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Final Report on the Evaluation of ASOS for the Kennedy Space Center's Shuttle Landing Facility

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1.0 Introduction

1.1 Purpose of the Report

This report documents the Applied Meteorology Unit's (AMU) evaluation of the effectiveness and utility of the Automated Surface Observing System (ASOS) in terms of spaceflight operations and user requirements. In particular, the evaluation determines which of the Shuttle Landing Facility (SLF) observation requirements can be satisfied by ASOS. This report also includes a summary of ASOS' background, current configuration and specifications, system performance, and the possible concepts of operations for use of ASOS at the SLF. This evaluation stems from a desire by the Air Force to determine if ASOS units could be used to reduce the cost of SLF meteorological observations.

1.2 Organization of the Report

The information is presented in six major sections. Section 1, Introduction, describes the ASOS program and its published capabilities. Section 2, ASOS Evaluations, describes and summarizes various evaluations comparing ASOS observations to manual observations. Section 3, Requirements Analysis, compares ASOS capabilities with spaceflight operations observation requirements. Section 4, Meteorological Sensors in the St. Johns River Valley, discusses the use of the meteorological sensors along the St. Johns River Valley to help improve the fog forecasting skill and supply additional data. Section 5, Proposed Concepts of Operations for ASOS at the SLF, describes the optimum ASOS configuration for the SLF along with the proposed concepts of operations for ASOS at the SLF. Finally, Section 6, Summary and Conclusion, summarizes the ASOS overall performance, relates it to spaceflight operations and user requirements, and ends with a final conclusion.

1.3 ASOS Description

This section describes ASOS and its operation including background, instrumentation, system architecture, and data dissemination. In addition, ASOS system specifications are noted and compared to the SLF and Transoceanic Abort Landing (TAL) site observational system specifications. This provides the reader with information on the capabilities of ASOS relative to other observational systems used by NASA.

1.3.1 Background of ASOS

ASOS, developed by AAI Corporation, is an integral part of the National Weather Service Modernization and Restructuring Program. The ASOS program is a joint effort between the NWS, the Federal Aviation Administration (FAA), and the Department of Defense (DoD). Starting in late summer 1991 and extending through 1996, up to 1700 ASOS systems will be installed across the United States, many replacing current part-time and full-time manual observing sites. As of August 2, 1993, there were 311 ASOS units installed. Of these, 22 were commissioned (which means ASOS has assumed the official observing role).

There have been a number of automated weather systems designed and procured by the federal government in the past that have successfully demonstrated the automation of temperature, dew point, wind and pressure observations. Research projects and studies on the feasibility of automating the observation process date back to the 1960's. The feasibility of automating the more subjective, spatially observed elements such as sky condition and visibility was first demonstrated during the joint FAA-NWS AViation Automated Weather Observing System (AV-WOS) experiments in the mid 1970's. "It was not until 1981 when the Joint Automated Weather Observing System (JAWOS) study concluded that the sensor and computer technology was mature enough to go forward with automation at airports" (Sessa 1993). Additional development and testing of present weather sensors by the NWS proved that rain, snow, and freezing rain could also be successfully detected, discriminated, and reported by an automated system. These advances in surface observing technology are now incorporated in the ASOS under the lead of the NWS (NOAA 1992).

ASOS consists of several meteorological instruments spread out along a single 40 foot long framework. Once each minute, ASOS updates the observation of all basic weather elements (sky conditions, visibility and obstructions to vision, sea-level pressure, temperature, dew point, wind, altimeter setting) and selected automated remarks. It also accepts manually entered remarks such as variable visibility and tower visibility. Each hour, ASOS automatically generates information in the coded Surface Aviation Observation (SAO) form. In addition, ASOS automatically issues a special report in SAO form whenever a parameter violates one of the special criteria thresholds.

The ASOS User's Guide (NOAA 1992) defines the standard ASOS configuration, the Combined Sensor group, which is illustrated in Figure 1.1. The Combined Sensor group consists of the following sensors: ceilometer (cloud height indicator), visibility sensor, precipitation identification sensor, freezing rain (ZR) sensor (not included where ZR potential is nil), three pressure sensors, ambient temperature/dew point temperature sensor, anemometer (wind direction and speed) sensor, and precipitation accumulation sensor. This group is typically located near the Touchdown Zone of the runway and on occasion at a center field location. At large airports or where the operational need is justified, an additional sensor array may be located at a secondary Touchdown Zone. The ASOS User's Guide refers to this array as the ASOS Touchdown Sensor group. This sensor array, illustrated in Figure 1.2, consists of a ceilometer and visibility sensor. Site surveys are conducted at each site to determine the best location(s) for siting the ASOS sensors.

Additional sensors or sensor groups may be added as part of the ASOS setup to function in either a backup or discontinuity role. In the backup role, the additional data are used if the primary sensor fails. Discontinuity sensors are employed where geographical or meteorological factors cause significantly different conditions to persist at two or more locations at an airfield and are installed in these areas of interest. When non-prevailing conditions are detected, the ASOS will alert users by automatically generating remarks which describe the situation (e.g. visibility and/or ceiling lower with the appropriate compass direction) and which will be included in the special SAO report (NOAA 1992).

The ASOS was designed and tested to operate in the most extreme environmental conditions. For example, some of the tested extremes include temperatures from -80°F to 140°F, desert conditions with high levels of dust to coastal conditions with salt fogs and sprays, and 120 knot winds with three inches of ice (Sessa 1993). A proven example of system performance in a severe weather event involves the ASOS unit in Concordia, Kansas. This unit survived a severe gust front with peak gusts to

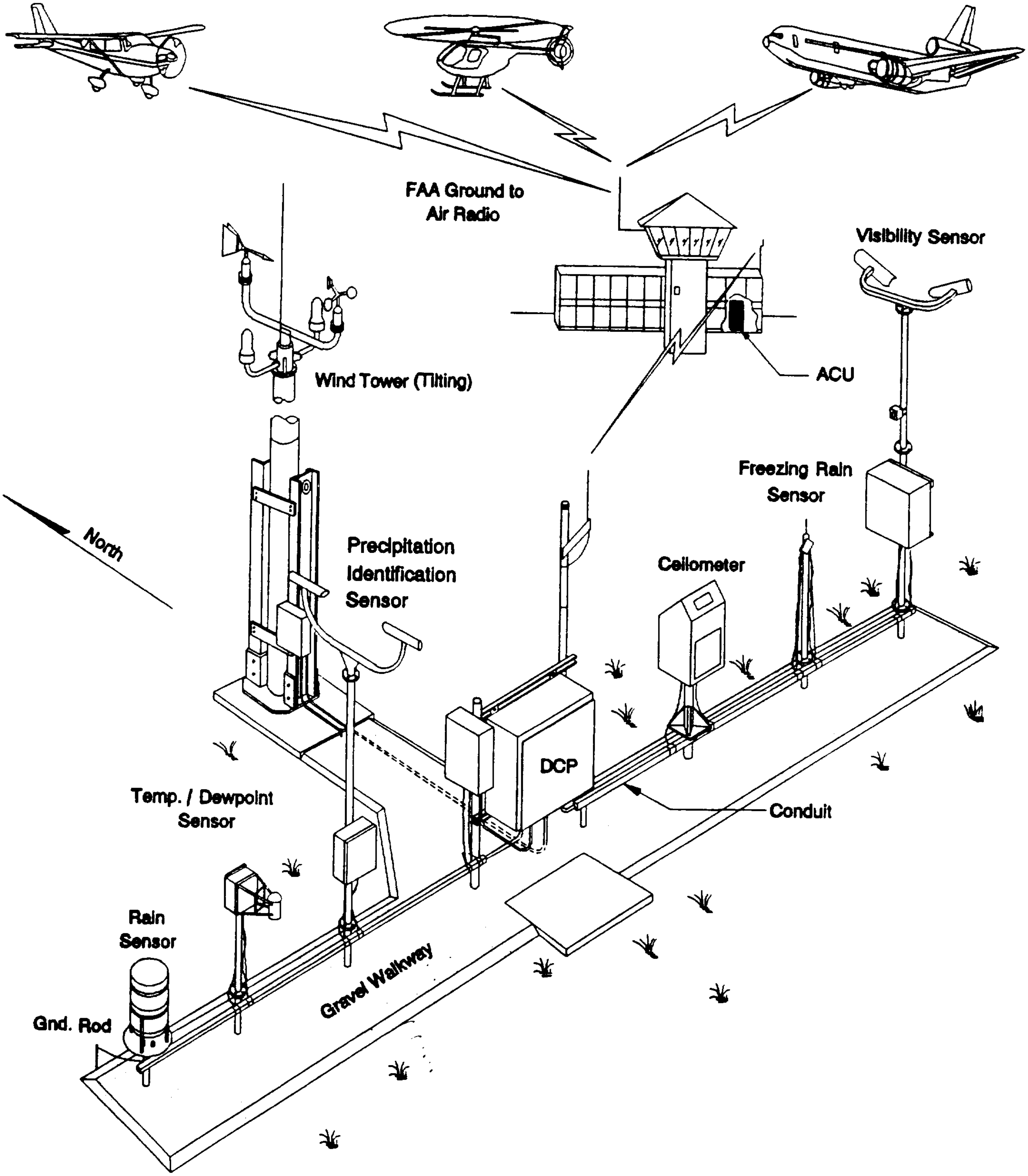

Figure 1.1. ASOS Combined Sensor Group Configuration (NOAA 1992)

