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THE DEVELOPMENT OF A FIXED BASE AUTOMATED WEATHER SENSING AND D--ETC(U)
JAN 78 W R TAHNK, R H LYNCH

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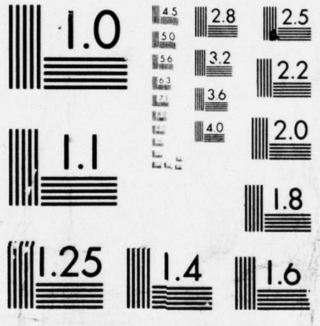

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AFGL-TR-78-0009
INSTRUMENTATION PAPERS, NO. 260

The Development of a Fixed Base Automated Weather Sensing and Display System

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6 January 1978

METEOROLOGY DIVISION PROJECT 6670
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AIR FORCE SYSTEMS COMMAND, USAF

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FOR THE COMMANDER

John Howard

Chief Scientist

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REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM
⑭ 1. REPORT NUMBER 2. GOVT ACCESSION NO. AFGL-TR-78-0009, AFGL-IP-260	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) ⑥ THE DEVELOPMENT OF A FIXED BASE AUTOMATED WEATHER SENSING AND DISPLAY SYSTEM.	5. TYPE OF REPORT & PERIOD COVERED Scientific. Interim. 6. PERFORMING ORG. REPORT NUMBER IP No. 260 ✓
7. AUTHOR(s) ⑩ William R. Tahnk Capt, USAF Richard H. Lynch	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Air Force Geophysics Laboratory (LYU) Hanscom AFB Massachusetts 01731	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS ⑯ 62101F 66700502 ⑰ 05
11. CONTROLLING OFFICE NAME AND ADDRESS Air Force Geophysics Laboratory (LYU) Hanscom AFB Massachusetts 01731	12. REPORT DATE ⑪ 6 JAN. [illegible]78 13. NUMBER OF PAGES 21
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) ⑨ Scientific interim rept.,	15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.	⑫ 23 p.
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)	
18. SUPPLEMENTARY NOTES	
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Modular automated weather system MAWS Automated sensors Markov model Automated display system	
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The Meteorology Division of the Air Force Geophysics Laboratory developed a computer-based observing system called MAWS (Modular Automated Weather System) to demonstrate the feasibility of automated observing and forecasting techniques using low-cost microcomputers. Scott AFB, Illinois, was chosen as the demonstration site, and operation commenced in January 1977. Instrumentation at five observing sites is polled periodically each minute, and then the data are transmitted on command to the central site	

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20. Abstract (Continued)

over voice grade telephone lines using microcomputers that were designed, built, and programmed by the authors. This use of on-site processing eliminated the need for expensive, high speed lines as well as centralized processing. Instead, a microcomputer in the base weather station acts as a supervisor to the four on-site microcomputers, directing the flow of information throughout the network. Parameters observed automatically include wind, temperature, visibility, pressure, and cloud base height. In addition, short range forecasts of visibility and cloud base height are generated. These data are then displayed on alphanumeric display devices located in operations centers around the base. MAWS data are also continually archived and the capability exists for hard copy printout when desired.

ABSTRACT

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The Development of a Fixed Base Automated Weather Sensing and Display System

1. INTRODUCTION

There exists in the Air Force today an immediate requirement for a stand-alone automated meteorological observing system which will operate in a fixed base environment. Such a system would provide the additional data needed to support new and sophisticated aircraft and communication systems, as well as represent a viable means of reducing Air Force manpower and expenditures with no degradation in weather support. Multicommand ROC 601-77, entitled Automated Weather Distribution System (AWDS) — which was recently validated at HQ USAF — provides a detailed presentation of the wide-ranging requirements herein and an outline of preferred solutions. An automated observing system is seen as a major component of AWDS.

Recognizing these needs and the immediacy of the solution, a project was initiated in January 1976 to develop a low-cost fully automated system which would be simple to maintain, modular in design, and open ended in its application. One phase of the overall project resulted in the installation of a prototype Modular Automated Weather System (MAWS) at Scott AFB, Illinois in January 1977 for the purpose of demonstrating the capabilities of current technology. This report will briefly describe the various components that make up the prototype MAWS, what its capabilities are, and the hardware and software refinements in the future for MAWS.

(Received for publication 28 December 1977)

2. SYSTEM DEVELOPMENT

MAWS is designed as a hands-off computer-based observing system which will automatically acquire, process, disseminate, archive, and display meteorological data gathered from sensors installed on the airfield. In addition, MAWS generates short range probability forecasts out to 3 hr for operationally significant thresholds of visibility and cloud base height. Finally, MAWS is capable of automatically maintaining surveillance over critical thresholds for certain weather parameters which are of significance to operational units, and of alerting them to the fact that the thresholds have been equalled or exceeded.

