR) Low speed, short range and low altitude performance
B	Medium Range Transport, with IFR capability Single or twin engine type piston or turboprop powerplant, flying medium or short ranges at medium to low altitudes Some with pressurized cabin

Table 1. Airspace User Categories (Cont'd.)

Category	Equipment and Use
C	<u>Long Range Transport</u>, with IFR capability. Twin or multi-engine, piston or turboprop powerplant, flying medium to long ranges at medium altitudes. Pressurized cabin.
D	<u>Subsonic Jet Transport</u>, with IFR capability. Twin jet or multi jet powerplants, flying medium to long ranges at high subsonic speeds and medium to high altitudes. Pressurized cabin. Includes military turbojets.
E	<u>Supersonic Jet Transport</u>, with IFR capability. Long range, supersonic speed, high altitude. Operational in 1970. Includes military turbojets.
F	<u>Light Helicopter</u>, VFR. Single or twin piston or gas turbine engines, low speed, short range, near sea level cruising altitudes.
G	<u>Transport Helicopter</u>, with IFR capability. Single or twin piston or gas turbine engines, low speed, short range, sea level to low cruising altitudes.
H	<u>VTOL Aircraft</u>. Low to high subsonic speed, low to medium cruising altitudes with short to medium range. Expected to be in military operation about 1965.

Each category was analyzed to determine all the activities comprising its operation. A common operational profile resulted, and the activities within it were grouped into six operational functions. The functions and activities listed in Table 2 accomodate all aircraft categories.

Table 2. Operations Profile for Airspace Users

Functions	Activities
Ground Operations	Activities which support pre-flight operations, such as aircraft maintenance and repair.
Advanced Planning	Activities which establish desired routes, altitudes, schedules and flight procedures, including preparation of flight plans.
Pre-Flight Planning	Activities just before take-off that verify the appropriateness of flight plans in terms of equipment performance and weather.

Table 2 Operations Profile for Airspace Users (Cont'd.)

Functions	Activities
Take-off and Climb	Activities from starting the aircraft engines to establishing cruise conditions at altitude.
Enroute	Activities within all cruise phases, from the initial level-off to descent from cruise altitude
Approach and Landing	Activities from the termination of the enroute phase through shutdown of engines in the parking area.

Activities in the operational profile were examined to identify those decisions in which weather information is a factor The decisions utilizing weather information were isolated and analyzed further to determine the specific information required. If a change in weather information could affect the decision, the weather information was taken as a factor in the decision. Finally, the characteristics of each piece of necessary weather information were described For each decision influenced, the study determined

- The nature of the required weather information
- The three-dimensional volume the weather information must cover
- The time period for which the information must be accurate

The requirements of airspace users identified and described through this method are summarized in Table 3

Table 3 Summary of Meteorological Requirements of Airspace Users Through 1975

Information Required	Area Covered	Time Period
Prevailing visibility, cloud base, surface wind speed and direction	airport surfaces	2-5 min
Terminal area ceiling, visibility and wind	terminal area	0-1 hr. local 0-12 hr. nationwide
Cloud bases over runways and approach/departure paths	controlled terminals	0-1 hr., all terminals
Slant range visibility along approach paths and runway visual range (RVR)	controlled terminals	0-1 hr., all terminals
Cloud lines and areas containing hazards (hail, turbulence)	as required	0-12 hr
Wind and temperature in significant regions over approach paths and runways from surface to 800 ft	approach paths and runways	0-12 hr.
Area cloud distribution through airspace	as required	0-12 hr., all airspace
Temperatures in departure airspace	departure area	2-5 min
Winds and temperatures aloft, flow patterns over nation at operating levels, 5, 10, 15, 20, 30, 40, 60, 80 thousand feet	all airspace	0-24 hr
Storm centers and associated frontal positions with hazardous weather description	as required	0-12 hr 0-24 hr
Fronts on surface and aloft, distribution nationwide of highs and lows	as required	72, 48, 24 hr

REQUIREMENTS OF AIR TRAFFIC CONTROL

The weather information required by air traffic controllers is determined by its effect on the safe and efficient utilization of the airspace. Safety results from keeping known traffic separated, and efficiency results from following flow control procedures. The aviation weather information required, therefore, was derived from an analysis of all functions through 1975 that will contribute to the separation of aircraft and the control of air traffic flow. The characteristics of air traffic control operations projected through 1975 are.

- Positive air traffic separation will be maintained through an organization dividing the U.S. into five or six regions, each region comprising three to five aviation areas, and each area comprising ten sectors. This division will facilitate continuous control of flights anywhere in the United States.

- Airspace will be divided into an upper zone where all traffic will be controlled, and a lower zone where VFR and IFR aircraft will be positively controlled in the approach and departure areas and in the corridors connecting these areas with assigned flight paths.

- Computers will process and store flight plan information and automatically display conflicts to the controller.

The projected air traffic control system was analyzed to determine all operational activities and the functions to which they are related. The result of this analysis is the operational profile presented in Table 4. Managing and controlling activities were grouped separately.