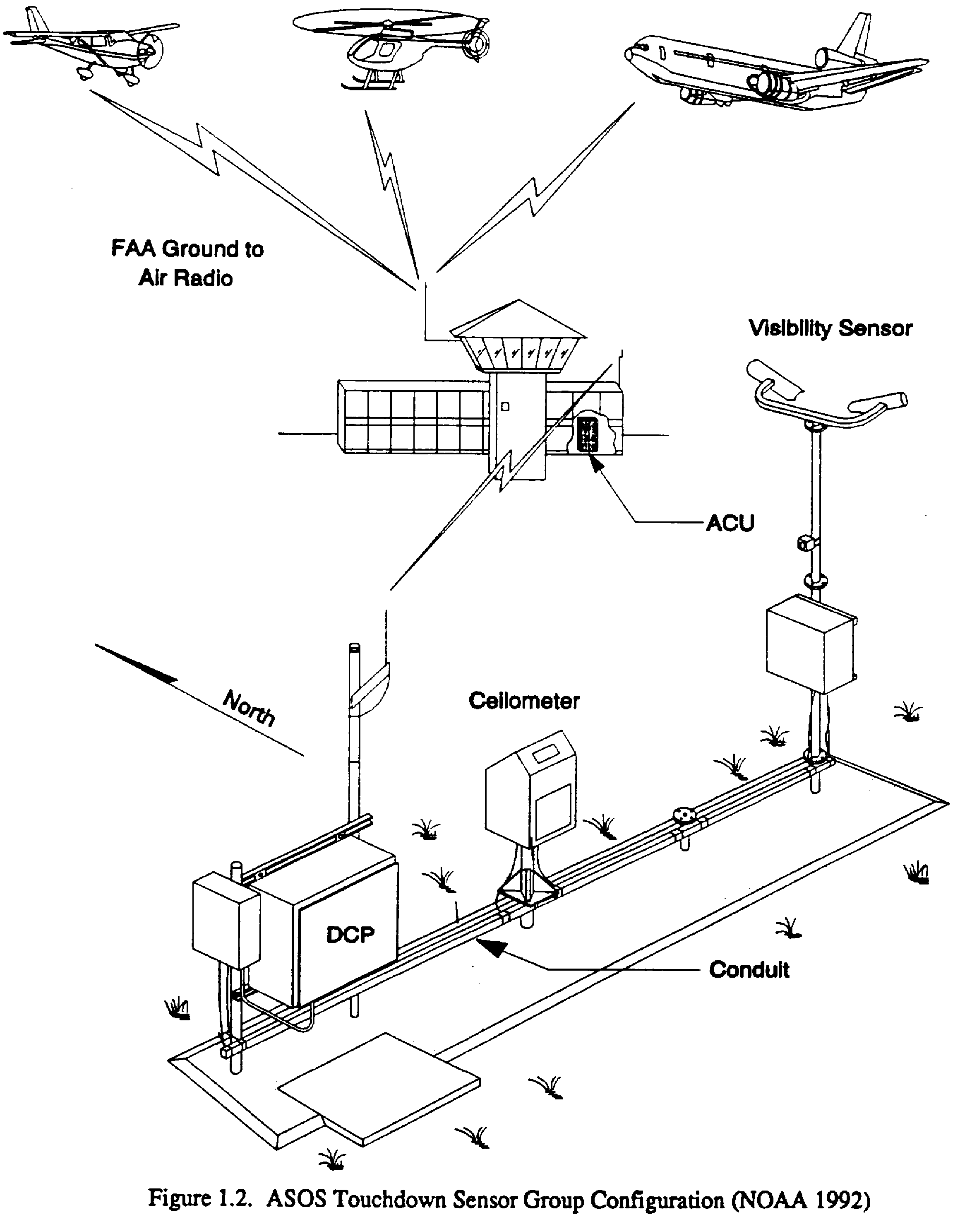

Figure 1.2. ASOS Touchdown Sensor Group Configuration (NOAA 1992)

110 mph. It was able to continue recording and disseminating minute by minute reports and operate normally throughout the event, switching onto its internal backup power when facility power was lost. The Uninterruptable Power Supply (UPS) battery kept it operating and retaining accurate readings for an hour and 20 minutes. The only damage sustained was attributed to flying debris (NWS Central Region 1992).

1.3.2 System Architecture

The ASOS is divided into two parts. The outdoor portion consists of one or more sensor suites and Data Collection Packages (DCP). The indoor portion consists of a central Acquisition Control Unit (ACU) and a series of display systems.

The DCP consists of computer, communications and power subsystems. The computer subsystem contains a primary CPU and a backup CPU which monitors the operation of the primary and takes over in the event of a failure. The unit also contains a number of communication boards and Built-In Test Equipment which continuously monitors the status of the DCP and sensors. The power subsystem consists of the DCP's own internal power supply (each has a built-in backup unit), the UPS (which provides backup facility power to the DCP and sensors), and power monitor, control, and conditioning circuits for each sensor. The communications subsystem also has a backup for its primary radio telemetry module. Each DCP has the ability to accommodate up to 16 sensors so the system's capabilities can be expanded as needed.

The ACU is the central data processing/dissemination component of ASOS. It consists of a computer, an UPS, a communications subsystem, and the local DCP. The local DCP allows the three pressure sensors and three additional sensors to be directly connected to the ACU. The computer collects data from all of the sensors and other weather systems, processes the data in accordance with NWS and FAA approved algorithms, and formats and distributes the information to users. The UPS is identical to the unit in the DCP and provides backup in the event of loss of facility power. The ACU also contains full redundant internal power supplies (Sessa 1993).

A basic system diagram of the data collection and data processing operation of ASOS is shown in Figure 1.3. In the normal mode of operation the DCP makes data requests and diagnostic requests of each sensor at a predetermined rate (e.g., every 5 seconds for wind data, 30 seconds for ceilometer, etc.). The DCP collects the data and test results from the sensors and periodically runs internal tests on itself. All of this information is then compressed and transmitted via radio modem to the ACU.

The ACU polls all of its DCPs and retrieves weather data and diagnostic test results at a preset rate. The ACU also retrieves additional information from other systems (RVR, ADAS) to which it is connected. Once the system has collected the data and evaluated the test results, the ACU runs data quality checks to determine its validity and then processes the raw sensor data according to NWS specified algorithms. After the sensor data passes these quality checks, the resulting weather information is output via peripherals and output ports. If the ACU detects a failure in either the hardware test results or the data quality checks (every ASOS component is tested at least every seven minutes) any output parameter which may be affected by the failure is marked as missing on the displays and output channels and a maintenance technician is automatically notified (Sessa 1993).

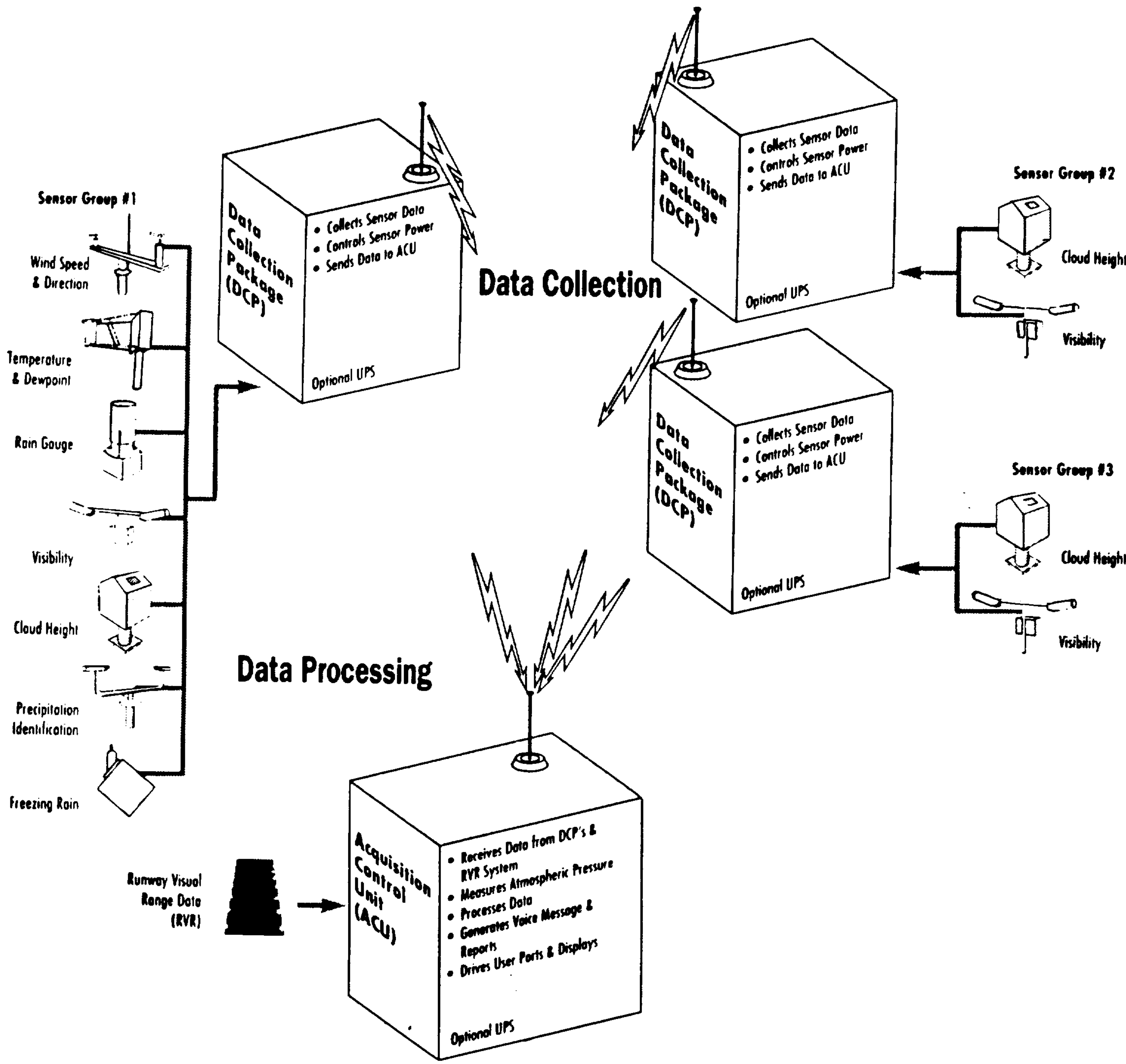

Figure 1.3. ASOS Data Collection and Processing Diagram (AAI/SMI 1992)