The microcomputer shown in Figure 1 constitutes the brains of the system. It is a laboratory designed, constructed, and programmed microcomputer which uses state-of-the-art industry components that are low in cost and high in reliability. Although not necessarily evident in Figure 1, the computer is made up of

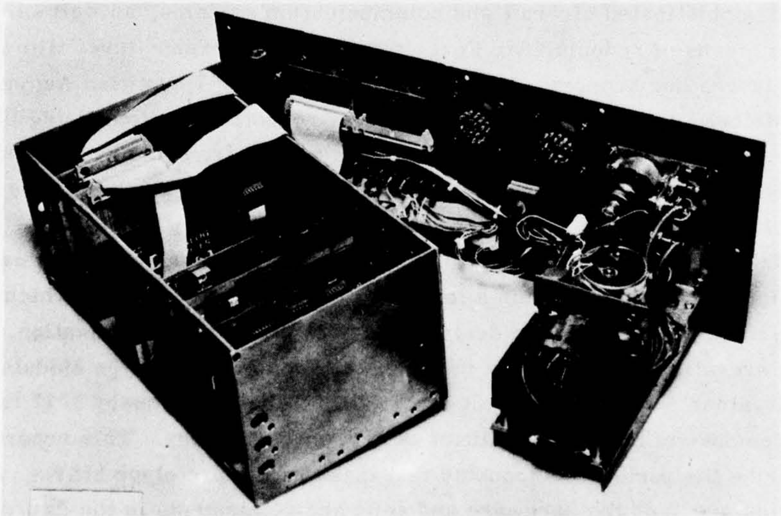

Figure 1. MAWS Microcomputer

a set of printed circuit cards which plug directly into the backplane. Each card serves a specific purpose, such as the central processor card or the communications interface card, and can be replaced without affecting the rest of the system, which is just one aspect of the modular design built into the MAWS system. These cards started out as hand wired versions of laboratory designs. Once it was determined through extensive testing that they met the design and performance specifications, detailed drawings were prepared and printed circuit cards were produced in quantity. From this "family" of cards, a microcomputer can be assembled quickly and economically to meet any specific requirement. A precision analog data acquisition and processing system can be assembled for component costs of about $2000. With a basic cycle time of 2 μsec, a typical instruction can be executed in 7 to 10 μsec and approximately 10,000 such instructions executed in 1 sec. As a result, the microcomputers in MAWS are capable of rapidly performing a great volume and variety of functions without taxing their full capability.

3. SYSTEM COMPONENTS AND PERIPHERALS

Rather than interface the microcomputers with all of the existing meteorological instrumentation at Scott AFB, the decision was made to introduce the Air Weather Service to sensors which had been used extensively in a successful research effort conducted at AFGL prior to the introduction of MAWS. Poles were erected at the two ends and the midpoint of the active runway as close to the conventional instrumentation as possible. These poles were then instrumented with our standard sensor package (see Figure 2) consisting of a forward scatter meter for visibility, a temperature/dew point set, and windspeed and direction sensors, at a height of 4 m in order to approximate the average cockpit height of Scott aircraft. In addition, a 50 m tower was erected as near to the approach zone as flying safety regulations would permit, and instrumented at the 25 and 40 m levels with the same sensor package. In summary, then, five observing sites were installed and instrumented, thereby providing the operator a fine scale cross section of temperature, wind, and visibility over the runway area.

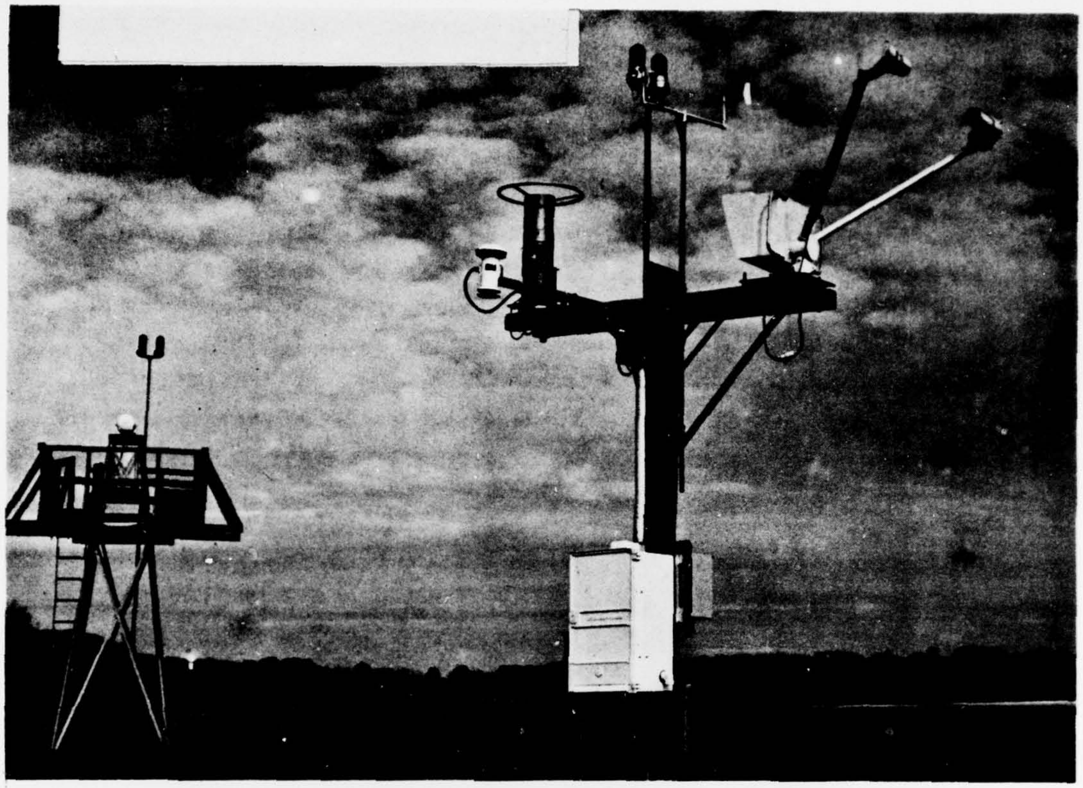

Figure 2. MAWS Instrumented Pole at Scott AFB

4. DATA PROCESSING, HANDLING, AND DISPLAY TECHNIQUES

Figure 3 is a schematic representation of the MAWS system at Scott AFB. Of particular note here is the application of the concepts of decentralized computers and on-site processing and manipulation of data. Microprocessors are deployed at each of the four sites and they acquire and process the data on command. Specifically, the temperature and visibility are sampled every 12 sec and the wind quantities every 6 sec, although all of the quantities could be sampled more than 500 times a second if needs warrant. Automated edit and self-test procedures are utilized in examining the data from the sensors to insure that erroneous data do not go undetected. The processed data are then relayed on command to the supervisory microcomputer at 120 characters per/sec across regular voice-grade telephone lines.