Table 4. Operations Profile for Air Traffic Controllers/ Managers

Function	Activities
<u>Controlling</u>	
Ground traffic	Directing aircraft movement on airport surfaces; assigning runways, issuing departure and route clearances
Departing traffic	Directing aircraft from take-off paths to flight paths; monitoring flight progress, requesting further information regarding pilot's intentions, modifying initial clearances, transferring control to other controllers.
Enroute traffic in lower zone	Directing aircraft within approach and departure areas and corridors connecting these areas with assigned flight paths; requesting position information, resolving conflicts, establishing sequence for arriving aircraft, handling emergencies.
Enroute traffic in upper zone	Directing all aircraft above a certain altitude between terminal areas; continuous monitoring of aircraft, changing flight paths to avoid conflicts, establishing sequence of arriving aircraft, transferring control to lower zone controller
Approaching traffic	Directing aircraft from flight paths to landing paths; continuous directing of aircraft, issuing clearances for sequencing arrivals and maintaining separation, transferring control to local controller.
Local traffic	Directing aircraft in take-off and landing pattern and in the immediate terminal vicinity; monitoring aircraft progress, issuing advisory messages and emergency clearances to maintain separation.
<u>Managing</u>	
Flight assistance service	Aiding airspace users encountering unforeseen conditions; information and advice for aircraft operation.
Supervision	Scheduling the staff and maintaining the equipment.
System Planning	Establishing policies, regulations and procedures for the use of the airspace and airports, and for the installation of facilities.

All the operational decisions made within these activities were identified and those influenced by weather information isolated. If the decision could employ weather information to eliminate or minimize any potential consequences to safe, orderly and efficient use of the airspace, that weather information became a requirement.

Each decision influenced by weather information was further examined to identify the particular information required. For each decision influenced, the study determined:

- The nature of the required weather information
- The three-dimensional volume the weather information must cover
- The time period for which the information must be accurate

The meteorological requirements of air traffic controllers/managers identified and described through this method are summarized in Table 5

Table 5. Summary of Meteorological Requirements of the Air Traffic Controllers/Managers

Information Required	Area Covered	Time Period
Prevailing visibility, cloud base, surface wind speed and direction	airport surfaces	2-5 min
Terminal area ceiling, visibility, and wind	terminal area	0-1 hr. local 0-12 hr. nationwide
Cloud bases over runways and approach/departure paths	controlled terminals	0-1 hr. 0-12 hr.
Slant range visibility along approach paths and runway visual range (RVR)	controlled terminals	0-1 hr. 0-12 hr.
Cloud lines and areas containing hazards (hail, turbulence)	terminal area and enroute	0-12 hr.
Wind and temperatures in significant regions over approach paths and runways from surface to 800 feet	approach paths, runways	0-12 hr.
Area cloud distribution through airspace	all airspace	0-12 hr.
Temperatures within departure airspace	terminal area	0-5 min.
Winds and temperatures aloft, flow patterns over nation at operating levels, 5, 10, 15, 20, 30, 40, 60, 80 thousand feet	all airspace	0-24 hr.
Storm centers and associated frontal positions with hazardous weather description	terminal area	0-12 hr.
Climatological history; wind direction and velocity, occurrence of instrument flight rules (IFR) conditions (ceiling and visibility)	nationwide, enroute and terminal areas	previous 20 years; previous 5 years with seasonal changes

REQUIREMENTS OF AVIATION METEOROLOGISTS

Aviation meteorologists are the third user of weather information. They are the analysts and forecasters who prepare operational information and the briefers who present it to the operational users. They require raw and processed observations of weather conditions.

The information that meteorologists will require through 1975 was identified from an analysis of their projected capability and functions. Capabilities were projected from information on anticipated techniques and equipment. The outstanding features in the projection are:

- Unification of the aviation weather service into a common aviation weather system with the fundamental purpose of providing weather information that is meaningful and useful in the operational situations of airspace users, air traffic controllers and managers. The system will generate and transmit information applicable to particular localities, to small and large areas of the continental United States, and to the entire continent.

- Improvement in the accuracy and detail of operational products through the use of computing machines and objective mathematical formulations. Computers will aid the meteorologist in generating analyses of both surface and upper air conditions directly from observational data. They will produce automatic forecasts of atmospheric conditions, and will average certain parameters which display a high degree of variability, such as winds and turbulence.

The products of the meteorologist will continue to be messages and charts. The time and space scales of analyses and forecasts will be governed by requirements of operational users. For each spatial scale, they will prepare forecasts that are useful within an appropriate length of time. To prepare the forecasts, the aviation meteorologist will require direct observations that allow him to analyze weather conditions within the time and space in which he works and also to analyze the next larger scale of atmospheric motions. Although his major function will continue to be forecasting, he will also analyze and interpret weather information for operational users. The functions he will perform according to the time and space scales required and his analyses and interpretation functions are presented together in Table 6.

Table 6. Operations Profile of Aviation Meteorological Activities through 1975

Function	Activities
Local forecasting	Preparing or revising specific forecasts of weather conditions for the next hour with an area of some 30 miles around terminals.
Area forecasting	Predicting the specific weather conditions for the next 24 hours over roughly five percent of the continental U.S.
Regional forecasting	Predicting the general weather conditions for the next 36 hours over roughly 20 percent of the continental U.S.
National forecasting	Predicting the general weather conditions for 96 hours to one week over all the continental U.S. and the northern hemisphere.
Aviation briefing	Synthesizing and interpreting meteorological information.
Pilot-to-forecaster service	Rendering weather advice requested by pilots in flight encountering unforeseen weather conditions.
Climatological service	Predicting distribution of weather conditions for the next 20 years on the basis of accumulated records.

These functions and activities provide the weather information required by the operational users. To prepare operational information in each of these functions, the aviation meteorologist requires raw and processed observations, analyses and forecasts. In order to provide pilots and controllers with forecasts of cloud height and amounts, for example, the aviation meteorologists requires raw observations of temperature, pressure, and wind, and also processed observations -- analyses and forecasts -- of these elements. Much of the information required by the meteorologist is seldom of use to the pilot or air traffic controller.

