# THE AFOS PROGRAM OF THE U.S. NATIONAL WEATHER SERVICE

BY

W. KLEIN

NATIONAL WEATHER SERVICE,NOAA

SILVER SPRING, MD.

U.S.A.

ABSTRACT

The Automation of Field Operations and Services (AFOS) program of the National Weather Service is providing a new dimension to local weather forecast procedures. For the first time, minicomputers, video displays, and a rapid communication system are being collocated at national centers and local weather stations throughout the country. As a result, great improvements over current conditions will be made in such areas as message composition, timeliness of warnings, data display and processing, professional productivity, and forecast monitoring, updating, verification, and methodology. In addition to discussing these benefits, I shall give a brief description of the basic AFOS system and its latest status. I shall also describe new applications being developed for use with AFOS such as providing computer-worded, objective public forecasts, automatically monitoring and updating aviation terminal forecasts, and facilitating pilot briefing.

## 1. Introduction

The National Weather Service (NWS) of the United States plans to have new automated equipment in most of its field offices and national centers by 1981. This program is called the Automation of Field Operations and Services, or AFOS. AFOS will replace teletypewriter and facsimile machines by cathode ray tube (CRT) displays (similar to TV sets), a hard copy device, and minicomputer systems. Each Weather Service Forecast Office (WSFO) and national center will have two minicomputers (Data General Co. Eclipse S-230). Each designated Weather Service Office (WSO) and River Forecast Center (RFC) will receive one minicomputer. With the AFOS system, weather observations, forecasts, and maps will be rapidly displayed on the CRT's. When needed, a hard copy device called a printer-plotter will provide paper copies of any displayed image in less than 20 seconds.

A typical forecaster console is illustrated in Fig. 1. Each console will consist of one or more CRT's and a keyboard similar to a typewriter. The exact number of consoles in an office (and CRT's per console) will vary, depending on the number and type of service functions in that office. For example, a forecast office may have seven AFOS consoles, while a WSO may have only three. An aviation forecaster at a WSFO will use a console with three CRT's, while a pilot briefer at a WSO may use a console with only two.

By pressing specific keys at the AFOS keyboard, weather maps and data can be displayed on the screen. By entering additional information such as product title, addressee, and transmission priority, information can be sent to offices throughout the country in a fraction of the time it now takes. Forecasts and warnings can also be transmitted over the NOAA Weather Wire to special users and to the news media for public relay.

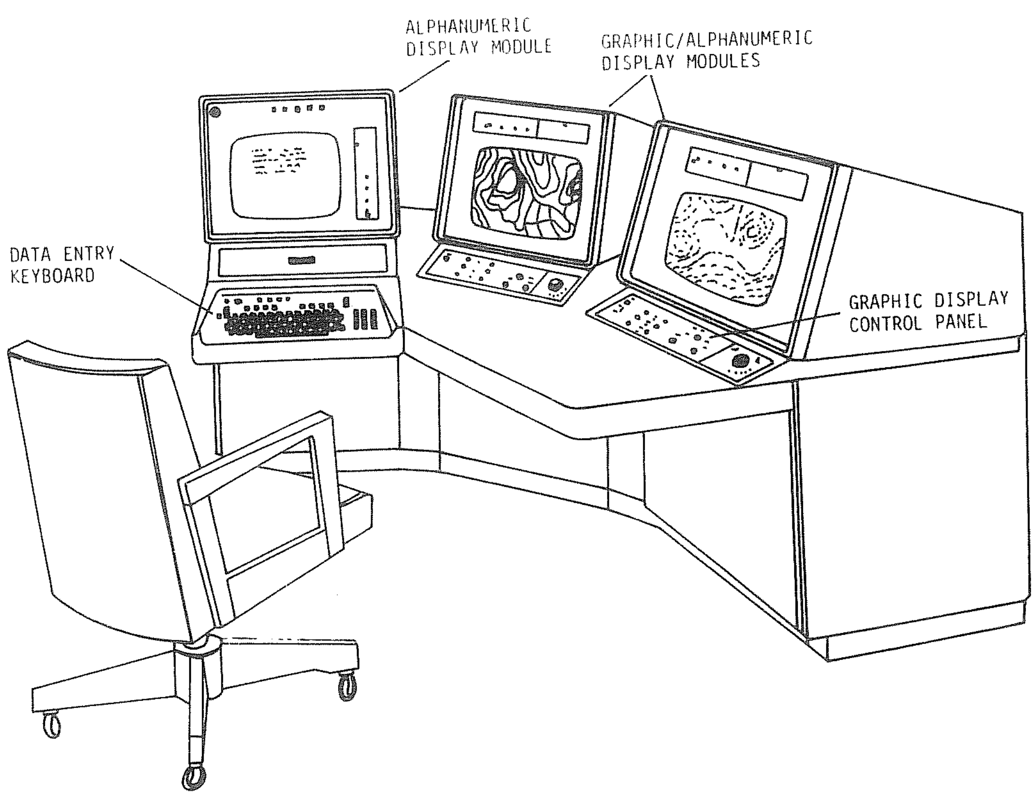



Figure 1. A typical Forecaster Console being installed in automated weather stations under terms of the AFOS contract. The keyboard cathode ray tube on the left will be used for displaying alphanumeric data and composing messages. The two graphic modules on the right will be used for displaying both weather maps and alphanumeric data.

## 2. AFOS benefits

Why this automation? NWS needs to do things faster and more efficiently to improve its job of monitoring and forecasting weather. Forecasters require current observations in order to make high quality forecasts. Forecasts and warnings, in turn, need to be disseminated quickly to people who might be affected and should take protective action. This requires modern, high-speed communications. For example, it will take less than a minute for high priority messages such as a flash flood alert to reach any station under AFOS. Graphics will be received in about one-third the time it now takes with facsimile. Cutting teletypewriter tapes will be eliminated. The advantage of AFOS over the current system in reducing warning response times is depicted in schematic form in Fig. 2.

In addition to fast communications, AFOS will save the forecaster time by automating routine tasks. Since teletypewriters and facsimile machines will be unnecessary, the time spent in tearing and posting paper will be eliminated. The forecaster will be able to compose his forecasts and messages directly on the screen; and, once prepared, the

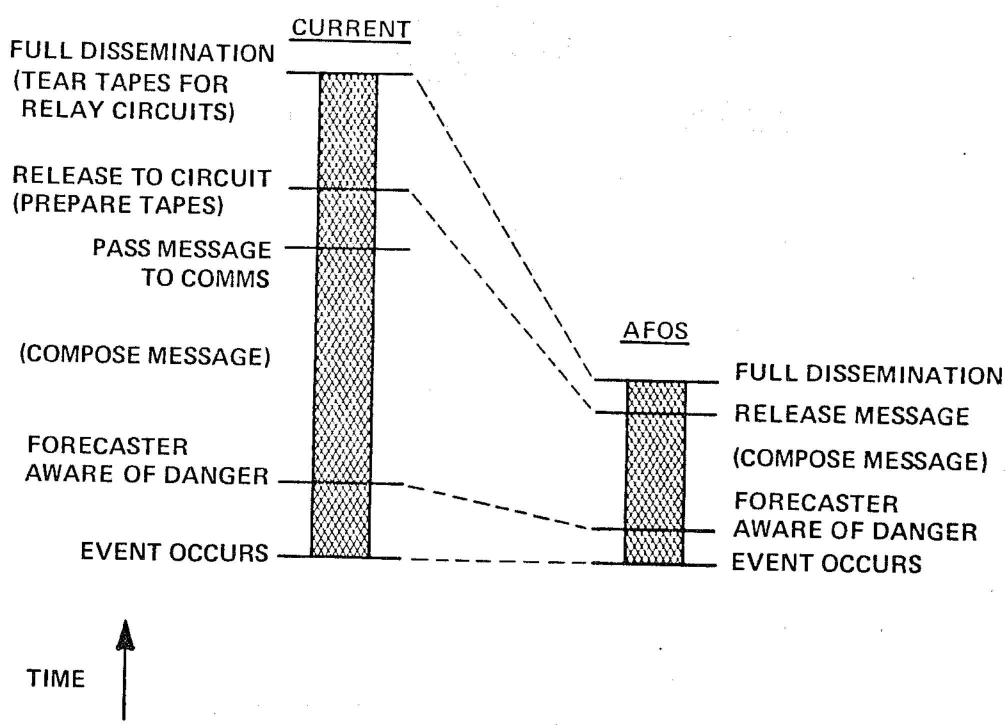



Figure 2. Expected improvements in warning response time produced by AFOS.

message will be automatically transmitted by AFOS to the users. In addition, composition of messages will be much easier. For example, the forecaster will be able to edit a previous message and send it as a new message, or he may simply fill in a standard message format. Finally, the forecaster will have new capabilities to help monitor and forecast the weather. As a result, the percent of a forecaster's time now spent on sub-professional activity should be cut in half under AFOS, while the percent spent on professional work should increase from about 50 to 75 percent.