1.3.3 Data Dissemination

ASOS data may be accessed through a variety of media. Video displays are available for on-site and remote users in the interactive (input terminal) and non-interactive (display terminal) mode. Additional video display hook-ups may be made available to airlines and external users of the airfield. Nationwide long-line

ASOS messages occur through the NWS and FAA communications network. The NWS communications network consists initially of the Automation of Field Operations and Services (AFOS) system but beginning in the mid 1990s, AFOS will be replaced with the Advanced Weather Interactive Processing System (AWIPS). This communication modernization is expected to be completed in the late 1990s.

Besides the long-line dissemination through the NWS and FAA, authorized remote users may also access ASOS data via the ASOS remote user dial-in port. Data observed each minute, the ASOS site characteristics, maintenance logs, etc. are available through this access port. Computer generated voice messages are provided by ASOS for local FAA radio broadcast to pilots and are made available for general aviation use through a dial-in telephone number provided at each location (NOAA 1992).

1.3.4 System Specifications

Table 1.1 lists the ASOS instrumentation specifications and compares them to the SLF and the TAL site surface observation equipment's range and accuracy. This is included to provide information on the capabilities of ASOS in relation to current observational systems used by NASA.

"ASOS sensor selection was performed through an analytical approach that took performance, specification compliance, acquisition cost, reliability and maintainability, and field experience into account. Sensor field experience weighed heavily in the decision. The sensors selected by AAI Corporation typically have several years of history, either as commercial products or as prototypes at Government testing labs such as the National Weather Service-Sterling Research and Development Center or Federal Aviation Administration-Otis Air Force Base. This conservative approach of selecting sensors with field experience has allowed AAI to concentrate on the final production version of ASOS compliant sensors rather than starting from the beginning of the development process" (SMI 1993).

The Vaisala ceilometer used in ASOS is the same instrument currently used at the SLF and the TAL sites. This laser ceilometer is capable of distinguishing between opaque and thin translucent clouds but will only report opaque clouds.

The scatter angle of the Belfort visibility sensor is nominally 40 degrees and the sampling volume is 0.75 cubic feet, basically a point measurement. The reportable increments of visibility (in statue miles) are: <1/4, 1/4, 1/2, 3/4, 1, 1 1/4, 1 1/2, 1 3/4, 2, 2 1/2, 3, 3 1/2, 4, 5, 7, and 10+. When two visibility sensors are compared against each other, they agree within ±1 reporting increment at least 90% of the time and ±2 reporting increments at least 97% of the time (SMI 1993).

Fog and haze are the only two visibility obstructions reported by ASOS. Other obstructions such as smoke, dust, and blowing obstructions are reported by ASOS as fog or haze depending on the visibility and the dew point depression. When the visibility falls below 7 miles and the dew point depression is less than or equal to 4°F, then fog will be reported. If present weather was also reported, F (fog) will be appended to the observation. Otherwise, when the dew point depression is greater than 4°F and no present weather is reported, then haze is reported as the obstruction to vision. However, haze is not reported when other weather is reported at the site.

The Light Emitting Diode Weather Indicator (LEDWI) sensor can detect and report precipitation in the following categories: R-, R, R+, S-, S, S+. In mixed

Table 1.1. ASOS Specifications Related to Current SLF and TAL Site System Specifications*

Parameter	ASOS Instrument	Range	Accuracy	Significant Differences from SLF and TAL (HANDAR)
Cloud Height	Vaisala, Inc. Model CT12K Ceilometer	100 to 12 650 feet above ground level	Greater of ±100 feet or 5%	SLF and TAL: no differences in the instrumentation
Visibility	Belfort Instrument Model 6200 Forward Scatter Visibility Meter	< .25 to 10+ miles	±.25 to ±2 miles over sensor's range	SLF: human eye; TAL-range: 0.17 to 18 miles, accuracy: ±15% RMS error
Day / Night	Photometer	0.5 to 3 foot-candles	±10%	SLF: not applicable; TAL: no sig. difference
Present Weather	Scientific Technology, Inc. Model OWI-240 Light Emitting Diode Weather Identifier	Detects light, moderate, and heavy rain or snow, and mixed precip.	99% of occurrence, 90% correct identification	SLF and TAL: human observer
Liquid Precipitation	Freiz Engineering Model 7450H Heated Tipping Bucket Rain Gauge	0 to 10.0 " per hour	Greater of ±0.02 inch or 4% of hourly total	SLF: no sig. difference TAL: for less than 1", <±0.02"; for more than 1", <±0.3% of Full Scale
Freezing Rain	Rosemount, Inc. Model 872C Ice Sensor	≥0.01"	Correct reports 99% of the time	SLF and TAL: human observer
Temperature	Technical Services Laboratory Model 1088 - Resistance RTD	-80°F to 130°F	±1°F from -58°F to 122°F	SLF: ±0.28°F and TAL: ±0.11°F for similar accuracy interval
Dew Point	Technical Services Laboratory Model 1088 - Chilled Mirror	-30°F to 86°F	±2°F RMS error from +30°F to 86°F	SLF: above 0°F, ±0.28°F; TAL: derived using RH sensor
Wind Direction	Belfort Instrument Model 2000 - Balanced, Splayed Tail Vane	0 to 359°	±5° (above 5 knots speed)	SLF: ±2° + orientation TAL: no significant difference
Wind Speed	Belfort Instrument Model 2000 - 3-Cup Anemometer	0 to 125 knots	Greater of ±2 knots or ±5%	SLF-range: 0.6 to 90 knots, accuracy: ±0.13 knot or 1% of wind speed; TAL-accuracy: ±5% RMS error
Pressure	Sentra Systems, Inc. Model 4600 Digital Pressure Transducer	572 mb to 1067 mb	±0.68 mb	SLF-range: 914 to 1084 mb, accuracy: ±0.2 mb; TAL-range: 600 to 1100 mb, accuracy: ±0.3 mb

*(SMI 1993), (AAI Corp. 1991), (Computer Science Raytheon 1993), (Handar 1993)

precipitation where the prevailing precipitation cannot be determined, it will report P-. Since ASOS currently has no instrumentation for detecting hail, it is expected that any hail viewed by the LEDWI will be reported as rain because the ASOS-detected scintillation signature produced by a falling hailstone is closer to that of rain than snow (NOAA 1992). The LEDWI data accuracy indicates liquid precipitation is correctly detected and reported as R or P not less than 99% of time and correctly identified 90% of the time. Solid precipitation is correctly detected and reported as S or P at least 99% of the time and correctly identified at least 97% of the time (SMI 1993).

The hygrothermometer used in the ASOS is a slight modification of the fully-automated HO-83 hygrothermometer which has been in operational use since 1985. The minor modifications made were intended to improve its performance.

The ASOS uses a modern automated version of the F420 wind sensor, for measurements of wind direction and speed. The electronics design has been updated for ASOS so that the electromagnetic signals generated by the rotating cup anemometer and wind vane are directly converted into reportable values by the ASOS. The wind sensors are mounted at the standard 10 meter (32.8 feet) height on counter balanced tilt-over towers to allow for easier and safer maintenance. Besides wind direction and speed, ASOS will report the following wind related parameters: gusts, squalls, shifts, variable wind direction, peak wind, daily peak wind and the fastest two-minute wind.

The criticality of pressure determination has resulted in the placement of three separate and independent pressure sensors at towered airports and two pressure sensors at other locations. The pressure sensors are unique in that they are the only sensors installed indoors, collocated with the ACU (Acquisition Control Unit). However, they are vented to the outside where required. A pressure report is issued only when there is acceptable agreement between at least two sensors. The pressure parameters available from ASOS are: sensor pressure, altimeter setting, pressure remarks (PRESRR, PRJMP, etc.), sea level pressure, density altitude, pressure altitude, and pressure change/tendency (NOAA 1992).

Algorithms and siting criteria have been developed for each of the ASOS weather elements but will not be discussed in this report. Much of the work is detailed in the ASOS User's Guide (NOAA 1992), Algorithms for the Automated Surface Observing System (NOAA 1993), and in the Federal Siting Standards (OFCM 1987). Table 1.2 is provided as a guide to the processing interval and areas of validity for each weather element.

Because ASOS is still in the early stages of deployment, the sensors and algorithms are continually being refined as the NWS gets more field experience with the equipment. Corrective action for many of the problems identified in the next section are planned for this year and 1994. The status of the current system and the plans for 1994 are listed at the end of the following section.