The raw and processed data required by the aviation meteorologist were identified from the products he must generate in order to satisfy the operational users. The observations, analyses, and forecasts that he requires for his products are summarized in Table 7, which states:

- The kind of information required
- The parameters required in each kind of information
- The geographical area each kind of information must cover

Table 7. Summary of Information Required by Aviation Meteorologists through 1975

A. Observations		
Meteorological Information Required	**Parameters**	**Area Covered**
Local observations	Clouds Visibility Surface winds Prevailing weather Temperature Dew point Station pressure Runway conditions	Airport and terminal area
Upper air observations	Geometric altitude Pressure altitude Temperature Dew point Wind speed and direction Ozone content Refractive index	Northern hemisphere
Enroute conditions	Turbulence Icing Precipitation Clouds Visibility	Continental U.S.

Table 7. Summary of Information Required by Aviation Meteorologists through 1975 (Cont'd.)

B. Analyses		
Meteorological Information Required	Parameters	Vertical Coverage
Surface analyses	Pressure Wind Prevailing weather Clouds Temperature Dew point Precipitation Frontal structures High and low pressure areas	Surface
Operationally significant weather	Clouds Precipitation Visibility Fronts Turbulence Icing Thunderstorms Tornadoes Hurricanes	Surface to 60,000'
Winds and temperature aloft	Three dimensional wind and temperature fields; Height and temperature of tropo-pause	Surface to 100,000'
Constant pressure surface analyses	Wind and temperature contours at constant pressure levels	Surface to 100,000'
Vorticity charts	Computed and contoured charts of vorticity fields	18,000 feet (500 mb)
Vertical motion charts	Computed and contoured charts of vertical motion fields	10,000 feet (700 mb) and 18,000 feet (500 mb)

Table 7. Summary of Information Required by Aviation Meteorologists through 1975 (Cont'd)

C. Forecasts		
Meteorological Information Required	Parameters	Vertical Coverage
Terminal forecasts	Surface wind Temperature Dew point Visibility Clouds Prevailing weather Altimeter setting Runway conditions Flight hazards	Surface
Surface prognoses	Pressure distribution Storms Fronts Clouds and precipitation areas	Surface
Clouds and precipitation forecasts	Cloud bases, tops, amounts Precipitation area showing type and intensity	Surface to 60,000 feet
Icing and turbulence forecasts	Structural icing and turbulence; showing location; vertical extent; and intensity	Surface to 100,000 feet
Wind-temperature forecasts	Three-dimensional wind and temperature fields, layer of maximum wind, height and temperature of tropopause	Surface to 100,000 feet
Constant pressure surface prognoses	Contoured values of wind and temperature fields at constant pressure levels	Surface to 100,000 feet
Vorticity and vertical motion prognoses	Projected fields of vorticity and vertical motion	18,000 feet (500 mb)

COMMON WEATHER INFORMATION REQUIREMENTS

To arrive at a single compilation of the weather information required by all elements in the aviation-meteorology complex, the specific requirements of airspace users, air traffic controllers/managers, and aviation meteorologists were combined. All the weather elements identified as requirements in all three groups were compared to determine those existing in common. In most instances, the same parameters are required by the three groups, even though the characteristics of the time and space coverage might vary.

The weather parameters were arranged according to the operational or meteorological functions in which they will be used. Each parameter was aligned with each operational or meteorological function determined for airspace users, controllers/managers, and aviation meteorologists. Commoness was ascertained by simply checking all the categories in which each element was required. Once the parameters were matched with the operational and meteorological function requiring them, they were placed into more specific categories of usefulness.

First, the parameters were grouped according to the time period for which the particular information must be valid. The time periods and examples of the decision situation are:

2-5 minutes -- decision to land or take-off

0-1 hour -- decision to descend from flight altitude or divert to an alternate terminal

0-12 hours -- decisions in planning specific flights, including selection of destination and alternate terminals

12-24 hours -- decisions in planning the next day's operations

1-7 days -- decisions in general planning and scheduling

Since the decisions of operational users always concern events that are about to happen, these users will always require forecasts. They will use observations as forecasts only for very short time decisions.

The decision-time categories were then assigned forecast periods and these were divided into terminal and enroute information as appropriate. A separate category was introduced -- upper air data -- because of the different nature of the observing and processing functions. Enroute conditions refer primarily to discontinuously distributed parameters that are observed by eye, radar, or aircraft response while the upper air data refers to the continuously distributed state parameters which are sampled at fixed points on a fixed time schedule.

All the operational information required is contained in eight packages designed for airspace users and air traffic controllers/managers. The content and general characteristics of the packages are shown in Table 8. The following definitions are employed

Terminal -- weather elements affecting the operation of aircraft while landing, taking off, departing, and approaching; such as surface wind, ceiling, visibility, prevailing weather at the airport and flight hazards within 30 miles of the airport.

Enroute -- weather elements affecting the safety or efficiency of flight; such as cloud distribution, icing, turbulence, precipitation.

Decision period -- the operational time for which the decision is made.

Contents -- the general identification of the information in the package.

Updating time -- the frequency of issue of the package.

Forecast period -- the time for which the information in the package is accurate or valid.

Distribution -- the area for which the information is accurate or valid and in which the information is disseminated.

Table 8. Packages of Common Aviation Weather Requirements Through 1975

Operational Packages	Decision Period	Contents	Updating Time	Forecast Period	Distri-bution
Basic Airway Observations	2-5 min	Terminal conditions and terminal area flight hazards	5 min	---	100 min
0-1 hour terminal forecast	0-1 hr	Terminal conditions and terminal area flight hazards	20 min	1 hr	500 min
0-12 hour terminal forecast	1-12 hr	Terminal conditions and terminal area flight hazards	3 hr	12 hr	Nation-wide
0-12 hour enroute forecast	1-12 hr	Enroute conditions and flight hazards	3 hr	12 hr	Nation-wide
0-24 hour terminal forecast	12-24 hr	Terminal conditions and terminal area flight hazards	6 hr	24 hr	Nation-wide
0-24 hour enroute forecast	12-24 hr	Enroute conditions and flight hazards	6 hr	24 hr	Nation-wide
0-24 hour upper-air forecast	0-24 hr	Winds and temperatures aloft	6 hr	24 hr	Nation-wide
Weekly outlook	1-7 days	General weather conditions, precipitation and temperature irregularities; forecasts of winds for 24-96 hours	1 day	7 days	Nation-wide

These packages of required weather information impose performance requirements on the proposed common aviation weather system and its subsystems which will be designed to satisfy them. They impose requirements in observing, processing and presenting the information, and in communicating it within the system and to the ultimate users. The required characteristics of these major functions are shown in Table 9.