3. AFOS communications

When the AFOS system is complete, a National Distribution Circuit (NDC) will connect all WSFO's and national centers in a closed loop. State Distribution Circuit's (SDC's) will also be established to connect WSO's and RFC's with their parent WSFO in a star-like configuration. Figure 3 is a schematic diagram of both the SDC and NDC.

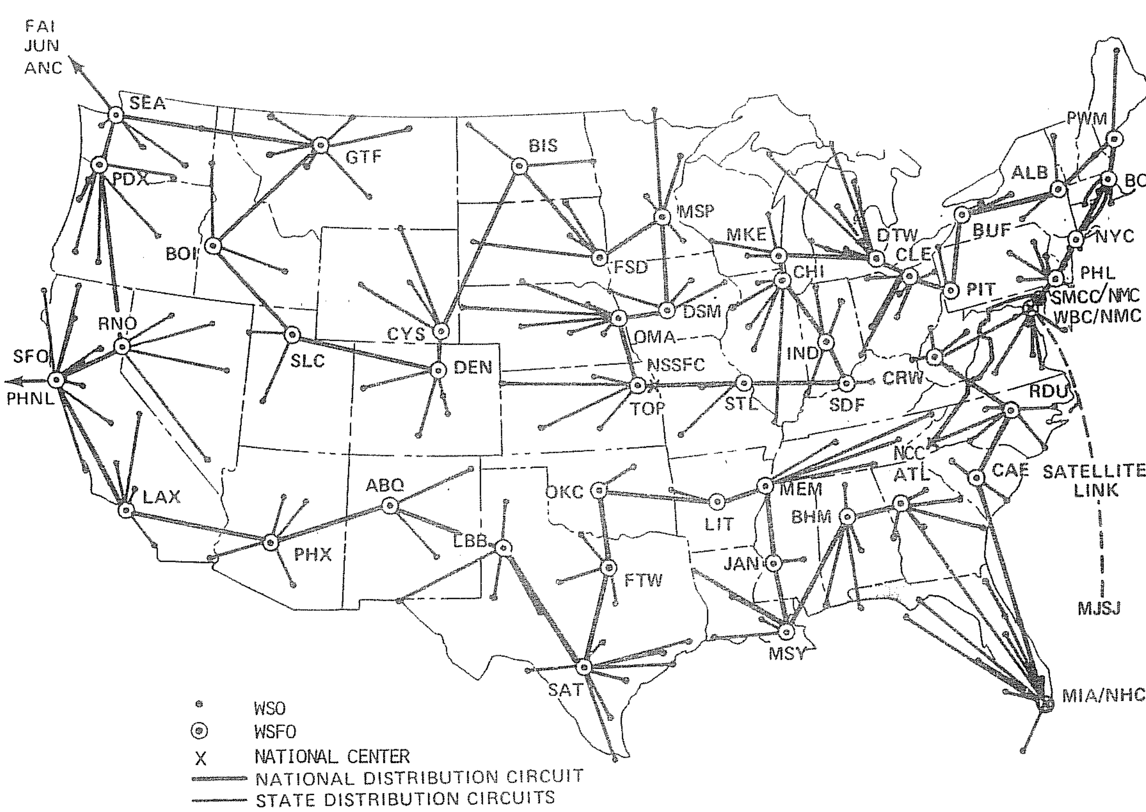



Figure 3. National Distribution Circuit, State Distribution Circuits, and call letters of forecast offices and national centers.

The NDC will consist of point-to-point, dedicated, voice grade lines, each operating at 2400 bits per second full duplex. All NDC communications will be computer-to-computer, store and forward, with full error checking. Data can enter the NDC at any one of the stations. Once on the circuit, a message will move from station-to-station, in both directions on the NDC from the originator. In a very short time, a message (or graphic product) will be received in duplicate by a station on the opposite side of the NDC. Receipt of the same message from both directions at a station signals the system to stop that message. The time it takes a message to get around the network is highly dependent on the message priority. In theory, a message can traverse the NDC in just 25 seconds. However, the "queuing time" at each node will cause the average transit times to range from 40 seconds for a high priority message such as a flash flood warning to 30 minutes for a low priority message such as an administrative item being transmitted during a heavy communications load.

The second level of the AFOS communications system will be the SDC's. These circuits will connect the WSO's, RFC's, and Weather Service Meteorological Observatories (WSMO's) within a forecast area to the parent WSFO. They will also allow the WSFO to pass messages down to the local level. Since each SDC will operate at 2400 bits per second full duplex via dedicated lines, many of the software and equipment modules will be common with those required for operation on the NDC. All data collected within a forecast area will flow along an SDC from the originating station to the WSFO and then onto the NDC for national distribution, as illustrated schematically in Fig. 4.

## 4. Systems Monitoring and Coordination Center

The AFOS network includes a network control point called the Systems Monitoring and Coordination Center (SMCC). The SMCC is a node on the NDC and has the responsibility for monitoring, in real time, the integrity of the AFOS network. The SMCC initiates corrective actions in the event of failure of selected communication lines and/or computer systems at the AFOS offices. The SMCC provides direct back-up including data base replenishment. The center was established during the spring of 1978 with location at Suitland, Maryland. It serves the function of inter-

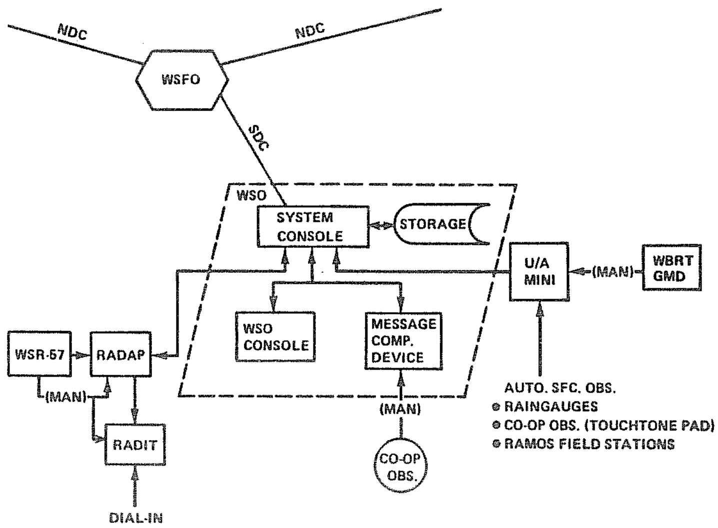



Figure 4. Schematic diagram to illustrate flow of radar, surface, and upper air data into the AFOS National Distribution Circuit via the WSO, SDC, and WSFO.

facing the NDC to the National Meteorological Center computers that generate forecast guidance and graphic products. The SMCC system is one of the largest minicomputer configurations ever put together, consisting of four Eclipse minicomputers, multiple high-speed communication lines, and 1.2 billion bytes of on-line disk storage. Figure 5 shows a schematic representation of the SMCC.

## 5. Graphics

The National Meteorological Center (NMC) is encoding its graphic products in a universal graphics format for transmission on the NDC. At a field office, the forecaster can call up and simultaneously display any three graphic fields on his graphic CRT. For example, the first field may be a map of the United States with sea level isobars. The second may be a plot of surface observations, and the third may be 500-mb contours. The forecaster has complete control over the presentation of the lines in the graphic overlays. For example, he can switch any set of isopleths from solid to dashed to dotted or back again at the touch of a button. He also has separate control over the intensity or brightness of any set of lines. With more than one graphics display, it is possible to request different data for each overlay or display screen, or multiple screens can share common data.