Table 1.2. Characteristics of ASOS Algorithms*

Parameter	Processing Interval (minutes)	Radius of Validity of Sensor Output (miles)
Sky Conditions	30	3-5
Visibility	10	2-3
Precipitation (R/S)	10	1-2
Freezing Rain	15	2-3
Temperature / Dew Point	5	5
Wind	2	1-2
Pressure	1	>5
Hail	1-10	<1/4 - 1

*(Bradley and Lewis 1993)

2.0 ASOS Evaluations

This section describes ASOS measurement accuracy, reliability, and maintainability. The review is based on previous evaluations of ASOS and includes comparisons of ASOS data to manual observations from various locations in the United States to highlight ASOS strengths and limitations. The last part of this section contains the ASOS system status report and the program's plans for 1994.

2.1 Comparison of ASOS Observations to Manual Observations

Evaluation Sites

Tables 2.1 and 2.2 list ASOS evaluation sites, the begin and end dates for data collection, and the variables involved. Table 2.1 consists only of the 16 stations which comprise the surface observation network in the Modernization And Restructuring Demonstration (MARD) and Table 2.2 contains a listing of additional sites that were evaluated at various times. The first 5 stations in Table 2.2 are contained in evaluations performed by the NWS Southern Observation and Facilities Branch, the remaining stations were individual evaluations.

2.1.1 Sites Evaluation Characteristics

A brief description of each evaluation site and the specific evaluation conditions (if any) are noted before presenting the evaluations of the meteorological variables.

NWS Southern Region

The comparisons of ASOS to manual observations from 13 March to 20 June 1993 for the Southern sites included Amarillo, Baton Rouge, Oklahoma City, Tulsa, and West Palm Beach and were compiled by the NWS Southern Region Observations and Facilities Branch.

Olympia, WA

ASOS was installed with version 1.7 of the operating software at the Olympia, WA airport in late July 1992 and accepted by the NWS in August 1992. The comparisons from September 1992 through June 1993 were subject to one update (Version 1.8) installed in January 1993. The Weather Service Office (WSO) where the manual observations were taken is located approximately 3/8 mile east northeast of the ASOS sensors (on the other side of the runway). The WSO HO-83 temperature and 420c wind equipment are located about an 1/8 mile south of the office, and the laser beam ceilometer is located near the north end of the runway, about a 1/4 mile north of the office.

Kansas City, MO

The wintertime comparison of ASOS and manual observations at the Kansas City International Airport involved transmitted-only data being processed into hourly, daily, monthly, and event-driven (low ceiling and visibility, and precipitation) categories. Hourly comparisons consisted of examining the recorded observations from both sources to measure the variability of the data over the short term.

Table 2.1. ASOS Comparison MARD Sites and Available Data Information*

Station Location	Begin Date	End Date	Variables Involved
Alamosa, CO	16 Oct 91 17 Oct 91	18 Jun 92 22 Aug 92	Ceiling Vis Precip Temp
Amarillo, TX	4 Mar 92 05 Mar 92	18 Jun 92 22 Aug 92	Ceiling Vis Precip Temp
Concordia, KS	05 Feb 92 11 Feb 92	18 Jun 92 22 Aug 92	Ceiling Vis Precip Temp
Colorado Springs, CO	16 Oct 91 17 Oct 91	28 Jul 92 22 Aug 92	Ceiling Vis Precip Temp
Dodge City, KS	08 Jan 92 08 Jan 92	19 Jun 92 22 Aug 92	Ceiling Vis Precip Temp
Denver, CO	13 Nov 91 15 Nov 91	27 Jul 92 22 Aug 92	Ceiling Vis Precip Temp
Goodland, KS	30 Jan 92 30 Jan 92	20 Jun 92 22 Aug 92	Ceiling Vis Precip Temp
Grand Island, NE	16 Oct 91 17 Oct 91	20 Jun 92 22 Aug 92	Ceiling Vis Precip Temp
Wichita, KS	07 Feb 92 08 Feb 92	20 Jun 92 22 Aug 92	Ceiling Vis Precip Temp
Lincoln, NE	16 Sep 91 18 Sep 91	30 Jul 92 22 Aug 92	Ceiling Vis Precip Temp
Kansas City, MO	12 Feb 92 27 Feb 92	30 Jul 92 22 Aug 92	Ceiling Vis Precip Temp
Oklahoma City, OK	26 Feb 92 29 Feb 92	18 Jun 92 22 Aug 92	Ceiling Vis Precip Temp
Pueblo, CO	13 Nov 91 14 Nov 91	28 Jul 92 22 Aug 92	Ceiling Vis Precip Temp
Springfield, MO	17 Feb 92 18 Feb 92	30 Jul 92 22 Aug 92	Ceiling Vis Precip Temp
Topeka, KS	14 Sep 91 15 Sep 91	28 Jul 92 22 Aug 92	Ceiling Vis Precip Temp
Tulsa, OK	15 Jan 92 16 Jan 92	18 Jun 92 22 Aug 92	Ceiling Vis Precip Temp

*(Cornick and McKee 1993), (McKee et al. 1992)

Table 2.2. Additional ASOS Evaluation Sites

Station Location	Begin Date	End Date	Variables Involved
Amarillo, TX	13 Mar 93	20 Jun 93	Vis
Baton Rouge, LA	13 Mar 93 17 May 93	30 Apr 93 20 Jun 93	Vis
Oklahoma City, OK	13 Mar 93	20 Jun 93	Vis
Tulsa, OK	13 Mar 93	20 Jun 93	Vis
W Palm Beach, FL	13 Mar 93	20 Jun 93	Vis
Olympia, WA	01 Sep 92	30 Jun 93	Sky_Cover* Vis Precip Temp Wind Pressure
Kansas City, MO	01 Dec 92	30 Apr 93	Sky_Cover Precip Temp Wind Pressure
Tulsa, OK	14 Apr 93 01 Jun 92 Oct 92 Jun 92 overview	14 Apr 93 15 Jun 92	Sky_Cover Vis Precip Temp Pressure Precip Temp Precip Temp Wind
Sterling, VA (SR&DC**)	01 Mar 92	01 Mar 93	Sky_Cover Vis Precip Temp Wind Pressure
Lincoln, NE	13 Jan 93	15 Jan 93	Sky_Cover Temp

* The variable Sky_Cover used in the Variables Involved column represents both ceiling and sky conditions.

** SR&DC is the acronym used to represent the Sterling Research & Development Center in Sterling, VA.

Tulsa, OK

A variety of weather conditions occurred in Eastern Oklahoma on 14 April 1993. A cold front supported by strong upper level dynamics ensured rapidly changing conditions combined with heavy rain, low ceilings and visibilities. This cold front provided a good test of how well the ASOS performs under changing conditions.

Sterling Research & Development Center

The Extended Reliability Test performed for one year by the NWS' Sterling Research & Development Center (SR&DC) in Sterling, VA involved two complete ASOS systems. These units were upgraded and retrofitted to the current fielded production system configuration prior to the evaluation. One ASOS system, typical of a major hub configuration, contained one Combined Sensor group at center field and one Touchdown Sensor group. The center field and touchdown groups were separated by approximately one-half mile. The other ASOS system, typical of a small towered airport configuration, contained only a Combined Sensor group (one sensor of each).

Lincoln, NE

Since the commissioning of ASOS, questions have arose concerning the accuracy of the temperature and dew point sensors. Because of these questions, Lincoln, NE was selected for a 48 hour field test to evaluate the winter performance and accuracy of the ASOS temperature and dew point sensors. The test was scheduled from 1200 Local Standard Time (LST) 13 January 1993, through 1200 LST 15 January 1993. The test was to compare temperatures of an unsheltered sling psychrometer and the ASOS temperature and dew point sensors. The Lincoln ASOS site is approximately one mile south and 24 feet lower than the old official temperature site. The center field HO-83 temperatures were also collected to determine if the 24 foot elevation difference between the new ASOS site and the old HO-83 site produced significant temperature discrepancies. The sling psychrometer was hung within a foot of the ASOS sensor being fully exposed to the environment except for a crude but effective cardboard shield. All readings were collected every 20 minutes for 48 hours with the exception of the center field temperatures which were collected by the observer at the WSO on the hour and 20 minutes past the hour.

MARD Sites

The MARD (Modernization And Restructuring Demonstration) sites are the 16 NWS weather stations within the MARD area of the central United States. Since the ASOS units were installed at the MARD sites at different times, the amount of simultaneous ASOS and manual observations varies among the different sites. Furthermore, the ASOS observations were only compared to the manual observation having at least four months of overlap data during this period. The ASOS instruments used in the study were not commissioned so adjustments and maintenance on the units were likely to have occurred during the data collection time period.

The evaluations performed using hourly observations of temperature and precipitation are part of the Climate Data Continuity Project. The project was launched in 1991 and coincided with the initial deployment of the NWS ASOS. The overall purpose of this project is to ease the transition into the ASOS era for the many users of climate data derived from primary NWS aviation weather stations. This project will focus on the early objective identification and documentation of potential impacts on climate records resulting from this fundamental change in how weather conditions are measured and recorded (Cornick and McKee 1993).

2.1.2 Evaluation of Meteorological Variables

A brief summary for each meteorological variable is provided prior to each individual site's evaluation. The information provided in each evaluation reviewed did reveal some differences in the data comparisons of ASOS to manual observations. However, the evaluations did not indicate if these differences were statistically significant. Of the evaluations reviewed, only one site (Sterling Research and Development Center) had multiple sensors. One of the two ASOS units at Sterling, VA, consisted of a Combined Sensor group and a Touchdown Sensor group (two ceilometers and two visibility sensors) separated by approximately 1/2 mile. Comments concerning the multiple sensors are also noted under the appropriate heading.