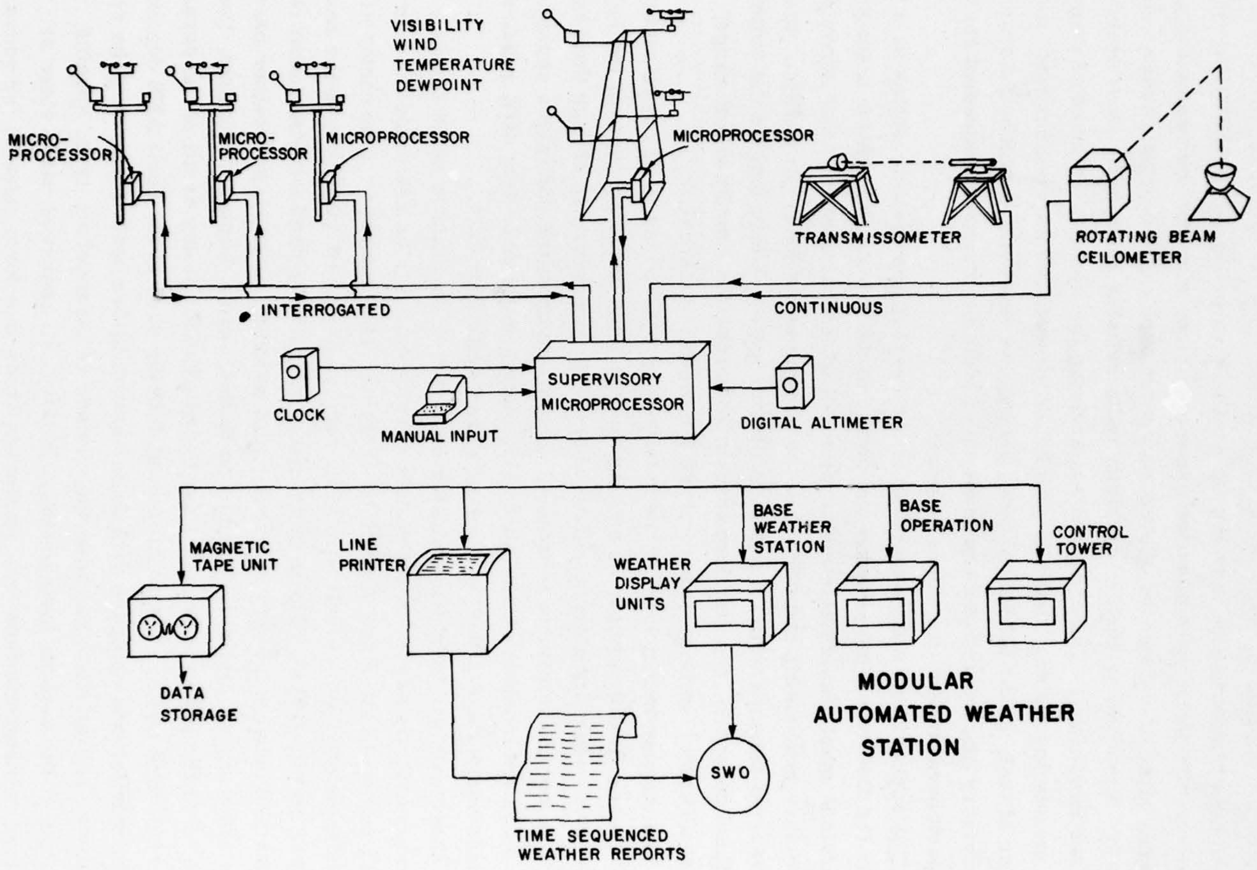

Figure 3. Schematic Representation of MAWS at Scott AFB

There are several distinct advantages to using this particular data processing and communication design. By condensing data with an on-site microcomputer, the need for expensive, high-speed conditioned lines is eliminated and the processed data blocks can be moved over ordinary voice-grade lines. Using the ubiquitous telephone system as the communications medium, one gains the ability to easily alter or expand the system as operational requirements change. Additionally, telephone service is normally quite reliable even in the most severe weather conditions. The computer supervising the system, relieved of many of the data processing chores, can now also be an inexpensive microcomputer. As a matter of fact, in the MAWS system, the remote data unit microcomputers and the supervisory microcomputer are made up of identical components except for analog and peripheral interfaces where required.

The supervisory microcomputer is the heart of the system, acting as a traffic cop in the flow of all information and data. In its role as the system manager, the supervisor must disseminate and archive all of the parameters after accomplishing further processing and editing of the remote units' data. In addition, there are several sensors which it must also interrogate. These include the ceilometers for cloud detection, the standard transmissometer for runway visual range, the digital altimeter setting indicator, and the digital clock/calendar.