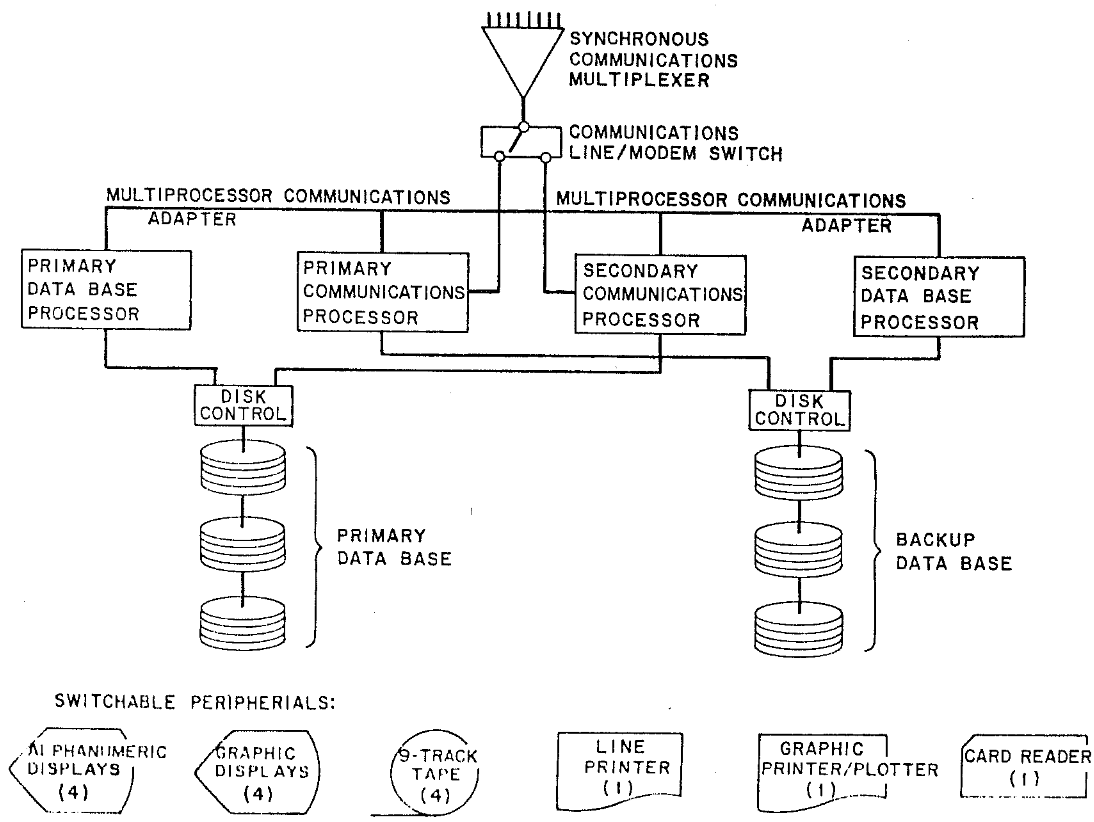



Figure 5. A schematic diagram of the AFOS Systems Monitoring and Coordination Center hardware.

The operator can use a zoom feature to magnify a selected area of display data, with a scale factor of 1:1, 4:1, 9:1, 16:1, or 25:1. As the zoom ratio increases, a successively smaller area fills the screen, and more data are plotted automatically. The magnified sector is chosen by a trackball on the control panel. With this, the forecaster can manipulate the location of a cursor on the display. Complete final displays are produced as hard copies, obtained from the printer-plotter.

Work was recently completed on a very useful and time-saving feature called "Procedures." This feature allows a person to designate, ahead of time, console commands which need to be performed in succession. If this feature isn't used, the console commands require individual entries at the AFOS keyboard at the time they are wanted. Once a set of commands is defined in a "procedure" and assigned a name, the "procedure" can be activated by that name from then on. For example, a forecaster may wish to routinely display a series of alphanumeric data and graphics. To do this, he must identify the products, their order, the screen on which each product is to be displayed, and the procedure name. Then, whenever he wants to see the products in order, he need only type in, on the AFOS console, the "procedure's" name.

At some time in the future, it may be possible to draw lines, vectors, or contours directly on the CRT display, using the cursor to designate the terminal point of each line segment. In addition, a procedure called "animation" will provide a series of time lapse graphic products. This feature may be used to review any series of weather maps, including derived satellite and radar products.

## 6. Product identification

Over 22,600 different products may be sent over the AFOS network. Each product has a nine-character identifier, which is used by the forecaster to call up specific meteorological information. The identifier is also used by the computer to decide if a product coming into the station should be stored. The identifier of the incoming product is checked against the station's list of products that should be retained (Product Inventory List or PIL). If the computer finds a match, the product is stored and sent on to the next station. Otherwise, the product is not kept but simply forwarded. See Fig. 6 for this procedure of AFOS product storage.

## 7. Data archival

NWS is required to retain certain weather information for a period of five years. In the past, this need was satisfied by the field

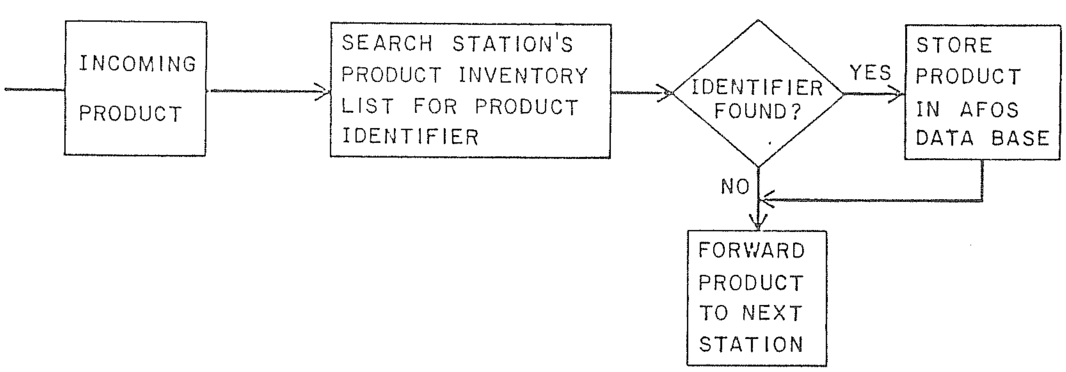



Figure 6. Procedure for determining the flow and storage of AFOS products.

offices, mostly in the form of rolls of teletypewriter paper. Under AFOS, these offices will no longer routinely make hard copies of the observations and forecasts they produce. Instead, each station will maintain its locally generated data on disk, for 3-5 days on-line and about 30 days off-line. All products from the entire NWS system will be retained for 30 days on-line in the SMCC. Most products will also be kept for 3-5 years in a new Centralized Archival System being established at the National Climatic Center in Asheville, N. C. The latter will be connected to the SMCC via a dedicated line (Fig. 3).

## 8. Backup

The AFOS system has several levels of backup capability. If one of the minicomputers at a WSFO breaks down, the other minicomputer at the station can do the work of both, albeit at a slower rate. If both computers shut down, one of the consoles in the station can receive and transmit data by acting as a remote terminal to the SMCC. The SMCC can later refresh the data base of any station which has been down. In the event of a complete computer outage at NMC, graphics routinely prepared at the Air Force Global Weather Central, Offutt AFB, Omaha, Neb., will be transmitted over the NDC in place of the NMC products.

The NDC has a built-in "fail-safe" capability if a communications failure should occur between stations. Since all data in the circuit are transmitted in two directions, a WSFO will not be isolated through a single line failure. Although the NDC uses dedicated communications lines, data can also be transmitted by establishing dial-up connections over commercial lines. Thus, the entire conventional telephone system is available for AFOS backup.

## 9. Schedule

On 30 January 1976 the U.S. Department of Commerce signed a contract with the Ford Aerospace and Communications Corporation to build and install 216 AFOS systems. The agreement (as amended) calls for delivery of about six field facilities per month beginning with Pittsburgh, Pa., in May 1978 and ending with Hilo, Hawaii, in November 1980 at a total cost of about $40 million. The system will be installed at 52 WSFO's, 135 WSO's, 13 RFC's, 4 national centers, 3 regional headquarters, the SMCC (2), the Experimental Facility (2), the Technical Training Center (2) and 3 other sites.

As of this writing (July 1978), the deliveries of AFOS equipment are proceding on schedule. At any one station, the first three months following installation will be used for systems checkout and on-site employee training. During the next three months, the station will operate with AFOS but retain its old equipment in a receive-only condition. Finally, during the last three-month period, the teletypewriter and facsimile machines will be removed. Thus, the first sites will go operational in the fall of 1978 and will be in an exclusively AFOS mode by early 1979. The transition period between installation of AFOS and removal of the old equipment will be gradually shortened to four months for the later stations. Therefore, AFOS should be completely operational by March 1981.