2.1.2.1 Sky Cover

<u>Summary</u>

Automation of subjective elements such as ceiling and sky conditions contain numerous complexities. The major problem is how to quantify subjective human judgment when necessary. Overall, most of the differences observed between the manual and ASOS observations can be ascribed to sensor limitations or the need for a refined algorithm.

Key points concerning comparison of ASOS to manual observations of ceilings and sky conditions include:

- Reporting of sky conditions compares reasonably well to the manual observation when there is fair cloud movement at or around the sensor.

- Comparing ASOS to manual ceiling observations indicates an exact match in 86.2% of the observation pairs and 92.7% of the pairs have ceiling heights within ±1000 feet. During periods of active weather, 76% of the observation pairs have ceiling heights within ±1000 feet.

- Fog has been shown to be the most frequently reported weather phenomena when large discrepancies occur between ASOS and manual observations.

- Reporting of incorrect or false layers often occurs due to ASOS vertical visibility being obstructed by precipitation, lifting fog, virga, and invisible moisture particles (area of high moisture concentration without a visible cloud/layer).

- Timing of reporting significant changes and trend analysis of ASOS compares favorably well to manual observations.

Individual Site's Evaluation

Olympia, WA

The laser ceilometer of the Olympia, WA WSO office is located approximately 1/5 mile northeast of the ASOS site near the north end of the runway. ASOS and manual observations of sky cover compared well as long as the clouds were moving at a fair speed. When the winds were calm or light, the ASOS sky cover observation quality decreased. During times of little movement, a cloud over the sensor, especially at low levels would produce a broken or even an overcast layer when visually less than half the sky was covered. On the other hand, there were occasions when broken sky conditions existed but there were limited clouds within view of the ASOS ceilometer so ASOS reported scattered clouds to no clouds below 12 000 feet.

Virga falling from cloud layers at 8000 feet and above often masked the cloud heights and no clouds below 12 000 feet were reported by ASOS. However, on other occasions, scattered clouds at heights from 1000 to 6000 feet would be reported by ASOS with no clouds reported at higher altitudes.

During the fog season, radiational cooling and ground fog conditions often caused ASOS to report a broken to overcast layer at 100 feet or between 400 and 1000 feet and occasionally up to as high as 1500 feet when no clouds were visually evident. The layer reported during radiational cooling events could be caused by an invisible moisture layer around the inversion height. The layer reported during a ground fog event may be caused by the lifting fog (NWS Western Region 1993).

For nine days in October 1992, winds were light to moderately strong and clouds moved rapidly over the ceilometer. Of the 107 visual ceilings (0600 to 1800 Local Standard Time), 85 (79%) differed by 500 feet or less from the ASOS heights. For visual ceiling heights at 5000 feet or less, 54 out of 81 (67%) were within 200 feet of the ASOS heights, and over 80% (65 of 81) were within 500 feet of ASOS values. Of the visual ceilings at 1000 feet or less, 17 of the 19 visual ceilings were within 200 feet of the reported ASOS ceiling (Stickney 1992b).

Kansas City, MO

The Kansas City, MO evaluation indicated that in general, both cloud heights and visibilities compared favorably in trend and in the timing of reporting significant changes, with ASOS indicating gradual changes earlier. In many of the cases examined during significant events, cloud heights and visibilities were very representative of the surroundings. An example of this situation is seen in the tracking of ceilings versus cloud heights from a snowstorm on 15-16 February 1993 between 2100 and 0000 UTC. Multiple cloud layers were reported by ASOS when the lower layers over the sensor became scattered or broken. The ASOS ceiling fluctuated between 1000 and 3000 feet during this period while manual observations remained steady between 700 and 900 feet. ASOS did report scattered clouds near the level reported by the human observer but not of sufficient coverage to constitute a ceiling (Browning 1993).

Tulsa, OK

Since the commissioning of the Tulsa, OK ASOS on 1 October 1992, periods of low clouds and visibilities have been handled well by ASOS. Because of the time needed to process cloud and visibility data, ASOS reports often lag manual observations by several minutes. This normally occurs with rapidly changing conditions, and rarely is the time lag great enough to affect aircraft operations (Teague 1993).

Sterling Research & Development Center

There was good agreement between ASOS reported ceilings and manual observations. With few exceptions, the differences observed between the manual and ASOS observations can be ascribed to sensor limitations or the need for algorithm refinement. Specifically, ASOS often reports false or incorrect cloud layers due to its vertical visibility being obstructed (status 3 reports) by precipitation, lifting fog, virga, and invisible moisture particles.

"A status 3 output means that the Cloud Height Indicator has not detected the base of a cloud, but that there is an obstruction present in the atmosphere that has, by the vertical visibility height, reduced the laser power to some nominal fraction of the transmitted energy, e.g., 50 percent" (Nadolski and Bradley, 1991). One case resulting from status 3 outputs was noted. During this event, ASOS reported 5 SCT M16 BKN 50 OVC. In this case the layer at 1600 feet did not exist, but was the result of status 3 reports during an ice pellet event. This occurrence of a false cloud layer was from precipitating clouds that were lower than normal for this phenomena. In general, false layers from 2000 to 3000 feet were reported when precipitation was occurring from clouds at or above 7000 feet.

"During the test on a number of occasions, ASOS reported clouds at various heights when no apparent clouds were visible. The reporting of clouds at 100 to 200 feet occurred on mornings with a strong inversion which could have capped moisture. In one case of higher clouds, a test radiosonde flight taken fairly close in time to an observation with the reported layer showed a moist layer at the height of the reported clouds" (NOAA/NWS 1993).

Multiple Sensors at the Sterling Research & Development Center

Table 2.3 gives the distribution of the remarks section for 475 hourly, daylight only observations used in the weather element comparison. The conditions listed under the Remarks column are defined as follows:

BKN V OVC = Broken Variable Overcast

BKN V SCT = Broken Variable Scattered

OVC V BKN = Overcast Variable Broken

BINOVC = Breaks In Overcast

CLDS LWR = Clouds Lower

CIG LWR = Ceiling Lower

CIG VRBL = Ceiling Variable.

Table 2.3. Distribution of Sky Condition Remarks for Multiple and Single Sensor Systems*

Remarks	Multiple Sensor	Single Sensor	Human
BKN V OVC	3	1	0
BKN V SCT	7	14	0
OVC V BKN	10	2	0
BINOVC	N/A	N/A	7
CLDS LWR	6	N/A	0
CIG LWR	4	N/A	0
CIG VRBL	0	13	3

*(NOAA/NWS 1993)

The observer did not report any variable cloud remarks, however, the observer did have 7 'BINOVC' remarks. Only one cloud remark is reported in the remarks section of each ASOS observation with the 'CLDS LWR' and 'CIG LWR' remarks taking precedence over the other cloud remarks. The multiple sensor site reported 'LWR' remarks while the single ceilometer system reported 13 'CIG VRBL', and the observer reported 3. In the ASOS 'CIG VRBL' remarks, the range of variability was 500 to 700 feet as compared to the human reports of only 200 to 300 feet (NOAA/NWS 1993).

Lincoln, NE

During the first day of the 48 hour temperature test in Lincoln, NE, the observer had been reporting mostly clear skies for approximately six and one-half hours when during the last half hour ASOS reported a 1500 foot broken deck when no deck existed. Prior to the special report, ASOS had been reporting 'CLR BLO 120'. Within 50 minutes a visual ceiling at 1800 feet moved in. "It seems ASOS detects possible moisture density differences even when no clouds are present. It was later found that the site was on the edge of the 900 mb moisture layer" (Grosshans and Clark 1993).

MARD Sites

In performing the MARD sites comparison of ASOS ceilings with manually reported ceilings, some accommodations had to be made since ASOS categories differ from manual categories. For example, manual observations with clear skies and skies with no ceiling below 12 000 feet are put into same category.

For the overall comparison of ceilings, the total number of matched pairs for comparison (64 137) were used and resulted in 86.2% exact matches and 92.7% were within ±1000 feet. Table 2.4 shows the complete results in the form of a scatter diagram. Occurrences of clear skies, or at least no ceiling below 12 000 feet (ceiling category ≥110) comprise 67% (42 962) of the matched pairs. Therefore, the complete sample results are biased by the large number of "no ceiling" events. The information provided did not present any general conditions (e.g., frontal nimbostratus) which may have existed in the events in which ASOS did not agree with the manual report (Cornick and McKee 1993).

Across the top of Table 2.4 is the category for manual observations of ceiling heights. Down the left side of Table 2.4 is the category for ASOS ceiling observations for the same event. The diagonal row of cells (shaded) from the upper left corner to the lower right corner constitutes the number of times ASOS agreed with the manual report within the range of the category. The other cells of Table 2.4 indicate the number of occurrences when ASOS and the manual observations differed by one or more categories. The lower left corner represents the frequency of events in which the manual report indicated a much lower ceiling than ASOS reported. The upper right corner represents the frequency of events where the manual ceiling height report is much higher than reported by ASOS (Cornick and McKee 1993).

A comparison of matched pairs characterized by reportable weather (9454 pairs) indicated 76.3% of the ASOS reports were within ±1000 feet of the manual reports. A subset of this data (8828 out of 9454) was created which contains only manual reports of rain, snow, fog, or drizzle. Of this subset, ASOS reported ceilings five or more categories (a category represents 1000 feet) lower than manual reports in 463 cases and, in 343 of the 463 cases, fog was reported. Thus, a possible explanation for many of the events with large discrepancies is the ASOS ceilometer incorrectly interprets the return from the fog droplets as a cloud base (Cornick and McKee 1993).