The manner in which all of these tasks are carried out need not be rigid, but can be made flexible simply by making manual input to the system via the keyboard. Interactive capability already exists wherein the operator can change the sensor status at any of the remote locations. Hence, an operator can take a sensor or even an entire location off the air to eliminate questionable data until repairs can be made and without affecting the rest of the system or data.

These data are then disseminated on a real-time basis in several ways. Alphanumeric display units acting in a receive-only status are placed in a prominent position in all of the operations centers. They operate concurrently with, yet independent from, a unit with send-receive keyboard capability in the base weather station (BWS). These units are continually updated with the latest observations and provide a ready means for met watching most of the weather parameters affecting the airfield. In addition to the plasma display of the data, the operator at the BWS may request hard copy printout of any or all of the parameters on a real-time basis. The printer is also being used in the Scott AFB demonstration to monitor and compare data from several instruments measuring the same parameter as well as to examine the efficacy of the number, type, spacing, and elevation of the various instruments. Finally, all observed parameters are archived on magnetic tape on a continuous basis in a form suitable for convenient recall for climatological or technique development purposes, and for use in refining the forecast model that is resident in MAWS.

Figure 4 is a front view of the microcomputer used in MAWS. The raw signals from the sensors are brought in through the connectors at the top, with one connector capable of carrying 8 channels of data. Interaction with the microcomputer is carried out using the eight switches on the front panel. Communication with the outside world is established by connecting the microcomputer to a phone line via a telephone modem. Also shown in Figure 4 is the keyboard and display unit used in MAWS. Figure 5, though, provides a better view of the three components that make up the MAWS data display. Each of the three components, the keyboard, the display, and the electronics unit, can be physically separated from the other, which readily lends itself to this type of application. Imagine a control tower with limited space in which one could actually mount the 5-cm thick display panel on the wall, place the keyboard on a table below the display panel, and locate the electronics unit under the table with only the display's umbilical cord showing.

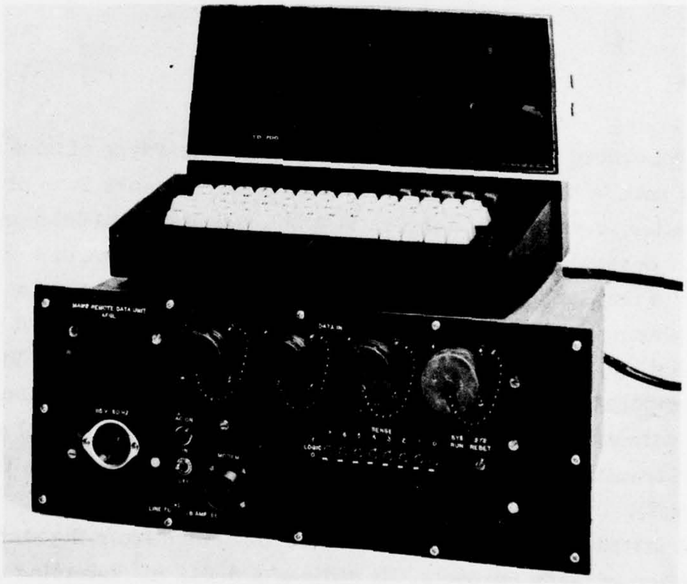

Figure 4. MAWS Display Unit and Remote Microcomputer

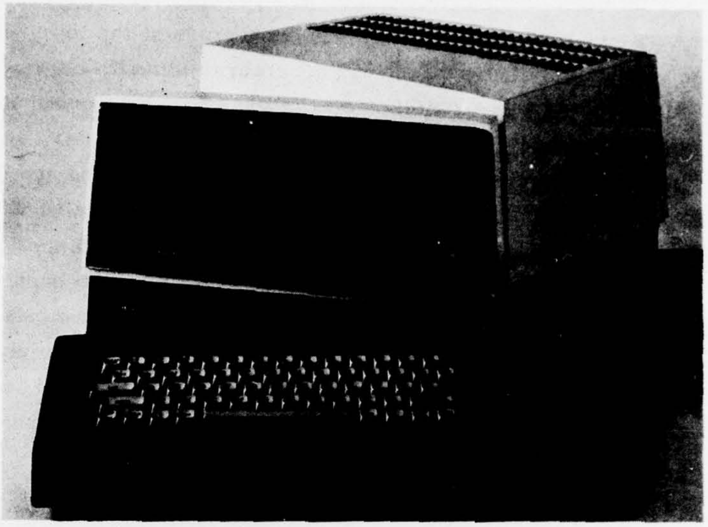

Figure 5. MAWS Display Unit

5. SENSORS

Before proceeding on to a discussion of the form and type of data which appears on the display unit, a brief description of the weather sensors is in order. As mentioned earlier, a variety of sensors is employed in the MAWS demonstration at Scott AFB. Several of these sensors were thoroughly tested in a similar type of application in the Hanscom AFB mesoscale field test experiment as previously described by Hering.[1] These included the EG&G Model 207 Forward Scatter Meter (FSM) for visibility, a Climatronics Mark I Wind Set, and an EG&G Model 110S-M Automatic Temperature and Dew Point Set (see Figure 2). In addition, the system is interfaced with a Sperry Digital Altimeter Setting Indicator (DASI) and the standard AWS transmissometer for Runway Visual Range (located to the left of the pole in Figure 2).