Table 9. Required Subsystem Characteristics

Presenting

Basic Air Obs.	0-1hr. Term. F/C	0-12hr. Term. F/C	0-12hr. Enroute F/C	0-24hr. Term. F/C	0-24hr. Enroute F/C	Upper Air F/C	Weekly Outlook	Facility	Activity Supported	Display Mode	Information Type
X	X	X	X	X	X	X	X	Meteorological Data Processing Facility	Facility Briefing/ ATC Center	Visual-Auditory	Code, numerical, plain text, graphic
		X	X		X	X	X	Meteorological Data Processing Facility	Recorded Telephone Briefing	Auditory	Code, numerical, plain text.
	X	X	X	X	X	X	X	Meteorological Data Processing Facility	Forecaster Telephone Briefing	Auditory	Code, numerical, plain text.
	X		X			X		Meteorological Data Processing Facility	Continuous Radio Broadcast	Auditory	Code, numerical, plain text.
X	X	X	X		X			Meteorological Data Processing Facility	Pilot-to-Forecaster	Auditory	Code, numerical, plain text.
X	X	X	X	X	X	X	X	Ground Briefing Facility	Facility Briefing	Visual-Auditory	Code, numerical, plain text, graphic
	X	X	X	X	X	X		Ground Briefing Facility	Telephone Briefing	Auditory	Code, numerical, plain text
X	X	X	X		X			Ground Briefing Facility	Airborne Briefing-in-flight request	Auditory	Code, numerical, plain text
X	X							Ground Briefing Facility	Airborne Briefing Arrival	Auditory	Code, numerical, plain text
X	X	X	X					Tower	ATC Local Control	Visual-Auditory	Graphic, alpha-numeric, text

Table 9. Required Subsystem Characteristics
Presenting (Cont'd.)

Message Type: Basic Air Obs.	0-1 hr. Term. F/C	0-12 hr. Term. F/C	0-12 hr. Enroute F/C	0-24 hr. Term. F/C	0-24 hr. Enroute F/C	Upper Air F/C	Weekly Outlook	Facility	Activity Supported	Display Mode	Information Type
X	X							Tower	ATC Ground Control	Visual-Auditory	Graphic, alpha-numeric, text
X	X	X	X			X		Center	ATC Enroute Control	Visual-Auditory	Graphic, alpha-numeric, text
X	X				X			ATC Center	ATC Transition Control	Visual-Auditory	Graphic, alpha-numeric, text
X	X							ATC Center	ATC Terminal Control	Visual-Auditory	Graphic, alpha-numeric, text
X	X				X			ATC Center	ATC Departure Control	Visual-Auditory	Graphic, alpha-numeric, text
X	X							ATC Center	ATC Precision Approach	Visual-Auditory	Graphic, alpha-numeric, text
X	X	X	X					ATC Center	ATC Tower	Visual-Auditory	Graphic, alpha-numeric, text

Table 9 Required Subsystem Characteristics (Cont'd.)

Processing

Product	Product Content	Updating Time	Product Time Increments
Processed Observational Information	Prevailing weather, frontal passages, terminal area flight hazards, user feedback	5 minutes	-----------
0-1 hr. Terminal Forecast	Surface wind, cloud base and top, visibility, (Prevailing, slant, runway), temperature dew point, weather, fronts, altimeter setting, runway conditions, flight hazards	20 minutes	20 minutes
0-12 Hour Terminal Forecast	Surface wind, clouds, visibility, significant weather, temperature, frontal passages, runway conditions, flight hazards	3 hours	3 hours
0-12 Hour Enroute Forecast	Weather synopses, enroute information on cloud, visibility, icing, turbulence, precipitation, storms and fronts	3 hours	3 hours
0-24 Hour Terminal Forecast	Surface wind, clouds, visibility, significant weather, temperature	6 hours	6 hours
0-24 Hour Enroute Forecast	Weather Synopses, enroute information on clouds, visibility, icing, turbulence, precipitation, storms and fronts	6 hours	6 hours
Upper Air Forecasts	Wind and temperature analyses and forecast - Constant pressure surface analyses and forecasts. Vertical motion and vorticity programs for meteorological use.	6 hours	6 hours
Weekly Outlook	Major weather patterns, precipitation and temperature fields. Upper air progress charts of wind and temperature at constant pressure levels.	24 hours	24 hours

Table 9 Required Subsystem Characteristics (Cont'd.)

Observing - Surface

Parameter	Units	Instrument Range	Instrument Accuracy	Instrument Resolution	Reporting Resolution	Reporting Mode
Temperature-Runway	°F	-50 to +120	±1	.5	1	10 min. avg.
Temperature-Surrounding Water	°F	+29 to +90	±1	.5	1	Inst.
Pressure	Millibar	670 to 1080	±.1	.05	.1	Inst.
Pressure Tendency	Millibar/3 hr.	±10	±.1	.1	.1	3 hr. change
Altimeter Setting	Inches/Hg.	20 to 32	±.01	.005	.01	Inst.
Wind Direction - Runway	Degrees	0-360	±10	2	10	10 min. avg. +2σ value
Wind Speed-Runway	Knots	0-150	±1	.5	1	10 min. avg. +2σ value
Wind Speed-Runway Components	Knots	0-100	±1	.5	1	10 min. avg. +2σ value
Precipitation-Type	Name code	Rain, snow, hail, drizzle, sleet	Type	Type	Type	Occurrence
Total and Rate	Inches-H_2O	0-10	±.01	.01	.01	Total, past hour
Precipitation- Area (includes precipitation frontal passage)						
Extent						
Position	Miles	0-250	±1	1	1	Inst.
	Degrees	0-360	±5	1	5	Inst.
Extent	Miles	0-100	±5	1	5	Inst.
Altitude	Feet	0-60,000	±1000	500	1000	Inst.