An interim NDC connecting the first stations receiving AFOS equipment was recently put into operation. As shown in Fig. 7, two separate NDC's can be established by switching: an inner loop connecting the

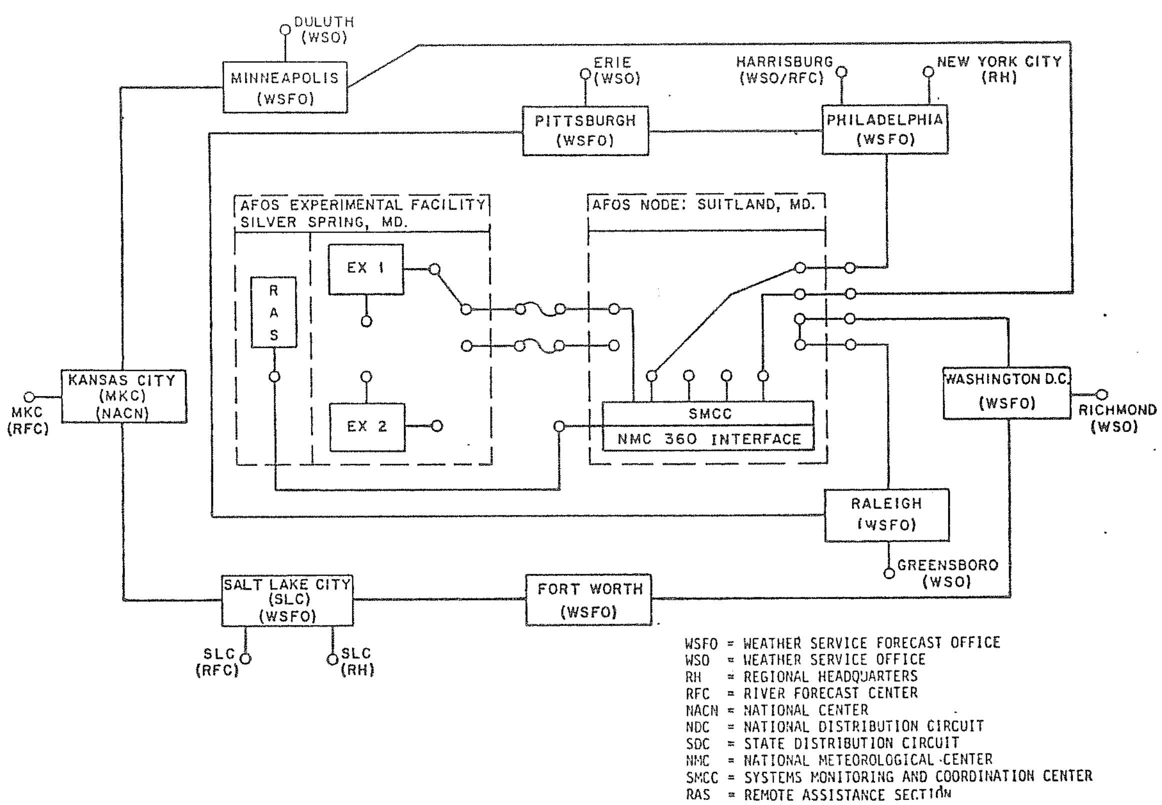



Figure 7. Single Field Loop Test Configuration for an NDC in the early stages of AFOS implementation. By switching, two separate NDC's can be established (the outer loop and the inner loop).

earliest stations implemented, and another loop connecting stations added later. This is the first network to be brought on-line using full duplex, balanced node, Advanced Data Communication Control Protocol (ADCCP) and a closed loop technique.

## 10. Forecast area designs

The 52 WSFO's are the backbone of the field forecasting operation and are responsible for warnings and forecasts for states, or large portions of states, and assigned zones. Before AFOS can be implemented at any WSFO, a detailed design of that office and the WSO's, WSMO's, and RFC's in its area of responsibility must be prepared. These designs identify the operations at each office and define the hardware, software, and communications needed to support and interface the office with AFOS. Figure 8 is a sample summary of the design for the Washington forecast area. Similar designs have been completed for 34 other forecast areas, and the remaining 17 should be finished during 1979.

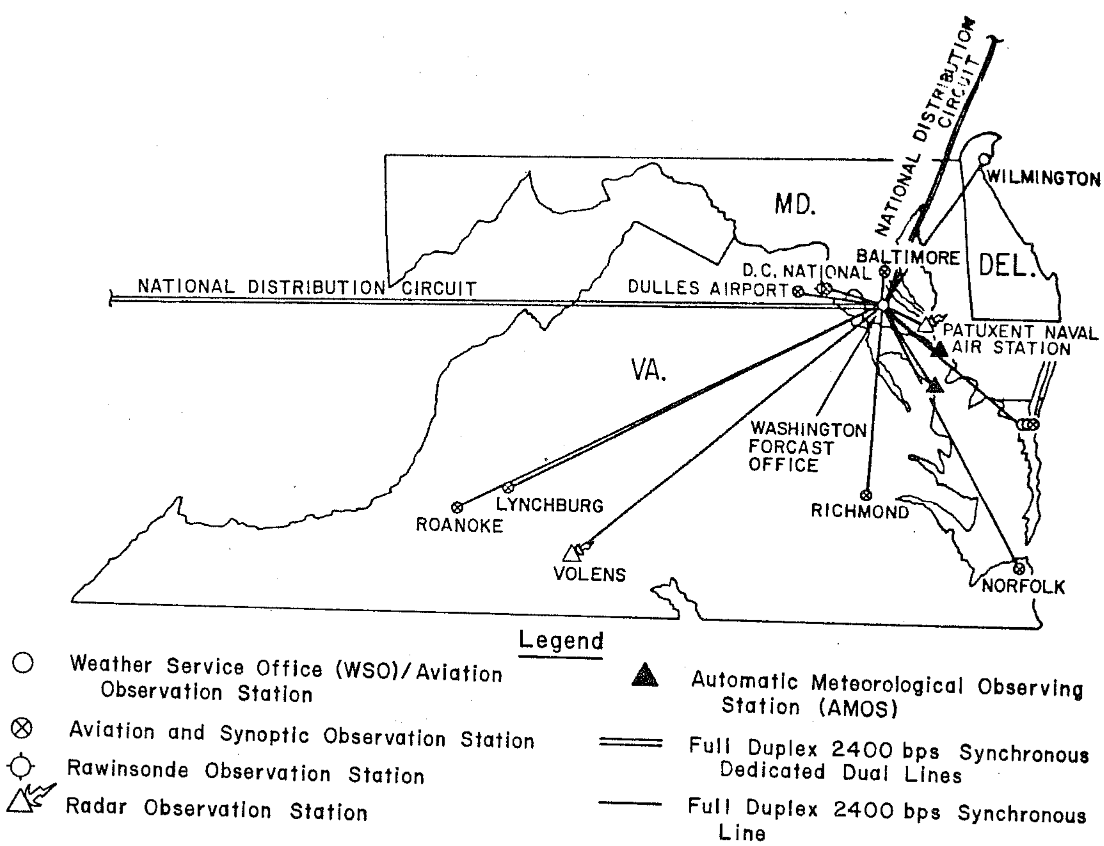



Figure 8. Summary of the Washington forecast area design.

## 11. Offices without AFOS

Not every NWS office is scheduled to receive an AFOS computer system. In fact, 94 WSO's and 51 WSMO's are not included in the original AFOS contract. An analysis of the 1981 design requirements for these 145 offices has been completed, and three configurations have been identified on the basis of the number, combination, and scope of the various tasks performed in each office. Thirty-one offices in the first group may receive CRT's for both alphanumeric and graphic data, as well as a printer-plotter, with facsimile eliminated. One hundred four offices in the second group may have CRT's for alphanumeric data only and a printer, but facsimile may continue to be used. Ten offices in the last group may have a printer only. (The printer is different from the printer-plotter because it is a hard copy device limited to receiving alphanumeric data.) As before, the number of consoles will vary with the needs of each office. In all cases, however, the consoles will be driven as "remote terminals" from minicomputers in neighboring AFOS offices. Drops in the Radar Reports and Warning Coordination System (RAWARC) and all other teletypewriter lines (Services A, C, and O) will be eliminated.

## 12. AFOS applications

As part of the AFOS program, the Systems Development Office is generating several new products and techniques not previously available in local weather offices. These AFOS applications are designed to help the forecaster do his job more quickly and more accurately.