The FSM instrument represents a notable departure from the standard AWS transmissometer in many respects. It utilizes a 0.048 m^3 sampling volume between a projector and receiver, that are separated by 0.9 m, to measure the visual range. Even though it is based on the amount of forward scattered light, the FSM is insensitive to the type of visibility restrictor present. In addition, it filters out

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1. Hering, W.S. (1974) Hanscom mesoscale field test facility, Proc. of AMS Fifth Conf. on Weather Forecasting and Analysis.

the background illumination, has the advantage of small size and ease of calibration and installation, and has an effective visual range of 0.06 km to >16 km. The wind set provides an extremely accurate method of determining the characteristics of the wind. It is light weight, has low power consumption and has a very low start-up threshold for windspeed. The EG&G temperature set is ideally suited for all types of meteorological research, and environmental control and monitoring applications. It utilizes platinum resistance thermometers for both temperature determinations to an accuracy of ±0.3 C. The dew point set employs a thermoelectrically-cooled detection mirror held exactly at the dew point (or frost point below 0^{o}C) and a condensate-detecting optical system to precisely determine the dew point temperature.

The DASI used in MAWS has proven to be an extremely rugged yet reliable pressure measuring device. It utilizes a highly-sensitive vibrating diaphragm to sense pressure, and has been specifically designed for use in aircraft operations. Its proven long-term stability and insensitivity to a wide range of pressure exposure makes it ideal for an automated system, and has led to its acceptance by the Federal Aviation Administration for use in control tower operations.

The AWS transmissometer measures visual range based on light projected toward a receiver located 152 m away. The visual range is directly related to the percent transmission of light through the sampling volume, and the effective range of the instrument, with a baseline of 152 m, is 0.2 km to >10 km. Unlike the FSM, the transmissometer requires frequent calibration, can only be moved by mechanized apparatus, and requires considerable real estate since the 152 m path from projector to receiver must be unobstructed.

An interface to the microcomputer was designed and built to acquire the analog signal from each of the sensors. The signal is then passed to an analog-to-digital converter capable of resolving 1 part in 4096, which for the temperature set yields an accuracy of ±0.024°C over the range of -50°C to +50°C.

While the above-mentioned sensors were easily automated, the integration of the Rotating Beam Ceilometer (RBC) into MAWS was by far the most complex interface and automation problem encountered in this effort. The rectified and filtered dc signal from two RBCs has to be acquired, processed, and analyzed automatically and continuously without affecting the manual determination of the cloud base height. In addition, the hardware had to be generalized enough so that it could be applicable to any RBC and any lamp. The resultant hardware interface successfully establishes a background level from each 90 degree scan of the source lamp, filters out spurious and unwanted returns, and provides for automatic gain and offset adjustment under software control. The conditioned signal is then analyzed by the software in real time to identify primary and secondary peaks, which represent the cloud base structure over the observing site for heights ranging from 15 to 1450 m.

6. DISPLAY PARAMETERS

Each alphanumeric display unit in the demonstration MAWS is provided four pages of display, each of which is updated once per minute. Pages one and two display the most operationally useful data, of the type currently transmitted by the observer to operational units on the base using the teleautowriter. These pages, therefore, have longer visual residence time on the display than pages three and four. An example of each of the four pages is provided with the individual page description.

6.1 Page 1: Basic Data Page (Figure 6)

6. 1. 1 CBH: Cloud Base Height

The normal 90 degree scan from the RBC is divided into 360 distinct bytes of data, each representing the magnitude of reflected and scattered light and tagged for each 0.25 degree of elevation up to 90 degrees. After acquiring 1 trace every 12 sec, the software applies a rigorous averaging and filtering scheme to arrive at a representative cloud base height for each minute. The result will be a value of sky condition in one of the following forms:

(a) An obscuration.

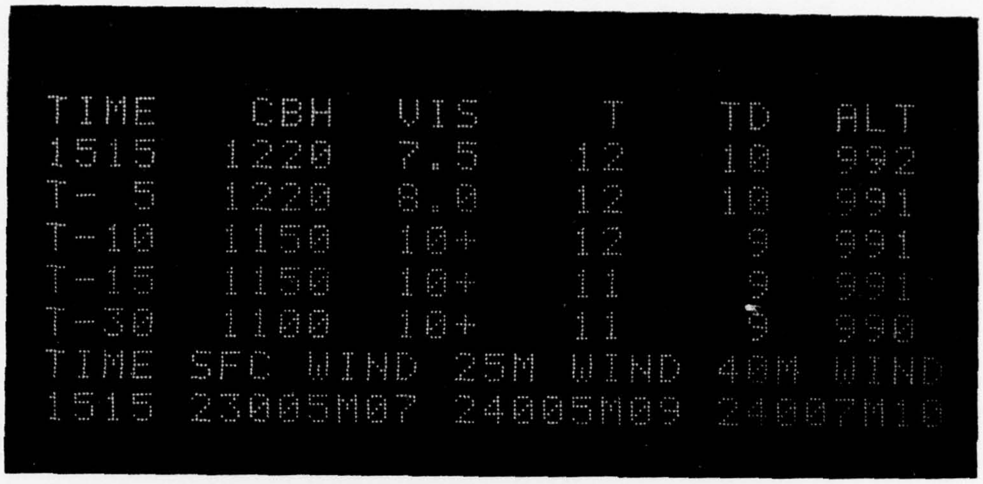
(b) A reportable cloud base height ranging from 15 to 1450 m (50 - 4800 ft) for a base line of 152 m (500 ft). This corresponds to clouds at elevation angles of from 5 to 84 degrees.

(c) No reportable cloud base height.