Table 9 Required Subsystem Characteristics
Observing - Surface (Cont'd.)

Parameter	Units	Instrument Range	Instrument Accuracy	Instrument Resolution	Reporting Resolution	Reporting Mode
Movement						
Direction	Degrees	0 360	±10	5	10	Inst.
Speed	Knots	0-60	±5	2	5	Inst
Type	Type	Hail, rain, snow	Type	Type	Type	Inst.
Rate	Inches H_2O/hr.	0-4	± 01	01	.01	Inst. +1 hr. integral
Precip Cloud Type	Type	Type	---	---	Type	Inst.
Snow Depth	Inches	0-30	±1	1	1	Inst.
Runway Conditions -						
Precip. Type	Name	Type	Type	Type	Type	Inst.
Precip Depth	Inches	0-30	± 1 to 1	.1 to 1	.1 to 1	Inst.
Braking Conditions	Relative	0-10	±1	1	1	Inst.
Runway Visual Range	Feet	0-6000	±100	25	100	10 min. avg. +2σ value
Slant Range Visibility	Feet	0-12000	±500	50	500	10 min. avg. +2σ value
Obstructions to Vision Type	Type	Haze, fog, sand, dust, smoke	Type	Type	Type	Inst.
Prevailing Visibility	Miles	0-3	± 1	.1	.1	Inst.
		3-10	±1	1	1	Inst.
		10	±5	5	5	Inst.
Dew Point	°F	-50 to +90	±1	.5	1	10 min. avg.
Clouds-Type	Name code	Type	Type	Type	Type	10 min.avg. +2σ value
Bases	Feet	0-1500	±50	25	100	Inst.
		1500-24,000	±150	100	500	Inst.
		24,000	±500	250	1000	Inst.
Tops	Feet	0-1500	±100	50	200	10 min. avg. +2σ value

Table 9 Required Subsystem Characteristics
Observing-Surface (Cont'd.)

Parameter	Units	Instrument Range	Instrument Accuracy	Instrument Resolution	Reporting Resolution	Reporting Mode
Tops (cont'd.)	Feet	1500-24,000	±200	100	500	10 min. avg. $+2\sigma$ value
		24,000	±500	200	1000	10 min. avg. $+2\sigma$ value
Severe Storm Detection-Vector Position	Miles	0-100	±1	1	1	Inst.
	Degrees	0-360	±10	5	10	Inst.
Int. Winds	Knots	0-200	±5	2	10	Inst.
Altitude	Feet	0-60,000	±1000	500	1000	Inst.

Table 9. Required Subsystem Characteristics (Cont'd.)
Observing - Upper Air

Parameter	Units	Instrument Range	Instrument Accuracy	Instrument Resolution	Reporting Resolution	Reporting Mode
Temperature - All Altitudes	°C	-90 to +50	±.5	.1	.1	Inst.
Low Level Profile	°C	-45 to +50	±1	.1	.1	Inst.
Pressure Altitude	Feet	0-100,000	±20→1000	5→250	100→1000	Inst.
Wind - Direction	Degrees	0-360	±10	2	10	Inst.
Speed	Knots	0-200	±5	1	1	Inst.
Low Level Profile Direction	Degrees	0-360	±10	5	10	10 min. avg. +2σ value
Speed	Knots	0-100	±2	1	1	10 min. avg. +2σ value
Vertical Shear	Knots/1000'	0-20	±1	.5	1	Inst.
Horizontal Shear	Knots/10mi.	0-10	±1	.5	1	Inst.
Dew point	°C	-90 to +50	±1	.5	1	Inst.
Turbulence - (Equivalent normal gust)	feet/sec	80	±5	1	1	Inst.
Position	Miles	200	±10	5	10	Inst.
Altitude	Feet	0-60,000	±1000	50	1000	Inst.
Icing Rate	Inches/min	0-1	±.05	.1	.1	Inst.
Refractive Index	N numbers	0-500	±2	1	1	Inst.
Ozone Content	Parts/million	0-10	±.4	.05	.1	Inst.
Weather Radar or Visual -						
Clouds - Tops	Feet	0-60,000	±1000	500	1000	Inst.
Type	Type	Type	---	---	Type	Inst.
Severe storm forms	Type	Type	---	---	Type	Inst.
Extent	Miles	0-100	±10	10	10	Inst.

Table 9 Required Subsystem Characteristics
<u>Observing</u> - Upper Air (Cont'd.)

Parameter	Units	Instrument Range	Instrument Accuracy	Instrument Resolution	Reporting Resolution	Reporting Mode
Precipitation- Type	Type	Rain, hail, snow	Type	---	Type	Inst.
Intensity	Relative	0-10	±1	1	1	Inst.
Location- Miles from check point	Miles	0-200	±10	5	10	Inst.
Density	GM/M^3	10^{-2} to 10	$\pm 10^{-3}$ to 10^{-1}	10^{-3}	10^{-3}	Inst.
Obstructions to Vision- Type	Fog, Haze, Smoke, Dust	Type	---	---	Type	Inst.
Prevailing Visibility	Miles	0-3	±.1	.1	.1	Inst.
		3-10	±1	1	1	Inst.
		10	±5	5	5	Inst.