Table 2.4. MARD Sites Ceiling Scatter Diagram*

		Manual Observation Ceiling Categories (in hundreds of feet)**											Total
		≤010	≤020	≤030	≤040	≤050	≤060	≤070	≤080	≤090	≤100	≥110	
ASOS Obs. Cig. Cat.	≤010	3983	279	28	16	11	8	2	1	2	4	342	4676
	≤020	391	2345	188	37	23	10	9	6	3	9	74	3095
	≤030	86	346	1452	157	52	18	22	8	11	19	139	2310
	≤040	47	63	284	1063	102	32	18	16	9	11	136	1781
	≤050	44	44	73	316	995	142	45	32	11	19	164	1885
	≤060	31	29	26	66	195	607	115	46	26	21	168	1330
	≤070	7	6	23	28	61	133	492	104	42	24	135	1055
	≤080	3	8	8	20	48	62	121	427	76	31	147	951
	≤090	4	5	9	13	16	35	46	146	393	82	191	940
	≤100	4	5	9	10	24	20	23	48	142	538	348	1171
	≥110	41	79	121	199	178	217	145	204	239	558	42962	44943
Total		4641	3209	2221	1925	1705	1284	1038	1038	954	1316	44806	64137

*(Cornick and McKee 1993)

**The definition of the values in the manual and ASOS ceiling categories can be represented by the ≤050 category which corresponds to the ceiling heights greater than 4000 feet but less than or equal to 5000 feet.

2.1.2.2 Visibility

<u>Summary</u>

Visibility is another weather element that is very difficult to automate. All evaluations indicated that meteorological siting of the visibility sensor is critical for accurate representation of the observation.

Key points concerning comparison of ASOS to manual visibility observations include:

- Comparing ASOS to manual visibility observations shows an exact match (i.e., same reportable increment) 81.8% of the time while 93.7% were within one reportable increment (standard ASOS reportable increment). Comparisons of matched observations when reported weather occurred (rain, snow, fog, drizzle) indicated a greater degree of disparity. The comparisons revealed 28.4% to be exact matches and 60.8% of the pairs were within one reportable increment.

- The quality of the ASOS observation usually decreases in the cases characterized by patchy ground fog[1]. Otherwise, most of the time, ASOS compares well to the manual observations.

- Many discrepancies between ASOS and conventional observations may be due to localized effects (e.g. having more dense fog in the sensor area than elsewhere).

- ASOS reports higher visibilities than manually observed visibilities during low visibility events. During the dissipation of fog events, ASOS visibilities typically increase at a much faster rate than manual observations. The reason for the differing rates of increasing visibility during the dissipation of fog events remains unexplained.

Individual Site's Evaluation

NWS Southern Region

The data compiled by the NWS Southern Region Observations and Facilities Branch comparing ASOS and manual observations of visibility indicate the test criteria were exceeded on 32 of 13 868 observations reviewed. The test criteria are shown in Table 2.5.

Examination of data from the 32 cases revealed that ground fog events, along with having more dense fog in the sensor area than elsewhere seemed to be the reason for many discrepancies.

Table 2.5. Criteria Used by the NWS Southern Region for Visibility Comparisons of ASOS and Manual Observations*

Visibility Observation	Test Criteria Acceptable Difference Between ASOS and Manual Observation
<1/4 - 3/4 mile	±1/4 statue mile
1 - 2 miles	±1/2 statue mile
2 1/2 - 4 miles	1 statue mile
5 - 10+ miles	1 reported value**

*(Grayson 1993a,b,c,d)

**Reported values between 4 and 10+ miles are 4, 5, 7, and 10+.

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[1] The AMU's recommendation for the use of multiple visibility sensors (stated in Section 5.1, Recommended ASOS Configuration for use at SLF) took into consideration that patchy ground fog occurs frequently in and around KSC. The use of multiple visibility sensors is anticipated to help determine a more representative visibility under these conditions.

Olympia, WA

In Olympia, WA, comparisons of ASOS and manual visibility observations were made during September, October, and November 1992. During daylight hours, ASOS visibilities were generally greater than manual when manual visibilities were in the range of one to three miles. ASOS was greater than three miles in nearly 50% of the observations when corresponding manual visibilities were one to three miles. With widespread fog and little or slow change, ASOS and manual visibilities were comparable. During improving conditions, as fog began to dissipate, ASOS visibilities increased at a much faster rate. During episodes of strong radiational cooling and ground fog, the manual and ASOS visibilities differed significantly.

Patchy ground fog under 50 feet was not handled well by ASOS. At this site, the visibility sensor was located next to the main runway with low cut grass and native weeds surrounding it. Ground fog patches would flow around and over the sensor causing ASOS to lower the derived visibility to less than three miles for a short time, then increasing to above three miles as the fog moved away from the sensor. During these times when ASOS reported changing visibility, the manual prevailing visibility remained constant (NWS Western Region 1993).

Tulsa, OK

Since commissioning on October 1, 1992 Tulsa, OK the ASOS has handled low visibilities well. Comparisons between ASOS and manual observations taken on 14 April 1993 showed that for visibilities of five miles or less, over half (7 of 12) matched exactly with the manual observations. The remaining five observation pairs differed by one-half to three miles (Teague 1993).

Sterling Research & Development Center

At SR&DC the data indicate there was good agreement between ASOS and the human observer. For the cases where there was a discrepancy, the data indicate that patchy ground fog was present and the visibility was generally one mile or less. A few of these cases were associated with the human observer having a slant visibility on certain markers.

Multiple Sensors at the Sterling Research & Development Center

Of the 475 hourly observations used to compare weather elements, the distribution of visibility remarks generated by ASOS is shown in Table 2.6. All comparative observations were taken during daylight hours. The observer was located approximately 1/3 mile to the east of the Combined Sensor group of the multiple sensor system. The Combined Sensor group of the single system was located just to the west of the multiple sensor system (NOAA/NWS 1993). The conditions listed under the Remarks column are defined as follows:

VRBL VSBY = Variable Visibility

SECTOR VSBY = Sector Visibility.

Table 2.6. Distribution of Visibility Remarks for Multiple and Single Sensor Systems*			
Remarks	Multiple Sensor	Single Sensor	Human
VRBL VSBY	1	0	0
SECTOR VSBY	1	N/A	4

*(NOAA/NWS 1993)

MARD Sites

The data from the MARD sites indicated that for an overall comparison of the 63 533 paired observations, 81.8% were exact matches while 93.7% were within ±1 reportable increment. Nearly 80.1% of the observations were reporting visibilities in the 10+ category illustrating the percentage of fair weather days. A comparison of paired observations characterized by reportable weather (9322 events) indicated 28.4% of the pairs were exact matches while 60.8% were within ±1 reportable increment (standard ASOS reportable increment). For example, if the visibility reported is 2 miles, ±1 reportable increment would be 1.75 miles and 2.50 miles (see section 1.3.4, System Specifications for complete listing of ASOS standard reportable increments).

The frequency distribution of differences between ASOS and manual visibilities reports during rain, snow, fog, or drizzle events indicates that ASOS reports higher visibility values than the human observer under these conditions. A frequency distribution of visibility differences for visibilities of three miles or less indicates ASOS reports higher visibility than the human observer in low visibility conditions (Cornick and McKee 1993).

2.1.2.3 Precipitation Accumulation and Identification

Summary

When reviewing this material, it is important to note the spatial variability of precipitation coupled with the fact that the manual precipitation gauges are not co-located with the ASOS gauges introduces statistical uncertainties in any precipitation data comparisons. In addition to the difference in locations of the precipitation gauges, the types of precipitation gauges used in the comparisons also differed.

Key points concerning comparison of ASOS to manual precipitation observations include:

- Matched pairs of manual and ASOS rainfall accumulations are very similar but ASOS tends to report less accumulation. In the event of high rainfall rates, the disparity between ASOS and manual rainfall accumulation is greater.

- Cases were noted where ASOS reports more very small rainfall events (0.01") when no precipitation occurred or after the rainfall event had ended. These events are probably associated with dense fog or dew which resulted in sufficient moisture accumulation in the gauge to register 0.01".

- Onset and ending of precipitation events by ASOS have been very accurate.

- Identification of precipitation type was reported correctly by ASOS most of the time. ASOS precipitation type errors generally occurred when the air temperature was close to freezing and the differentiation between rain and snow became difficult.

Individual Site's Evaluation

Olympia, WA

For monthly precipitation totals at Olympia, WA from September 1992 to June 1993, ASOS' precipitation totals on 8 out of 10 months were less than the station weighing rain gauge (one month was an exact match). The ASOS total precipitation of 36.73" was 93.9% of the 39.12" measured by the station weighing rain gauge (NWS Western Region 1993).

During September, there were eight rain events. The total rainfall reported by ASOS for these eight events was 0.09" less than the station reported rainfall total (2.35" vs. 2.44"). For the 14 days of precipitation during October, ASOS reported 0.15" less precipitation than the station weighing rain gauge. Of these 14 events, both sensors reported identical rainfall totals for 4 days, the difference between the gauges was either 0.01" or 0.02" for 8 days, and the difference in rainfall was 0.03" and 0.06" for the 2 other days.

November 1992 contained several periods of moderate to heavy rain that may have overloaded the ASOS tipping bucket rain gauge sensor. The ASOS total rainfall of 6.27" is 91.9% of the 6.82" measured by the station weighing rain gauge. Part of the difference may be explained by the approximate 3/8 mile separation of the ASOS and station weighing rain gauges (Stickney 1992a,b,c).