6. 1. 2 VIS: Prevailing Visibility

As a means of determining the prevailing visibility for a station, an observer is reporting on his ability to recognize dark objects against the horizon sky in the daytime and lights at night. According to Allard's law (when lights are used as targets) and Koschmieder's law, one can prescribe the instrument equivalent of prevailing visibility based on the atmospheric extinction coefficient which is directly related to the amount of forward scattered light. As will be shown later, this conversion from extinction coefficient to prevailing visibility differs from the conversion to Runway Visual Range (RVR) due to the assumed intensity of the light source and the threshold luminance values.

Using the output from the FSM at the 25 m level of the tower, the 1-min mean instrument equivalent of prevailing visibility is computed based upon a light intensity of 25 cd at night and 5.5 percent threshold contrast in the daytime. Taken at this height, the FSM output is presumed to approximate the visibility as determined manually from the control tower. The reported range of values is from 0.06 to 10+ km (0.05 to 7+ mi).



```
TIME    CBH  VIS    T   TD  ALT
1515   1220  7.5   12   10  992
T- 5   1220  8.0   12   10  991
T-10   1150  10+   12    9  991
T-15   1150  10+   11    9  991
T-30   1100  10+   11    9  990
TIME SFC WIND 25M WIND 40M WIND
1515 23005M07 24005M09 24007M10
```

Figure 6. MAWS Display: Page 1

6.1.3 T AND TD: Ambient and Dew Point Temperature

The T and TD values are 1-min mean values of temperature reported to the nearest whole degree. The reported value will range from -50 to +50 C (-59 to +120 F)

6.1.4 ALT: Altimeter Setting

The system acquires the altimeter setting once every 53 sec from the DASI and displays it in inches of mercury.

Note: All of the above-mentioned parameters are reported for the current time as well as for 5, 10, 15, and 30 min earlier to show the trend in the data.

6.1.5 SFC WIND; 25M WND, AND 40M WND

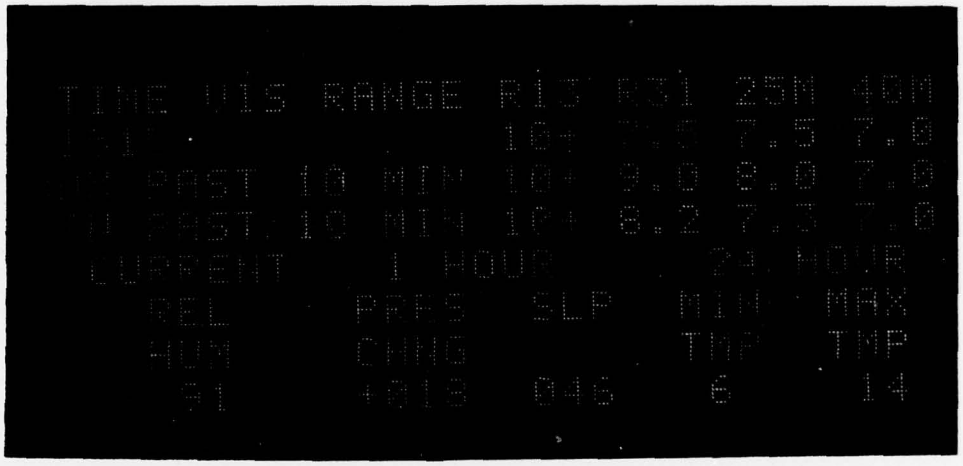
With the Scott configuration of wind sets on the surface and at the two levels of the tower, MAWS is able to provide the operators a rather complete picture of the horizontal and vertical variability in the wind up to 40 m over the airfield. The system uses 10 samples to formulate the 1-min mean wind direction and speed values. In addition, the wind speed is continually being sampled (as often as 1000 times per sec) at all locations so that the maximum instantaneous wind speed (displayed immediately after the M on the bottom row of Figure 6) is also reported for the latest 5 min period. The wind direction is reported in whole degrees to the nearest tens of degrees and the wind speed in msec^{-1}.

Note: The CBH, T, TD, and SFC WND values reflect conditions at the active end of the runway, because its selection is under the control of the operator. The default runway for the system at Scott is 31.

6.2 Page 2: Three Dimensional Portrayal of RVR (Figure 7)

6.2.1 VIS RANGE: Runway Visual Range (RVR)

The RVR is determined instrumentally based on FSM measurements of extinction coefficient. Although one uses the same threshold luminance and intensity values in the daytime for prevailing visibility and RVR (above 1200 m), for all other times the computation of RVR is based on intensity values associated with runway light setting 5. The latest RVR is reported once a minute for the two ends of the runway and for the two levels of the tower, based on the average of 5 values 12 sec apart. In addition, the minimum and maximum values in the past 10 min are displayed. Hence, the user has a continuous display of the real-time variability of the RVR in three dimensions: in the vertical, the horizontal, and in time. The reported RVR ranges from 0.15 to 10+ km (0.09 to 7+ mi).



```
TIME VIS RANGE R13 R31  25M  40M
1517           10+ 8.5  7.5  7.0
MX PAST 10 MIN 10+ 9.0  8.0  7.0
MN PAST 10 MIN 10+ 8.2  7.3  7.0
 CURRENT    1 HOUR       24 HOUR
   REL      PRES  SLP  MIN   MAX
   HUM      CHNG       TMP   TMP
    91      +019  046   6     14
```

Figure 7. MAWS Display: Page 2

6.2.2 CURRENT REL HUM: Relative Humidity

The relative humidity is computed each minute and reported in whole percent based on the latest temperatures observed at the active end of the runway.