Once a new technique or application is developed, it has to be coded for the minicomputer, evaluated in the AFOS Experimental Facility, and integrated into the AFOS software before it finally becomes part of the operational system. This procedure is illustrated schematically in Fig. 9. Some of the AFOS enhancements currently under development can be listed briefly as follows:

- Computer worded forecasts
- Aviation monitoring and updating
- Pilot briefing
- Interactive forecasting
- Flash flood forecasting

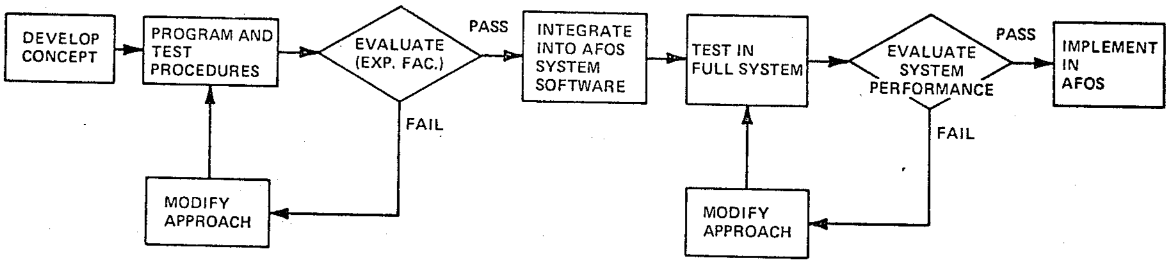



Figure 9. Illustration of the flow of forecast application tasks in the AFOS program.

- Sectional plotting and analysis
- Time- and cross-section displays
- Radiosonde plotting and analysis
- Forecast verification

The first four of these applications of the AFOS system will be explained in the remainder of this lecture.

## 13. Computer worded forecasts

The object of this task is to automatically generate computer-worded forecasts in the same form as the final product. For nearly ten years, Dr. H. R. Glahn of the Techniques Development Laboratory (TDL) of the NWS has been experimenting with producing public weather forecasts in worded form by computer. His first efforts were reported in 1970 (Glahn, 1970), and the description below is taken from his latest work on the subject (Glahn, 1978).

With the development of AFOS and Model Output Statistics (MOS) (Glahn and Lowry, 1972), it is now feasible to produce computer forecasts of good enough quality to be useful as a starting point for field forecasters. A forecaster can save considerable time by using the automated product, yet he will still be able to exercise all the control he desires over the final product.

### 13.1 Input to program

The most important input to the computer worded forecast (CWF) program consists of objectively-produced, digital weather forecasts. Currently, these are MOS forecasts arranged in matrix form, as shown in Fig. 10. These forecasts were made from a 0000 GMT model run. The three forecast periods--today, tonight, and tomorrow--are indicated, as well as the appropriate GMT valid times. For most elements the

TDL AUTOMATED FORECASTS (USING EARLY GUIDANCE)
FRIDAY 16 JUNE 1978

WASHINGTON, DC

| ELEMENT | UNITS | 12Z | 18Z | 00Z | 06Z | 12Z | 18Z | 00Z |
|---|---|---|---|---|---|---|---|---|
| | | VALID TIME | | | | | | |
| | | (---TODAY--- | ) | (--TONIGHT | --) | (--TOMORROW | --) | |
| TEMP M/M | DEG F | | 80 | | 66 | | 84 | |
| TEMP | DEG F | 63 66 | 74 78 | 78 75 | 70 68 | | | |
| POP(12) | PERCENT | | | 11 | | 20 | | 25 |
| POP(6) | PERCENT | | 7 | 7 | 10 | 17 | 15 | 21 |
| POF | PERCENT | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| R SHR(L) | PERCENT | | 49 | | 51 | | 76 | |
| DRZL(L) | PERCENT | | 11 | | 20 | | 0 | |
| RAIN(L) | PERCENT | | 40 | | 30 | | 25 | |
| TSTM | PERCENT | | 0 | | 1 | | 6 | |
| QPF | CATEGORY | | | 1 | | 1 | | 1 |
| CLOUDS | CATEGORY | 1 | 4 | 4 | 2 | 4 | 4 | 3 |
| WIND D/S | DEG MPH | 1403 | 1504 | 1606 | 1703 | 1606 | 1810 | 1610 |
| CIG | CATEGORY | 6 | 6 | 6 | 6 | | | |
| VIS | CATEGORY | 6 | 6 | 6 | 6 | | | |

WASHINGTON, DC    SUNNY THIS MORNING, BECOMING OVERCAST BY MIDDAY. LITTLE CHANGE IN TEMPERATURE, HIGH NEAR 80. LIGHT AND VARIABLE WINDS. TONIGHT--MOSTLY CLOUDY WITH A SLIGHT CHANCE OF SHOWERS. LOW IN THE MID 60S. LIGHT AND VARIABLE WINDS. SATURDAY--CLOUDY WITH A SLIGHT CHANCE OF SHOWERS. HIGH IN THE MID 80S. PROBABILITY OF RAIN 10 PERCENT TODAY, 20 PERCENT TONIGHT, AND 20 PERCENT TOMORROW.

Figure 10. A model output statistics (MOS) automated forecast matrix and the resultant computer worded forecast.

first valid time, 1200 GMT (Z), is 12 hours after initial data time for the numerical model. The MOS forecasts also depend, in some cases on surface observations up to 6 hours after 0000 GMT. Each of the forecast elements is explained briefly below:

TEMP M/M--The max temperature is given for today and tomorrow and the min for tonight. Actually, these forecasts each cover a 24-h period (midnight to midnight, local time), and, therefore, the first max is not for just the daylight hours.

TEMP--A specific-time temperature forecast is currently available for projections of 9, 12, ..., 27, and 30 hours. These forecasts help determine the wording concerning temperature. Since the MOS forecast max is for a 24-h period and the local forecasts are usually for a 12-h "daytime" period, adjustments of the MOS forecast max is sometimes made to conform with an expected daytime max.

POP(12)--These are forecasts of the probability of occurrence of $\geq$.01 in of precipitation (liquid equivalent) in each of the 12-h periods. Besides determining, in large part, what wording to use regarding precipitation, they are used in the probability statements, rounded to tens of percent.

POP(6)--Forecasts for each of the two 6-h periods within each of the 12-h periods are given. They help determine changes in precipitation (precip) occurrence and cloudiness within the 12-h periods.

POF--Forecasts of the probability of frozen precipitation, given that precipitation occurs, are available for seven specific times--every 6 hours starting with 1200 GMT.

R SHR(L), DRZL(L), AND RAIN(L)--These are forecasts of the probability of rain showers, drizzle, and nonshowery rain, respectively, given that liquid precipitation occurs. There is one forecast of each variable valid in the middle of each 12-h period. These are mutually exclusive and exhaustive categories; therefore, except for roundoff, the sum of the three probabilities equals unity. These forecasts are not disseminated by teletype or facsimile; the technique was developed specifically for input to the CWF's.

TSTM--The unconditional probability of a thunderstorm occurring at the station sometime during each 12-h period is given. Actually, this predictand was determined from 3-hourly observations and will, therefore, be biased toward low values. This is no real problem for use in the CWF's, since a correspondingly low threshold can be used to determine when thunderstorms will be mentioned. The threshold is quite arbitrary, in any case, and must be determined by experience. Relatively little effort has gone into producing these thunderstorm forecasts.

QPF--Categorical forecasts of quantitative precipitation are given for each of the 12-h periods. Categories 1 through 5 indicate <.25 in, .25-.49 in, .50-.99 in, 1.0-1.99 in, and $\geq$2.0 in, respectively. Threshold probabilities were determined in order to transform probability forecasts into categorical forecasts in such a way that the threat score would be maximized.

CLOUDS--Clear, scattered, broken, and overcast sky conditions are given by category numbers 1 through 4, respectively, for each of seven projections. Probabilities of each of these categories are objectively determined, and the categories are specified from these probabilities.

WIND D/S--Wind direction to tens of degrees and speed in knots are given in the usual convention for each of seven projections. A separate regression equation is evaluated for speed and for the U and V components. Direction is determined from the components, and the regression estimate of speed is inflated.

## 13.2 Characteristics of forecasts

The main goal in developing the CWF program was that the resulting forecasts would be saleable and operationally useful. Therefore, no major departures from the forecast format currently in use by local forecasters were made. Generally, the NWS operational manuals were followed.

In order to achieve the above goal, the program was designed to allow considerable flexibility in choice of phrases. For instance, one station or NWS Region might desire quite detailed forecasts, while another might want considerably abbreviated forecasts. Also, different preferences may prevail as to what constitutes "windy," "very cold," etc.