Table [illegible] Required Subsystem Characteristics (Cont'd)

Communications

Teletype	Graphics	Telephone	Radio	Video	Oral	Written	Subsystem Supported	Message	Sent From	Sent To	Distribution Extent	Transmission Speed
X			X				Observing	Surface Observations	Observing Sites	Data Processing/User	Local	100 wpm
X								Upper Air Obs.	Observing Sites	Data Processing	Local	100 wpm
X				X				Weather Radar Reports	Observing Sites	Data Processing	Local	100 wpm (TWX)
		X		X	X			PIREPS	Pilots in flight	Collection Site	Local	120 wpm
		X						Satellite Obs	Satellites	RCVR/ Processing	Local	100kc BW 10 mc BW
		X	X		X	X		User Feedback	Ground Users	Data Processing	Local	120 wpm
X							Processing	Synoptic messages	Obs/Proc. sites	Data Processing	Nationwide	100→1000wpm
X	X							Radar and PIREP summaries	Data Proc.	Data Processing	Nationwide	100→1000 wpm
X	X							Analyses and Forecasts	Data Proc.	Proc. / Presentation	Local→ Nationwide	100→1000wpm
X								Comp. to Comp. Relay	Data Proc.	Data Processing	Special Circuit	1000 wpm
							Presenting	Facility Briefing -				
X			X	X				Present conditions	Obs. Sites	Presentation	Local	100 wpm
		X						Phone link to F/C	Presentation	User	Local	120 wpm
				X				TV link to F/C	Presentation	User	Local	3mc. BW

Table 9. Required Subsystem Characteristics (Cont d.)

Communications

Teletype	Graphics	Telephone	Radio	Video	Oral	Written	Subsystem Supported	Message	Sent From	Sent To	Distribution Extent	Transmission Speed
X	X						Presenting	Forecasts	Presentation	User	Local ⟶ Nationwide	100 wpm 120 scan/min.
		X						Telephone Briefing	Presentation	User	Local	120 wpm
			X					Pilot-to-Forecaster link	Presentation	User	Local ⟶ Area	120 wpm
			X					Continuous weather broad-casts	Presentation	User	Local ⟶ Area	120 wpm
								Air Traffic Control System Support-				
X	X							Usable Air-space	Data Process-ing	Presentation	Local ⟶ Nationwide	100 wpm 120 scan/min.
X	X			X				Terminal, Enroute	Presentation	User	Local ⟶ Nationwide	3 mc. BW(TV)

PROPOSED SOLUTIONS TO PROBLEM AREAS

The requirements of aviation for weather support through 1975 were compared with the capabilities of the existing service. As a result of this comparison, deficiencies were isolated and grouped into problem areas. Feasible solutions to specific problem areas were then determined. The solutions advanced are legislative, procedural, or technical.

Table 10 is a compilation of the major problem areas, specific deficiencies, and feasible solutions. These are presented first for the total system and then for each subsystem. A priority is assigned to each solution based upon the following criteria:

Priority 1 - Solution imperative now

Priority 2 - Solution required now, imperative by 1964

Priority 3 - Solution required by 1975

Implementation of a common aviation weather system with maximum speed and economy requires a well integrated approach to system design. Actual system design time phasing depends not only upon the technical development of components of the system, but also upon total system development and adequate funding. Therefore, the time phasing of feasible technical solutions should be related to a total system plan. Table 11, the Master Phasing Plan for the Common Aviation Weather System, presents our estimate of a feasible development schedule based upon.

- Technical feasibility of specific solutions
- Feasible time phasing of specific solutions into total system development

Table 10. Summary of Major Problem Areas

Aviation Weather System

Problem Areas	Specific Deficiencies	Feasible Solutions
Transferring meteorological information from the aviation weather system to operational users	Non-standardized presentation procedures, situations, and formats	Nationwide standardization of presentation procedures, situations, and formats
	Presentation in formats, and terms not understood by operational users	Development of standardized formats giving meteorological information in terms having operational significance to users
	Inadequate separation of operational and weather services information on communication links	Separate communication distribution systems (alpha-numeric & graphic) for weather services and operational users
Producing forecasts with sufficient detail and accuracy to satisfy requirements of operational users	Lacks forecast models available to produce accurate and detailed short-term forecasts	Development of objective forecast models employing: dynamic equations empirical equations statistics and probability with provision for real-time updating by means of observations and user feedback data
	Lacks forecast models available to produce accurate and detailed area and regional forecasts	
	Insufficient processing time available for all-manual processing meeting user requirements	Use of machine computing aids with objective forecast models. Interpretation and initial conditions insertion by human
Acquiring sufficiently detailed and timely meteorological data for processing into products for operational users	Inadequate vertical coverage	Improved balloon and rocket sounding vehicles; systematized reporting from aircraft
	Inadequate horizontal coverage, including ocean areas contiguous to U.S.	
	Inadequate accuracy, representativeness	Augmented surface and upper air sounding networks. Upper air observations from ships at sea.
	Insufficient parameters sampled	

Table 10. Summary of Major Problem Areas

Aviation Weather System (Cont'd.)

Problem Areas	Specific Deficiencies	Feasible Solutions
	Delays in transporting data to processing facilities	Improved observing instrumentation, including radar. Standardized sampling procedures, more frequent observations. Development of techniques for sampling; important examples are slant range visibility, clear air turbulence Collect all meteorological data on single high speed, communication network. Transfer large amounts of data in graphical form where possible.

Table 10. Summary of Major Problem Areas (Cont'd.)