6.2.3 1 HOUR PRES CHNG: 1 Hour Change in Sea Level Pressure

The hour-to-hour change in sea level pressure is reported in tenths of millibars, with the tendency also reported (either + or -).

6.2.4 1 HOUR SLP: 1 Hour Sea Level Pressure

The sea level pressure, reported in tenths of millibars, is computed from the hourly altimeter setting using a standard barometric formula.

6.2.5 24 HOUR MIN TMP, MAX TMP

The minimum and maximum temperature in the past 24 hr is reported to the nearest whole degree C.

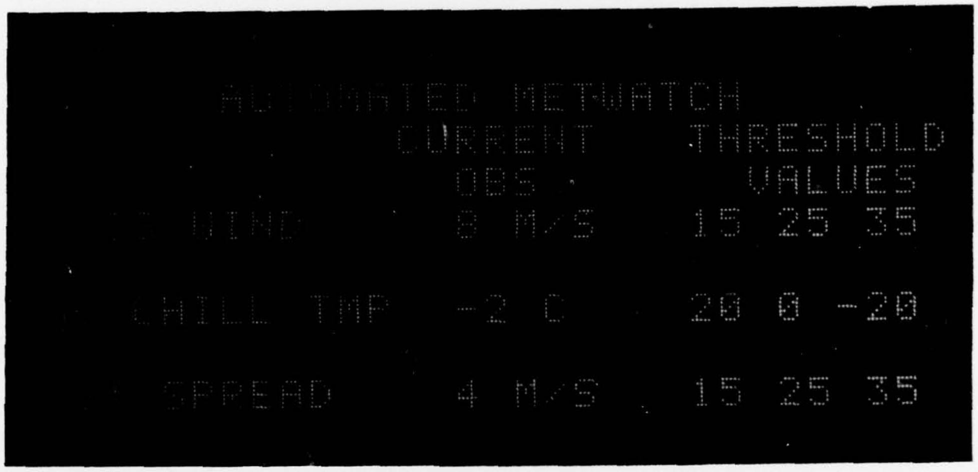
6.3 Page 3: Probability Forecasts (Figure 8)

Using 20 years of unconditional climatology data of visibility and ceiling at Scott AFB, algorithms resident in MAWS were developed for use in a Markov stochastic model to generate exceedance probabilities for short range forecasting. The following independent variables are used as input to the model on a real-time basis: the current active runway RVR and cloud base height, time of day, season of year, forecast time, sunrise time, and thresholds. The result is the probability of exceeding those thresholds at forecast time. For the Scott demonstration, the forecast times chosen were 15, 30, 60, and 180 min and the thresholds are 1200 m and 400 m for RVR (0.75 and 0.25 mi), and 305 m and 90 m for CBH (1000 and 300 ft). The probabilities are reported in whole percent ranging from 0 to 100. The lower limit of the forecast probability range is the actual climatological frequency of occurrence for that event, also expressed as a percent, but with decimal point shown.

Figure 8. MAWS Display: Page 3

6.4 Page 4: Automated Met Watch (Figure 9)

Certain parameters have been specified as met watch criteria for Scott AFB based on their operational significance. The system computes the parameters described below and then compares the result against the thresholds that have been entered into the system. In principle, if a threshold is equalled or exceeded, MAWS would automatically activate an alarm at the operations center of the unit affected by the criteria, thereby alerting them to a hazardous condition. For example, if a cross wind component of 15 msec^{-1} is critical to C-130 operations, an alarm would automatically sound at Scott Operations Center when that value was equalled or exceeded.



```
       AUTOMATED METWATCH
                CURRENT    THRESHOLD
                  OBS        VALUES
   WIND         8 M/S     15 25 35

  CHILL TMP    -2 C       20 0 -20

   SPREAD       4 M/S     15 25 35
```

Figure 9. MAWS Display: Page 4

6.4.1 CROSS WIND

The cross wind component is reported in msec^{-1} and compared against the thresholds of 15, 25, and 35 msec^{-1}.

6.4.2 WND CHILL TMP

The wind chill temperature is reported in whole degrees C and compared against the thresholds of 20°C, 0 C, and -20°C.

6.4.3 GUST SPREAD

The wind gust spread represents the difference between the maximum and minimum instantaneous wind gusts observed over the latest 5 min period and reported in msec^{-1}. The thresholds of interest are 15, 25, and 35 msec^{-1}.

Note: All three parameters on page four are computed using the surface data from the active end of the runway and are updated once a minute.

7. DATA REPRESENTATIVENESS

Two major departures from standard practice which MAWS demonstrates are total reliance on automated sensors to observe cloud base height and prevailing visibility. As a demonstration of the representativeness of the automatically observed data versus manually observed data, Figure 10 is a plotted depiction of two episodes of inclement weather at Scott AFB. The upper plot shows the sensor equivalent cloud base height, as determined by MAWS, versus the manually observed values. The lower plot is a comparison of the sensor equivalent and the manually observed prevailing visibility during an episode of very low visibility. The number of points plotted reflects the number of observations taken during that period by both the automated and manual methods. Clearly, the two observing techniques track each other extremely well. In the case of the cloud base height comparison, it should be noted that the observer relies almost exclusively on the CRT display of the same RBC output that the automated technique has analyzed. Prevailing visibility, on the other hand, is determined manually from totally independent considerations as compared with the MAWS automated determination of same, and yet the comparison is excellent.