Even with the desire to allow flexibility by a "user" in specifying control parameters, certain guidelines had to be adopted. Three of these are:

- four basic weather elements would be included--wind, temperature, cloud, and precipitation,
- the forecasts would be segmented by period--today, tonight, and tomorrow--except for very simple forecasts in which periods could be easily combined, and
- the most important elements would be put near the beginning of the segment.

A sample computer worded forecast is given at the bottom of Fig. 10.

## 13.3 Plans for the future

The CWF program has been written for the IBM 360/195 in Suitland, Md., and forecasts can be produced daily for any of about 230 stations. As AFOS equipment is installed at a WSFO, we will produce forecasts for that station and for the stations and zones for which it is responsible. These will be sent via the NDC and will be available to the WSFO before the issue time of the early morning forecast.

When MOS forecasts are not available for a particular station or zone, interpolation will be made from two to four stations for which MOS forecasts are available. Both a CWF and the digital forecast matrix will be transmitted.

A version of the CWF program will also be available for the local AFOS minicomputer. This will allow four options for the use (or nonuse) of the CWF at the WSFO:

a. Complete acceptance--If the forecaster is satisfied with both the wording and the digital values in the CWF, he can disseminate the CWF with little more than the push of a button.

b. Minor revision--If the forecaster wants to make minor changes to the wording or numerical values, that can be done with the text-editing capability of the AFOS equipment.

c. Major revision--If the forecaster wants to make considerable revision of the digital forecasts, he can do so on the AFOS KCRT and then initiate the CWF program on the local mini. Wording will then be generated which conforms to the amended digital forecast. Options a, b, and d are then available for this locally-produced CWF.

d. Total disregard--This option is always open.

It may turn out, as AFOS implementation nears completion, that all CWF's should be produced on the local mini rather than be sent over the NDC. This option would trade circuit loading for minicomputer time and can be exercised any time it seems appropriate.

The present program does not combine periods when the forecast conditions are much the same for two or more of the periods. This feature will be added at a later date. In addition, terminology dealing with "watch" situations, blizzards, winter storms, and snow fall depths will be added. The program produces forecasts for the today, tonight, and tomorrow periods in that order. After TDL gets the initial reaction from field forecasters, using CWF's in the AFOS environment, it will make any necessary program modifications. It will then write the software to produce CWF's for the tonight, tomorrow, and tomorrow night periods for use in the late afternoon and early evening. Another extension of the effort will be to produce "updates" that can be issued in the late morning and late evening.

## 14. Terminal alerting

The goal of this task is to develop a system which will automatically monitor and update aviation terminal forecasts on the basis of surface observations at that terminal. The description below is taken from a detailed paper by Vercelli and Heffernan (1978) of TDL.

At the present time, a meteorologist issues aviation terminal forecasts (FT's) for each terminal in the area of responsibility of the WSFO. Once the forecasts have been produced and disseminated, they must be continually monitored in case changing weather situations require issuance of an updated FT.

To aid in this process, a software package has been developed which will automatically monitor the FT's for each station by comparing the incoming surface airway observations with the corresponding forecast groups in the FT. If the system determines that a problem exists, or may develop shortly, at one or more of the terminals, it will generate a Terminal Alerting Procedure (TAP) message for each of those terminals. The TAP message will consist of both a statement of the immediate problem and an updated, single-station probability forecast.

### 14.1 Method of operation

The required software will be integrated locally into each WSFO in the AFOS network. An immediate benefit of having the monitoring and updating programs stored in the WSFO minicomputer is that there will be no need to involve the large computers at NMC for this task.

In the AFOS system, the aviation forecaster will compose each FT in a fixed format using the message composition feature of the AFOS software. When the entry is complete, the forecaster will depress the "enter" button which will store the forecast locally and disseminate it on the State and National Distribution Circuits. The software monitoring the FT's will be scheduled to execute automatically each hour after the receipt of the surface airway observations. It will also be queued to run on the receipt of a special or late observation.

Each terminal for which the WSFO is responsible will be monitored each time the software is executed. Upon receipt of an observation, the software will locate the corresponding forecast group of the FT and compare both the observation and FT to a stored list of alert and amendment criteria. The system will then determine if the FT is invalid or in danger of becoming invalid with respect to changes in ceiling, visibility, wind speed, hazardous precipitation, and thunderstorms. Table 1 shows the alert and amendment criteria for ceiling and visibility. The forecaster will be notified by a TAP message if a problem exists. If an amendment is necessary, the alarm light on the forecaster's console will flash and the alarm buzzer will sound. In the case of an alert, only the alarm light will be activated. By depressing the alarm light (and the audio alarm clear button for the former case) the forecaster will display both the cause of the TAP and an updated single-

Table 1. Alert and Amendment Criteria.

| CEILING (feet) | | Observed | |
|---|---|---|---|
| Criterion | Forecast | Amend | Alert |
| 1 | No ceiling, > 5000 | ≤ 3000 | 3100-4000 |
| 2 | 2000-5000 | ≤ 1000 | 1100-1500 |
| 3 | 1000-1900 | No ceiling, > 10,000, Decreased ≤ 1/2 Forecast | 8000-10,000, Decrease=1/2 Forecast + 100 |
| 4 | < 1000 | No ceiling, Difference ≥ 300 | Difference=200 |

| VISIBILITY (miles) | | Observed | |
|---|---|---|---|
| Criterion | Forecast | Amend | Alert |
| 1 | ≥ 6 | ≤ 3 | 4 |
| 2 | 3-5 | < 2 | 2 |
| 3 | 2 | Difference > Forecast - 1 | 1, 3 |
| 4 | < 2 | Difference > Forecast ± 1/2 | Difference = Forecast ± 1/2 |

station ceiling and visibility guidance forecast valid at projections of 1, 2, 3, 4, and 6 hours from the time of the last observation. Examples of an alert and an amendment TAP message are shown in Figs. 11a and 11b, respectively.

The inputs to the forecast equations will be the current surface observations for that terminal. Only one special observation will be permitted as input, and all corrected observations will be taken into account.

## 14.2 Equation development

The probability guidance forecasts provided to the forecasters are based on a sophisticated form of conditional climatology called single station statistics (SINGSTAS) (Crisci and Lewis, 1973). For each terminal, a unique set of single-station equations was derived. These require only locally available meteorological information to

(a)

BAL TAP MESSAGE 6/29/78 1212 GMT
BAL FT MAY REQUIRE AMENDMENT FOR CEILING
PRESENT VALUE 4000 AMENDMENT VALUE LE 3000

BAL SINGSTAS FCST 6/29/78 1212 GMT

| VALID TIME | CEILING CATEGORY PROBABILITIES | | | | | | VISIBILITY CATEGORY PROBABILITIES | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 |
| 1300 | 0 | 0 | 1 | 12 | 74 | 14 | 0 | 0 | 0 | 1 | 7 | 92 |
| 1400 | 0 | 0 | 1 | 14 | 62 | 23 | 0 | 0 | 0 | 3 | 12 | 85 |
| 1500 | 0 | 0 | 3 | 16 | 55 | 26 | 0 | 0 | 1 | 5 | 16 | 79 |
| 1600 | 0 | 1 | 4 | 16 | 49 | 30 | 1 | 1 | 2 | 9 | 18 | 70 |
| 1800 | 0 | 2 | 8 | 13 | 45 | 33 | 1 | 1 | 3 | 10 | 16 | 69 |

(b)

BAL TAP MESSAGE 6/29/78 1235 GMT
BAL FT REQUIRES AMENDMENT FOR CEILING
PRESENT VALUE 2500 AMENDMENT VALUE LE 3000

BAL SINGSTAS FCST 6/29/78 1235 GMT

| VALID TIME | CEILING CATEGORY PROBABILITIES | | | | | | VISIBILITY CATEGORY PROBABILITIES | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 |
| 1330 | 0 | 0 | 6 | 63 | 27 | 4 | 0 | 0 | 0 | 1 | 7 | 92 |
| 1430 | 0 | 1 | 9 | 51 | 27 | 12 | 0 | 0 | 0 | 3 | 12 | 85 |
| 1530 | 0 | 2 | 12 | 47 | 25 | 14 | 0 | 0 | 1 | 5 | 16 | 79 |
| 1630 | 0 | 2 | 12 | 40 | 29 | 17 | 1 | 1 | 2 | 9 | 18 | 70 |
| 1830 | 0 | 5 | 12 | 30 | 28 | 26 | 1 | 1 | 3 | 10 | 16 | 69 |

Figure 11. Sample TAP messages alerting the forecaster that an FT for Baltimore may require an amendment (a) and will require an amendment (b).

produce six-category ceiling and visibility forecasts. The categories chosen for ceiling and visibility are based on significant values for aircraft operations and the frequency of occurrence of each category (Table 2).