Presenting Subsystem

Problem Areas	Specific Deficiencies	Feasible Solutions	Priority
Procedures for presentation to operational users	Lacks standard procedures for presentation	Create standardized presentation procedures for nationwide use	1
	Lacks standard situations for presentation	Limit variety of presentation situations to a small number, each associated with a particular type of facility e.g., FSS	1
Formats for presentation to operational users	Lacks standard formats for alpha-numeric presentation	Nationwide standardization of alpha-numeric presentation formats and modes	1
	Lacks standard formats for graphic presentation	Nationwide standardization of graphic presentation formats and modes	1
	Lacks hard-copy alpha-numeric presentations	Provide copies of selected Service A transmissions to users	2
	Lacks hard-copy graphic presentations	Provide copies of selected operational facsimile products to users	2
Training of operational users in use of meteorological data	Lacks training of procedures for training operational users in use of specific products	Brief orientations courses in detail necessary to suit specific users' needs; includes general aviation and ATC/M	2
	Lacks training or procedures for training general aviation or ATC/M system in significance of meteorological information	Brief courses explaining operational significance of meteorological information, and its use in optimizing particular user's operations.	1

Table 10 Summary of Major Problem Areas (Cont'd)

<u>Processing Subsystem</u>

Problem Areas	Specific Deficiencies	Feasible Solutions	Priority
Meteorological forecasting techniques	Lacks objective technique for short period (0-1 hr) terminal forecasts	Development of forecast models based upon dynamic equations empirical equations statistical probability	1
	Lacks adequate technique for detailed area forecast	Development of forecast models based upon dynamic equations empirical equations	1
	Lacks adequate technique for detailed regional forecasts	Development of forecast models based upon dynamic equations	1
	Insufficient detail in upper-air forecasts	Further refinement of dynamic models presently used for machine processing	2
Use of meteorological feedback data from users	Lacks adequate input data filtering or value assessment technique	Standardized feedback reporting format including time and place of observation	1
	Lacks technique for objective insertion of feedback data into forecast mathematical models	Development of forecast models based upon dynamic equations with provision for taking differences and derivatives of stored forecast data and observed data	1
Forecast product content	Little information directly useful for presentation to operational users	Restructure output products in terms meaningful to operational user; information does not necessarily change, but units, ranges of values etc. will change	1

Table 10. Summary of Major Problem Areas

Processing Subsystem (Cont'd.)

Problem Areas	Specific Deficiencies	Feasible Solutions	Priority
	Insufficient detail in forecasts especially discrete hazards and weather development	Development of forecast models based upon dynamic equations and including at least two derivatives of variables to handle accelerating systems	1

Table 10. Summary of Major Problem Areas

Observing Subsystem

Problem Areas	Specific Deficiencies	Feasible Solutions	Priority
Manual measurement techniques	Present procedures do not result in representative parameter measurements	Establish procedures which result in representative parameter measurements. For example, wind speed value should result from a 10 minute sampling with average and max. deviation noted. Both avg. and 2σ value should be reported regardless of absolute value	1
Automatic measurement techniques	Wind speed and direction measurement-are: Not representative Lacks detail of coverage	Determine 10 min. avg. and 2σ value of both speed and direction. Instruments located at operationally significant geographical points with adequate exposure. Applies to upper-air aircraft reports of winds. Additional balloon and rocket launching stations, particularly in Western U.S., Pacific Ocean and Mexico.	1
	Slant range visibility measurement technique	Research in techniques of direct slant range measurement. Perhaps employ laser principle for sampling source	1
	Cloud base measurement representative value	Determine 10 min. avg. and 2σ value	1
	Severe storm detection technique	Continued research in pulsed, pulsed doppler and CW/FM doppler radar	1

Table 10. Summary of Major Problem Areas

Observing Subsystem (Cont'd)

Problem Areas	Specific Deficiencies	Feasible Solutions	Priority
Automatic measurement techniques (cont'd.)	Clear air turbulence detection technique	Continued research in atmospheric processes and techniques for direct detection	2
	Air and dew point temperature measurement- Not representative	Applies to surface Determine 10 min. avg. + 2σ value	2
	Lacks accuracy at high altitude	Sensor development to eliminate radiation and low temperature effects	2
	Ozone content measurement technique	Continued development of ozone sensors for balloon, rocket and aircraft	2
	Refractive index measurements - lack detail of coverage	Continued development of refractive index sensors for balloon, rocket and aircraft	3
	Air density measurements lack detail of coverage	Initiation of synoptic measurement network located with balloon launching stations	3
	Radar weather observations - lack detail of coverage	Extend weather radar observing network to western U.S.	1
	Icing and turbulence measurement technique	Research in techniques of objective methods of airborne measurement of icing and turbulence.	1

Table 10. Summary of Major Problem Areas

Communication Subsystem

Problem Areas	Specific Deficiencies	Feasible Solutions	Priority
Available communication links	Lacks civil pilot-to-forecaster link	Nationwide implementation of VHF pilot-to-forecaster service on single allocated frequency. (P-F system currently under test at Kansas City and Washington, D.C.)	1
	Lacks operational facsimile circuit	Create separate facsimile circuits for operational users, requires splitting present circuit into weather services and operational users circuits	2
	Lacks means of effective local dissemination of operational (Service A) alpha-numeric products to generate aviation users	Distribution via radio link (L/MF or commercial radio frequencies) of Service A teletype coded messages. Receiving and decoding at any location within 150 mi. of transmitter	2
Information distribution	Services A, O, and C carry both operational and weather services information	Distribute Service A products to operational users. Distribute Service O-C products to weather services	1
	Present facsimile circuit carries weather services information to operational users	Present circuit products distributed to weather services. Operational graphic products distributed only to operational users	2
Information transmission speed	Service C will require high speed interchange circuit when all weather services alpha-numeric messages are carried on this circuit alone	Implement planned CODIS system	1