8. FUTURE DEVELOPMENT

Future versions of MAWS will be sporting rather significant hardware and software refinements over the prototype system installed at Scott AFB. The application of emerging state-of-the-art technology will further reduce the cost and time that goes into assembling a MAWS-type system. The future systems will have such improvements as redundancy of components, uninterruptible power supply, and single-board computers where applicable. The programs will be made even more generalized so that an operator need only input certain data at program initiation to tailor the software to the particular application or base. We will continue to expand the built-in edit and debug procedures and add test programs for self-diagnosis of questionable components, sensors, peripherals, phone lines, and modems.

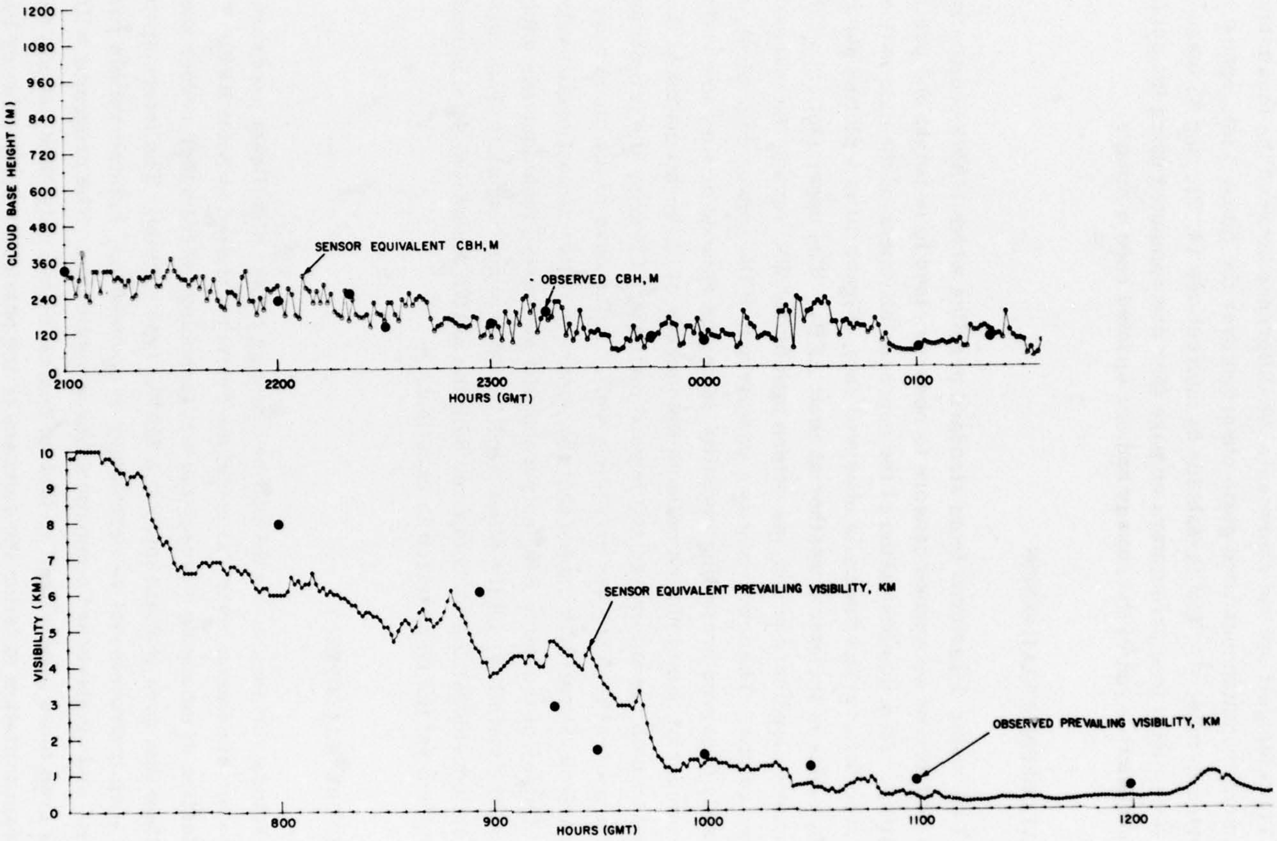


Figure 10. Comparison of Sensor Equivalent vs Manually Observed Data at Scott AFB

From a meteorological standpoint, further work will be done in a number of areas. Additional sensors will be examined for possible inclusion in a MAWS-type observing system. These would include laser-based ceilometers and slant visual range indicators, runway condition indicators, radiometers, automatic rain gauges, and inexpensive pressure transducers. Likewise, the specification and/or prediction of a number of other parameters remains to be done. These include cloud type and amount, type and intensity of present weather element or visibility restrictor, slant visual range, rate of precipitation accumulation, air quality, wind shear in the horizontal and vertical, runway condition, and severe weather parameters. While some of these planned activities may involve the use of the Scott demonstration model, most will be conducted within broader project objectives and will be the subject of later reports and articles on automation.

9. CONCLUSION

Although the Scott AFB prototype MAWS system will continue to undergo modification and improvement, it goes a long way towards fulfilling the needs of AWS for an automated observing system as described in Multicommand ROC 601-77, entitled Automated Weather Distribution System (AWDS). In fact, it touches on many of the AWS requirements for the future, such as the need for high speed communications, the use of automated on-base data dissemination systems, the ability to generate accurate short-range forecasts and met watch the weather automatically, and the potential for interfacing with other weather systems of the future and with a host of DOD command, control, and communications systems.

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