Kansas City, MO

Precipitation in the form of rain, freezing rain, drizzle, freezing drizzle, or snow occurred on 75 of the 151 days in the Kansas City, MO study. Rainfall accumulation by ASOS was near WSO values during rain events (except one instance during extreme rainfall where ASOS observed less). However, ASOS recorded significantly lower amounts (74% less) of precipitation accumulation (water equivalent) during snow events than the WSO report (Browning, 1993). One possible cause for the lower precipitation accumulation during snow events is the evaporation or sublimation of snow resulting from the heating required to melt and measure frozen precipitation (NOAA 1992).

Tulsa, OK

Data for Tulsa, OK also indicated that ASOS precipitation accumulation was similar but generally less than the station Weighing Rain Gauge (WRG) accumulation. The fact that the two rain gauges are over one mile apart accounts for some of the accumulation differences. Data from Tulsa, OK also indicates the present weather sensor (LEDWI) has been very accurate for the onset and ending of precipitation.

One problem encountered with the ASOS is the reporting of precipitation after rainfall had ended. Most of these cases were the result of heavy dew occurring after the end of measurable rainfall (Devore and Teague 1993).

The daily totals of precipitation from the two gauges for 14 April 1993 were similar (ASOS: 1.22", WRG: 1.17"), as were the hourly totals. Twenty out of the 24 hours reported rainfall amounts ranging from a trace to 0.28". The differences between the two gauges were very slight, varying by a maximum of 0.04".

October 1992 only had four precipitation events. For the month, there were substantial differences in precipitation between the gauges on days with heavy precipitation, although the ASOS' total accumulation exceeded the station observation by only 0.31" (3.53" vs. 3.22"). For June 1992, the monthly total precipitation for the two gauges were very similar (ASOS: 8.32", WSO: 8.41"). Example rainfall totals include (June 2) ASOS: 1.79" WRG: 1.33", (June 6) ASOS: 0.80" WRG: 0.89", and (June 14) ASOS: 1.51" WRG: 1.65" (Teague 1992; Teague 1993).

Sterling Research & Development Center

During SR&DC's test, a number of cases indicated ASOS reported incorrect discrimination of precipitation. In one event, one ASOS unit reported light rain while the other ASOS reported light snow. The temperature was 38°F, and the precipitation was determined to be rain. In a second event, a long period of very light rain was not reported by ASOS while 0.03" of precipitation accumulated over many hours. During a long-lasting ice pellet event in which two inches of ice accumulated on the ground, both ASOS stations incorrectly identified the solid precipitation as liquid rain. Finally, during a blizzard in 1993, a period of precipitation with ice pellets was again incorrectly identified as rain by ASOS. In addition, on a number of occasions, ASOS reported precipitation accumulation when dew, resulting from dense fog occurred (NOAA/NWS 1993).

MARD Sites

Total ASOS precipitation during the precommissioning period of the MARD sites was similar to but less than the conventional observation for valid comparison days at all stations except Goodland, NE (GLD). ASOS precipitation totals ranged from 109% of conventional observations at GLD down to 70% of conventionally measured precipitation from all 16 stations combined. With the exception of GLD, the largest percentage differences between ASOS and conventional measurements were observed at the drier stations in the western portion of the test area.

In this study, 940 days were analyzed in which measurable precipitation (≥0.01") at either ASOS or the conventional gauges or both had been reported. Out of the 940 precipitation days, ASOS reported precipitation on 98 days which the conventional observation did not and the conventional observation reported precipitation on 105 days which ASOS did not.

For the entire comparison period, ASOS and the conventional precipitation measurements were within 10% of each other. The number of reported measurable precipitation days were nearly identical (ASOS: 842 versus conventional: 835) but ASOS tended to report considerably more very small (0.01") events and less days with precipitation greater than 0.15". The conventional gauges reported no precipitation on many of the ASOS limited precipitation days. As mentioned before, many of the ASOS limited precipitation events may have resulted from dew deposition. The frequency of small events (0.04"-0.15"), which makes up a sizable portion of precipitation days, shows very similar frequencies for the two sensors (McKee et al. 1992).

2.1.2.4 Temperature

Summary

Overall, the evaluations indicated that ASOS temperature measurements are 1° to 2°F cooler than the manual observations. Possible reasons for this difference include sensor siting, local effects, elevation, and data processing.

Individual Site's Evaluation

Olympia, WA

In Olympia, WA the WSO HO-83 temperature sensor is located 1/8 mile south of the NWS office and the ASOS sensor is located 1/4 mile to the west of the office. Both sites are over grass or natural vegetation. Comparing the maximum temperatures of both sensors from September 1992 to June 1993, ASOS maximum temperatures are 0.8°F to 1.9°F cooler than the manual observation. The minimum temperature comparison for the same time period also shows a cooler reading from ASOS but to a lesser degree, 0°F to 1.5°F, averaging 0.6°F. The cooler measurements by ASOS may be explained by siting differences, but it is interesting to note that as daily maximum temperatures increase, the difference between ASOS and the HO-83 increases (NWS Western Region 1993).

Kansas City, MO

In each of the five months studied at Kansas City, MO the monthly averages of maximum and minimum temperatures between ASOS and the manual observations differed by less than 1°F. On a daily basis, the ASOS maximum temperature ranged from 2°F warmer to 4°F cooler than the WSO values and the ASOS minimum temperature ranged from 4°F warmer to 3°F cooler. ASOS maximum temperatures were within 1°F of manual observations for 95% of the days while minimum temperatures were within 1°F for 82% of the days. Similar results were seen when hourly temperatures and dew points were examined. ASOS hourly temperatures were within 1°F of manual observations for 93% of the cases and ASOS hourly dew point measurements were within 1°F of manual observations for 83% of the cases (Browning 1993).

Tulsa, OK

In June and October 1992, the ASOS temperatures (maximum and minimum) were approximately 2°F cooler than manual measurements. Part of the difference may be due to sensor siting. The standard WSO sensor was located near a large aviation ramp to the north, with a busy street about 100 feet south. The ASOS sensor is located over a large grassy area, several hundred feet from the airport runway and a smaller taxi way. The fetch to the ASOS temperature instrument is from a large grassy area with some trees, compared to asphalt and concrete for the standard WSO sensor (Devore and Teague 1993).

Lincoln, NE

The overall performance of the ASOS temperature and dew point sensors during the 48 hour temperature test in Lincoln, NE was good. The test indicated that ASOS temperatures (wet and dry bulb) were approximately one degree (0.89°F) cooler than the sling psychrometer measurements. The temperature errors are within the ASOS sensor accuracy requirements (temp: 0.90°F - 1.80°F, dew pt: 1.3°F - 7.9°F).

The greatest temperature difference at Lincoln occurred shortly after sunrise (0940 LST) with calm winds and full sunshine. The sling psychrometer measured a rapid rise to 10.8°F. The ASOS sensor did not detect this increase and remained six degrees cooler. This appeared to be related to a stratification of cooler air near a snow field with calm winds. The aspirator of the ASOS sensor may have pulled colder air from the lower layer and consequently did not measure the true temperature at sensor height. By 1000 LST, the temperatures from the two systems were again close. The temperature sensor performance may be improved by reversing the aspirator fan to pull air from above the temperature and dew point sensors and not from below. It was suggested that many of the errors or differences in response may be corrected by improvement in sensor aspiration (Grosshans and Clark 1993).

The ASOS dew point measurement proved more erratic but not beyond acceptable system requirements (ASOS User's Guide, B-1). On two occasions, under sunny skies and some wind, the ASOS dew point measurement did not match the sling psychrometer consistently, usually reporting a cooler temperature. In contrast, under overcast skies, the ASOS dew point measurement was much closer to the sling psychrometer's, especially when the relative humidity approached 100%.

There were large temperature differences between the ASOS and the sling psychrometer when comparing the two sites under conditions of high radiational cooling. Under clear morning skies (0700 LST), ASOS reported -1°F while the HO-83 reported 4.9°F. By 0820 LST both sensors were within one degree. Another incident occurred during an evening of clearing skies that provided a sharp temperature drop. By 1800 LST ASOS reported 6.4 °F compared with 13.1°F at the old site. These two incidents indicate the lower elevation of the ASOS site is one cause of the temperature discrepancies between the two sensors (Grosshans and Clark 1993).

MARD Sites

Temperature differences were quite consistent over wide ranges in temperature during the precommissioning analysis period of the MARD sites with ASOS reporting cooler temperatures than the manual observations. For the entire period of comparison, ASOS daily maximum temperatures were identical to or 1°F to 2°F cooler than the manual daily maximum temperature for 87% of the days. Similarly, ASOS daily minimum temperatures were identical to or 1°F to 2°F cooler than manual daily minimum temperatures for 81% of the days. Temperature differences between ASOS and manual observations of ±3°F or greater occurred on 10.7% of the days for daily maximum temperatures and on 13.4% of the days for daily minimum temperatures. In nearly 95% of the cases where large temperature differences occurred, ASOS reported cooler temperature readings than the manual instrumentation. Large differences were more common at some of the sites suggesting site and exposure differences or data problems.

The composite 16-station average systematic temperature difference (ASOS versus manual) for the period September 1991 through May 1992 was -1.51°F for daily maximum temperatures and -1.36°F for daily minimum temperatures. A notable decline in the mean systematic temperature difference between the sensors occurred during the summer months of June through August. The composite average difference (ASOS versus manual) decreased to -1.05°F for daily maximum and -0.71°F for daily minimum temperatures.