TDL developed the forecast prediction equations using the Regression Estimation of Event Probabilities (REEP) screening procedure (Miller, 1964). In this procedure, the predictors and predictands are binary variables; that is, they may take on a value of either 1 or 0 depending, respectively, on whether the value of a particular element is, or is not, within a given range.

The multiple linear regression equations were developed in a stepwise manner by successively selecting the best predictors from a large number of predictor variables. This screening procedure continued until a total of 30 predictors had been selected. The details on testing for the optimum number of predictors can be found in the report by Crisci and Lewis (1973).

A single set of potential predictors was compiled for use in the screening regression which would be applicable in any season, at any time of day, and for any terminal. The predictors were derived from the basic observational elements shown in Table 3. Some predictors are individual elements such as temperature, ceiling, visibility, etc. These were designated "simple" predictors. More complex predictors were derived by linking together simple predictors, not only from a single hourly observation, but also from as many as four consecutive hourly observations through the use of the logical operators "AND" and

Table 2. Ceiling and Visibility Categories.

| Category | Ceiling (ft) | Visibility (mi) |
|---|---|---|
| 1 | < 200 | < 1/2 |
| 2 | 200 - 400 | 1/2 - 7/8 |
| 3 | 500 - 900 | 1 - 2-1/2 |
| 4 | 1000-2900 | 3 - 4 |
| 5 | 3000-7500 | 5 - 6 |
| 6 | > 7500 | > 6 |

Table 3. Basic observational elements from which simple and Boolean predictors were obtained for SINGSTAS equation development.

| Element | |
|---|---|
| Ceiling Height | Altimeter Setting |
| Prevailing Visibility | Total Cloud Amount |
| Wind Direction | Relative Humidity |
| Wind Speed | Lower Sky Cover |
| Weather | Time of Day |
| Dry Bulb Temperature | Day of Year |
| Dew Point Temperature | |

"OR." These compound, or Boolean, predictors were derived in an effort to describe initial conditions believed to be important in the occurrence of low ceilings and low visibilities, but which could not be described by the simple predictors alone.

Whenever possible, the data base used in the derivation of the SINGSTAS equations consisted of 10 years of hourly surface observations (approximately 88,000). Equations were not developed for a terminal unless at least 5 years of data were available. The most commonly used time period was from 1 January 1955 through 31 December 1964. All data were obtained from the National Climatic Center in Asheville, N.C.

Each of the regression equations is of the form:

$$F_h = a_0 + a_1x_1 + a_2x_2 + \ldots + a_{30}x_{30}$$

where $F_y$ is the probability of occurrence of the event y given the conditions represented by the selected predictors, $x_i$ (i=1,30); $a_0$ through $a_{30}$ are the coefficients. For both ceiling and visibility, and for each time projection, six equations were derived--one for each of the six predictand categories shown in Table 2. The predictors in all six equations are identical but the coefficients are, of course, unique. Table 4 shows a portion of the 1-hour ceiling prediction equations for Pittsburgh, Pa. to illustrate their form. Due to the binary nature of the predictands, the equations give the probabilities of occurrence of each category, $F_y$, for a given element by adding the coefficients associated with predictors whose value is 1.

Table 4. A portion of the 1-hour ceiling prediction equations for Pittsburgh, Pa.

| Predictors | Predictor Coefficients for Predictand Categories | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| $a_0$ Constant | .001 | -.006 | -.007 | .049 | .607 | .356 |
| $a_1$ Ceiling at $t_0$ > 7500 ft | .000 | .001 | -.002 | -.031 | -.528 | .560 |
| $a_2$ Ceiling at $t_0 \leq$ 100 ft and weather at $t_0$ fog or ground fog | .308 | -.236 | -.109 | .025 | -.013 | .025 |
| $a_3$ Ceiling at $t_0 \leq$ 400 ft | -.020 | .407 | -.260 | -.123 | -.005 | .001 |
| $a_4$ Ceiling at $t_0 \leq$ 900 ft | -.001 | .058 | .476 | -.418 | -.096 | -.020 |
| ⋮ | | | | | | |
| $a_{30}$ Ceiling at $t_0 \leq$ 400 ft and weather at $t_0$ drizzle or freezing drizzle | .058 | .021 | -.078 | .003 | -.019 | .015 |

Research efforts in the future will be centered around improving the accuracy of the guidance forecasts. TDL will also be expanding the guidance to variables other than ceiling and visibility.

## 15. Pilot briefing

The object of this task is to facilitate pilot briefing with the AFOS equipment. The software has just been completed, and a summary paper has been written (O'Neil et al., 1978). The presentation below is taken from this paper.

In order to provide a rapid recall of aviation information along a route of flight, the NWS has incorporated the Aviation Information Retrieval System (AIRS) into its newly developed AFOS system. The AIRS program is a special applications routine that runs on the AFOS Data General minicomputers. With a minimum of key-ins and within a few seconds, the briefer has assembled for display the pertinent alphanumeric information along a specified route of flight. The AIRS program also allows the briefer to complete, with a minimum number of entries, the pilot briefing log for the official record.

### 15.1 Procedures using the AFOS computers

To initialize the AIRS program, the briefer provides the following information:

- Departure point
- Intermediate points (optional)
- Destination point
- Type of briefing

Once the briefer types a valid command at the AFOS console for a route of flight, he then strikes the "enter" key. This activates the AIRS program and processing begins. When processing is completed, an initial display is placed on a selected AFOS screen. This display will contain the following information:

- The surface aviation observations (SAO's) and terminal forecasts (FT's) for departure, destination, and any intermediate points.

- A "menu" listing the data available for display and the character keys to be depressed to retrieve each data type.

Figure 12 presents a sample initial display of the AIRS program for a briefing from Washington, D. C. to Atlanta, Ga.

```
***OBSERVATIONS & TERMINAL FORECASTS AT
   TAKE-OFF & DESTINATION
  DCA SA 151805 CLR 12 156/061/043/32008/999

  DCA 151515 CLR. 09Z VFR

  ATL SA 151807 CLR 10 168/076/042/30008/003
      FEW CU W

  ATL 151010 CLR CHC 4 HK TIL 13Z.  16Z 250 SCT 2212
      OCNL 40 SCT 23Z 250-BKN.  04Z VFR..
       ENTER THE KEY FOR EVERY CATEGORY DESIRED

       KEY          CATEGORY

        E          EVERY CATEGORY
        Y          SYNOPSIS
        W          SEL's WATCHES
        S          SIGMETS
        A          AIRMETS
        O          SAO's
        P          PILOT REPORTS
        F          FTA's
        T          TWEBS
        D          FD1, FD2, FD3
        V          AVIATION AREA FORECASTS
       ------ ----------------------------
        L          LOG THE BRIEFING
        X          SUSPEND THE BRIEFING
```

Figure 12. Sample initial display of the AIRS program for a low altitude briefing.

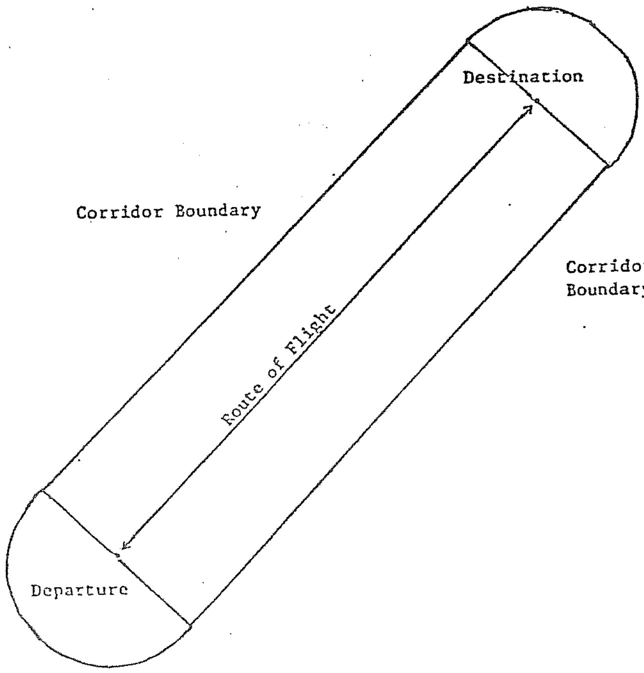
All product types listed in the menu in the initial display are available for call-up. For a Low Altitude briefing they are:

- TWEB (Transcribed Aviation Weather Broadcast) Synopses associated with any route which has a leg within the flight corridor.
- Severe local storm (SEL) forecasts covering any area through which the flight corridor passes.
- Sigmets and Airmets for any aviation area the flight corridor passes through.
- Surface Aviation Observations (SAO's) for any reporting system within the flight corridor.
- Pilot Reports for any state the flight corridor passes through.
- Terminal Forecasts (FT's) for any location within the flight corridor for which a forecast is prepared.
- TWEB Route Forecasts for any route which has a route leg within the flight corridor.
- Winds Aloft (FD1, FD2, FD3) for any forecast point within the flight corridor.
- Aviation Area Forecasts for any aviation area the flight corridor passes through.