Table 11 Common Aviation Weather System, Master Phasing Plan

Year	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970 through 1971	1972 through 1974
Observation		Improved instrumentation for surface reports Extended pilot reports to FSS and P/F	Shipboard winds-aloft measurement Improved radar precipitation measurements	Improved airborne instrumentation (rocket-balloon A/C) Operational satellite for cloud cover	Increased numbers balloon and rocket observations	Automatic data reduction of balloon-rocket information	Automatic shipboard observing stations Digital readout instrumentation	Slant range visibility measurement Automatic aircraft reports of meteorological data	24 hour satellite observations		
Communication		VHF link from commercial and private users to processing	Ship reporting radio network Met teletype circuit (Service C)	Satellite obs teletype relay circuit		Computer format transmissions from ship, balloon, and rocket observing sites	Automatic aircraft reporting link			Direct reporting of 24 hr satellite observations, relays of low orbit satellite obs.	
Processing		Improved 0-12 hr terminal forecast Improved 0-24 hr terminal forecast	Operational 0-1 hour forecast of trends	Improved 0-12 hr area forecast Improved 0-24 hr area forecast	Detailed upper air forecast Improved weekly outlook	Processed basic airways observations			Operational 0-1 hr terminal forecast		System "debugging" and detailed optimization
Communications	L/MF continuous weather broadcasts	Operational FAX circuit Interim ATC support links Operational teletype circuit (Service A)	Pilot-to-forecaster link On-Base distribution circuits Canned telephone briefing links	VHF cont weather broadcasts Automatic message selection for telephone briefing	Operational ATC support links	Coded broadcasts of Service A data for general aviation use				24 hr. satellite operational teletype & FAX relay	

Table 11. Common Aviation Weather System, Master Phasing Plan (Cont'd.)

Year	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970 through 1971	1972 through 1974
Presentation	P/F test and evaluation L/MF continuous weather broadcasts	Briefing formats and procedures Standard continuous weather broadcast format Operational Service A format ATC weather use procedures	Manual prep of FAX operational products Closed circuit TV briefing to F/C and auditory link ATC test with weather inputs	USWB operational FAX products presented Operational P/F link VHF continuous weather broadcasts Auto phone selection of briefing	P/F link integrated with ATC Operational ATC support from processing centers	Direct link to F/C from FSS and briefing facilities	Hardcopy FAX charts for pilots Automatic printout of phone briefing information		Auto. P/F link to commercial carrier Automatic continuous weather readout air and ground Automatic conversion of meteorological information into ATC operational terms (acceptance rate, usable airspace)		
Users											

CONCLUSIONS

A comparison of aviation weather information requirements through 1975, as determined in this analysis, with the information now provided by the aviation weather services, resulted in these conclusions:

- The aviation weather service currently provides meteorological products that rarely can be used for operational decisions without further interpretation. Essentially, the present system serves only one user group, the aviation meteorologists.

- The present air traffic control and management system only reacts to adverse weather conditions; it does not anticipate and plan ahead for critical weather. No organized methods exist for utilizing the present meteorological products to improve the current operation. Automated traffic control systems now under development will need meteorological products presented in different form and of greater accuracy and realiability than those at present

- Methods of observing must be improved to obtain representative data, and the spacing of the observing points must be proportioned to the size of the phenomena to be observed.

- The airspace users have a critical need for a weather system which presents operationally-oriented weather information This need is particularly urgent for the general aviation group which is the largest user segment

- The definition, detail, and accuracy of weather information must be improved before it can become operationally useful and significant to controllers

- Airspace users, controllers, and managers must receive more training in the application of meteorological information to operational situations

- The weather system must plan for the expansion of the airspace to higher altitudes Air operations above 50,000 feet require an improved network of weather observing points to these altitudes A research effort is necessary to

  - determine the characteristics of clear air turbulence and methods of forecasting them

  - achieve a thorough understanding of the wind and temperature fields at these altitudes

  - relate the intensity of sonic booms to meteorological conditions

- First priority effort should be devoted to the design of a Common Aviation Weather System whose basic configuration and internal operation permit maximum use of current and foreseen techniques and processes to produce meteorological products for operational users.

These conclusions, and the requirements established in the course of this analysis program, lead inevitably to the development of basic concepts for the design of an aviation weather system:

- The aviation weather system must serve all users in the detail and accuracy which is operationally significant to each.

- Meteorological information furnished each user segment must be easy to assimilate without further interpretation.

- Only that meteorological information having operational significance to a particular user segment should be furnished to that segment.

- In satisfying the common meteorological requirements of all user segments, a common aviation weather system will evolve which will function with minimum expense, minimum complexity, and maximum utility.

To realize the system objectives, intensive research and development will be necessary in several areas. Research and development in the use of local observational networks, for example, will be necessary to provide information with enough detail and accuracy to be of use in the operation of major terminals. In other areas, simple changes in procedures or the introduction of instrumentation and electronic techniques now available can achieve immediate and system-wide benefits. Improvements not requiring extensive development are:

- Better presentation of information through the use of easily assimilated formats

- More representative observations of wind, ceiling, and visibility at and around terminal areas, through the use of more appropriate averaging times and specific measures of variability.

- Realignment of the message content and circuit structure, and greater reliability of teletype communication.

- Preparation of an hourly forecast of the trend of operationally significant weather events, making full use of currently available techniques and observations.

- More frequent observations, especially during periods of marginal weather conditions, through the use of automated terminal weather observing, recording, and transmitting equipment.

- More attention to the needs of general aviation pilots, through increased radio and telephone weather broadcast programs, and the establishment of pilot-to-forecaster service. (A concerted training effort is required to insure that information disseminated by these means will be understood and used in the operational situation).