## 15.2 AIRS flight corridors

When the AIRS program is activated by entering a valid command, the alphanumeric aviation products within a corridor along the specified route of flight are copied from the data base and packaged for display according to product type.

The flight route used by the AIRS software is a straight-line route connecting the departure point, any specified intermediate points, and the destination. Depicted in Fig. 13 is the configuration of the AIRS information coverage for each leg of a flight. Also shown is the configuration for a flight with two intermediate points.



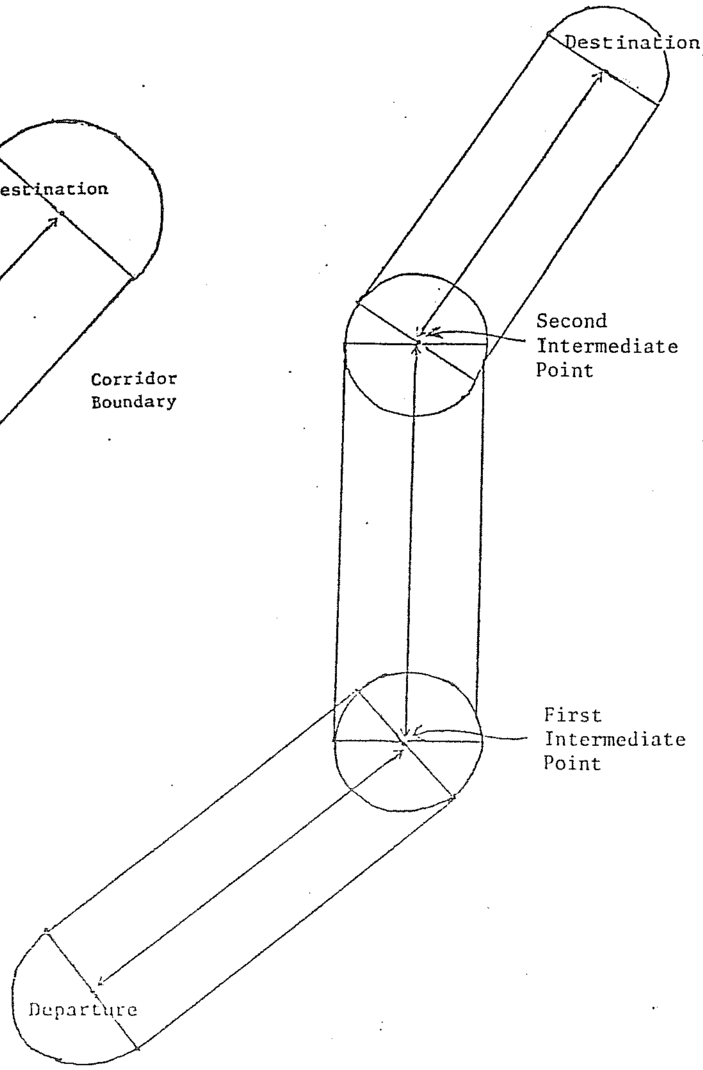




Figure 13. Configuration of AIRS information coverage for each leg of a flight (left) and for a flight with two intermediate points (right).

The corridor width along the straight-line route can be set by each office for each product type. For instance, the briefer may want a much larger corridor width for Winds Aloft forecasts than for surface observations. Also, a NWS office in the West would likely choose a larger corridor width for surface observations than one on the East Coast.

As can be seen in Fig. 13, information is also retrieved inside a semicircular area joining the corridor boundaries around the departure, intermediate, and destination points. The diameter of the semicircle is equal to the corridor width.

Products that fall within the flight corridor for each product type are sorted for display. The products are displayed in the order of the flight sequence within each product type grouping. Presented in Fig. 14 is a sample of an AIRS display of terminal forecasts and surface observations for a flight from Washington to Atlanta.

```
***TERMINAL FORECASTS
  DCA 151515 CLR. 09Z VFR..
  IAD 151515 CLR. 09Z VFR..
  CHO 151515 CLR. 09Z VFR..
  LYH 151515 CLR. 09Z VFR..
  ROA 151515 CLR. 09Z VFR..
  INT 151515 CLR. 09Z VFR..
  HKY 151515 CLR. 09Z VFR..
  AVL 151515 CLR. 09Z VFR..
  GSP 151515 250 SCT.  09Z VFR..
  AHN 151010 CLR CHC 3GFK TIL 13Z. 16Z 250 SCT
     2212 OCNL 40 SCT. 23Z 250-BKN. 04Z VFR
  ATL 151010 CLR CHC 4HK TIL 13Z.  16Z 250 SCT 2212
     OCNL 40 SCT
```

```
***OBSERVATIONS
  DCA SA 151805 CLR 12 156/061/043/32008/999
  IAD SA 151803 CLR 12 142/063/042/35006/995
  ADW SA 151800 CLR  7 142/061/041/00000/994
  CHO SA 151803 CLR 15 145/060/043/21005/996
  LYH SA 151803 CLR 25 142/067/038/23005/996
  ROA SA 151803 CLR 25 141/071/043/12008/996
  INT SA 151800 CLR  7    /072/045/00000/994
  HKY SA 151804 CLR 10 150/076/039/22005/008
  AVL SA 151807 CLR 12 165/070/034/12004/005
  GSP SA 151805 CLR 15 159/073/040/22009/002
  AHN SA 151804 CLR  8 155/079/041/26006/001
  ATL SA 151807 CLR 10 168/076/042/30008/003
      FEW CU  W
```

Figure 14. Sample of AIRS display of terminal forecasts and observations for a Washington National to Atlanta flight.

Once products are displayed on the screen, the capabilities of display paging and time indexing can be used. The briefer can look at multiple screens of data and, by striking a "previous version" key, look at older reports of all the data displayed by the AIRS program.

## 16. Interactive forecasting

One of the major benefits of AFOS will be the routine availability of locally-generated plots and analyses. These will include mesoscale versions of familiar charts, plus new types of analyses. An example of the latter is the isentropic cross section developed by Professors Cahir and Norman under contract at the Pennsylvania State University. They developed minicomputer programs which can produce, upon request of the forecaster, cross sections of potential temperature, geostrophic wind, relative humidity and Richardson number, plus extrapolated soundings at any point. These programs utilize significant-level data points explicitly to produce a more detailed vertical picture than can be inferred from conventional analyses on quasi-horizontal surfaces. As a result, the cross sections should help forecasters recognize frontal structures, unstable regions, zones of possible turbulence, jet stream structures, cloudy regions, and dry zones. In a follow-on contract, Cahir and Norman developed a "decision-tree" capability by means of which the forecaster would interact with the AFOS system to predict frontal weather from the cross sections plus surface, radar, and satellite data. Recently they applied a one-dimensional cumulus cloud model to help the forecaster estimate convective precipitation from radiosonde observations. Their latest report has just been printed (Cahir and Norman, 1978).

## 17. Future plans

As the AFOS system is implemented, we plan to develop additional forecast applications, subject always to availability of the necessary resources. One proposal being considered would utilize pilot reports as forecast aids and as a data source to update and monitor in-flight advisories and route forecasts. Another would depict geostrophic wind and vorticity at the earth's surface, without pressure reduction to sea level, in the manner described by Sangster (1960). A third proposal would program a numerical model of the Boulder wind developed by Klemp and Lilly (1974) on the minicomputer of the Denver WSFO. Other possibilities under consideration involve forecasts of small scale temperature variations, land-sea breezes, mountain-valley winds, Great Lakes snowfall, and many other mesoscale phenomena. Ultimately, any useful prognostic or diagnostic techniques capable of being programmed on a minicomputer may become part of the AFOS system.

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