The differences in daily maximum temperatures at Denver, CO were greater than the temperature difference for nearly every other station throughout the winter and spring. During the summer, however, a change occurred in the (ASOS versus manual) temperature difference which left Denver with one of the smallest temperature differences. This change was found to be associated with a modification to the dew point measuring portion of ASOS HO-83 units. The modification of the dew point sensor has been made at all sites in the network to improve the quality of each dew point device.

Examination of hourly temperatures indicated larger temperature differences between the sensors were most common from 2300 to 0400 UTC and least likely from 1200 to 1700 UTC. The period from 2300 to 0400 UTC are the evening hours across the MARD area while 1200 to 1700 UTC are the morning hours. These are the times of day when temperatures rise and fall most rapidly. ASOS reports each hour at precisely 56 minutes after the hour while manual observations are typically completed several minutes earlier. Since most of the time ASOS reports are cooler than manual measurements, these differences are enhanced by the slightly later ASOS observation time when temperatures are falling and diminished where temperatures are rising (McKee et al. 1992).

2.1.2.5 Wind

Summary

The evaluations from Olympia, WA and Kansas City, MO indicated that, generally, ASOS reports wind speeds approximately 1 to 2 knots less than the manual observations. The separation of the ASOS and station wind sensors may account for a portion of the wind speed difference.

Individual Site's Evaluation

Olympia, WA

At Olympia, WA the station 420c wind sensor is approximately 1/4 mile southeast of the ASOS sensor, yet monthly average wind speeds from the two sensors were within 1 to 2 knots. Generally, the station average wind speeds were greater than ASOS average wind speeds. During September 1992, the difference in the monthly average of daily peak wind speeds was within one mile per hour, 18.3 mph (15.9 kts) for ASOS and 18.9 mph (16.4 kts) for the station sensor. The daily average wind speeds were 5.7 mph (5 kts) for ASOS and 6.6 mph (5.7 kts) for the station sensor. Of the 30 days, both sensors reported identical average wind speeds for 6 days, the station sensor reported average wind speeds 1 to 4 mph (0.9 to 3.5 kts) greater than ASOS for 18 days, and ASOS reported average wind speeds 1 to 6 mph (0.9 to 5.2 kts) greater than the station sensor on 6 days.

During October 1992 ASOS reported daily average wind speeds less than the station sensor. Of the 31 days, both sensors reported identical wind speeds on 3 days, the station sensor reported wind speeds 1 to 9 mph (.87 to 7.82 kts) greater than ASOS for 23 days, and ASOS reported wind speeds 1 to 3 mph (0.87 to 2.61 kts) greater than the manual sensor on 5 days. For November 1992, the ASOS monthly average peak wind speed of 15.7 mph (13.6 kts) was 2.6 mph (2.3 kts) less than the station average peak wind speed of 18.3 mph (15.9 kts). The daily average wind speed of 5.21 mph (4.52 kts) reported by ASOS was 0.7 mph less than the station daily average wind speed of 5.91 mph (5.13 kts) (Stickney 1992a,b,c).

Kansas City, MO

At Kansas City, MO during the 1992-93 wintertime comparison, the ASOS monthly average wind speeds were consistently less than the WSO monthly average wind speeds (ASOS average wind speeds were 1.5 knots less than the WSO reports). Daily ASOS wind speed averages ranged from 4.3 knots greater to 6.8 knots less than the daily WSO wind speed averages. These daily ASOS wind speed averages were within ±2 knots of the WSO averages 67% of the time and within ±1 knot 37% of the time (Browning 1993).

2.1.2.6 Pressure

Summary

The documentation reviewed indicated the ASOS pressure sensors are the most sensitive sensor of the ASOS system. Overall, the ASOS sensors tend to report pressure values 0.01" to 0.03" (0.34 mb to 1 mb) lower than the manual observations.

NWS maintenance personnel indicated that they are unaware of any systematic bias with the ASOS pressure sensors (Wissman 1994, personal communication). However, they did discuss some of the causes for the incorrect pressure readings from various sites that have since been corrected. Some of the incorrect pressure readings were caused by:

- On-site personnel changing the site elevation of the airport,
- On-site personnel closing the door on the pressure vent hose,
- Personnel (at two sites) comparing the ASOS pressure readings to either antique or incorrectly calibrated pressure sensors, and
- Maintenance activities.

Individual Site's Evaluation

Olympia, WA

Olympia, WA indicated that the ASOS and station pressure sensors were the most compatible instruments evaluated. From September 1992 to June 1993, ASOS consistently reported the monthly average pressure values 0.3 mb less than the station monthly average values (NWS Western Region 1993). Examination of the pressure observations taken twice daily from ASOS and the manual observer during September and October 1992 indicated ASOS values were 0.1 mb to 0.5 mb less than the manual readings (Stickney 1992a,b).

Kansas City, MO

The wintertime comparison at Kansas City, MO revealed ASOS readings to be consistently lower than WSO readings, averaging 0.02" Hg (0.68 mb) less. When examined on an hourly basis, pressure differences generally ranged from 0.01" Hg (0.34 mb) to 0.03" Hg (1.02 mb) less than the WSO readings (Browning 1993).

Tulsa, OK

Comparisons between ASOS and manual pressure observations taken on 14 April 1993 showed how accurate the ASOS pressure sensor can be during rapidly changing conditions. This day brought numerous showers and a few thunderstorms producing a highly fluctuating surface pressure pattern to Tulsa, OK. "Several pressure rising and falling rapidly remarks were annotated to the observations. The most significant pressure feature turned out to be a pressure jump that was caught by ASOS. The barogram chart that was kept at the WSO for comparative purposes clearly showed just how accurate the sensor was during this event. Several significant pressure jumps have been noted since commissioning the ASOS, and each time the sensor and associated algorithm performed flawlessly" (Teague 1993).

Sterling Research & Development Center

Of the 475 observations in the reliability test data set from the SR&DC, both ASOS units reported pressure values less than the manual observations. A mean pressure difference of 0.03" Hg (1.02 mb) was noted between one of the two ASOS units and the manual observations. The mean pressure difference between the second ASOS unit and the manual observations was generally 0.02" Hg (0.68 mb) (NOAA/NWS 1993).

2.2 Reliability and Maintainability

This section will describe the known reliability and maintainability of the ASOS system. The first part of this section consists of data from approximately 7.5 months of ASOS operations. The maintainability and reliability information presented in this report includes data summarized nationally and for the state of Florida (FL). In addition, comments from individual ASOS sites are included. The last part of this section describes the optional ASOS maintenance policy provided by the NWS.

NWS has a reliability reporting system called the Engineering Management Reporting System (EMRS) which has not been specifically tailored for the peculiarities of ASOS. Data provided by the EMRS for approximately 30 weeks from November 1992 to June 1993 is shown in Table 2.7. The national region contains commissioned and noncommissioned sites from within the east, south, central, west, and Alaska regions. As of June 10, 1993, the National region had approximately 245 sites and FL had 9 sites (excluding the western panhandle). The standard requirements for the parameters listed in Table 2.7 were unavailable at this time, therefore, a direct comparison of the systems current performance to the required performance could not be completed. However, it should be kept in mind that ASOS is still in the early stages of the program and system performance will improve in time.

Table 2.7. ASOS National and FL Level of Reliability for 30.3 Weeks of Data*										
Region	Pop	# Fails	# Major Fails	MTBF (days)	Avail	Major Avail	MRT (hrs)	MDT (hrs)	RT	NT
National	161.78	569	27	60	.954	.999	67	55	0.63	0.31
Southern	40.40	320	16	26	.860	.995	90	83	0.83	0.60
FL excluding W panhandle	6.97	31	2	47	.963	.994	42	35	0.88	0.61

*(NWS 1993)

Pop: Population is the total number of systems multiplied by the total operating hours in the period (this period is 30.3 weeks).

Fails: The total number of maintenance actions which may or may not be due to a hardware failure. These maintenance actions include actions that may occur on-site or remotely. These items and their associated time spans can vary from minutes to days. For example, the time involved in a technician remotely dialing into the system to perform diagnostics or the time it takes for a technician to travel to the site and replace hardware.

Major Fails: Total number of failures that prevents the complete product (SAO) from being transmitted over long line communication networks. These failures also include the safety related information (wind speed, direction, pressure, visibility, and cloud height) that has not been included in the SAO.

MTBF: Mean Time Between Failures. This number is the population (Pop) multiplied by the number of days in the period divided by the number of failures (# Fails). This is the mean time between corrective action.

Avail: Availability is the total number of operating hours divided by the total number of possible operating hours. Availability is based on the number of failures (# Fails). It is assumed that ASOS would operate 24 hours a day, 365 days a year. Therefore, the total number of possible operating hours in this period (30.3 weeks) is 5090.4 hours.

Major Avail: Major Availability is the total number of operating hours divided by the total number of possible operating hours. Major Availability is based on the number of Major Failures. This is the operational availability.

MRT: Mean Restore Time (hours).

MDT: Mean Delay Time in hours and includes all delays (i.e., logistic delays, test equipment delays, etc.).

RT: Routine Time is the preventive maintenance time (weekly hours/equip).

NT: Repair Time including any bench time (weekly hours/equip).

Table 2.8 shows the estimated standard workload for each technician responsible for 20 systems and the measured workload for FY92 and FY93, thus far. For the National region, FY92 shows almost a two fold increase in the measured workload over the estimated workload. This increase has been attributed to a learning curve for the technicians. For the first 30.3 weeks of FY93, the workload has decreased and should continue to do so through the upcoming years as the learning curve decreases and the system becomes more refined.

Table 2.8. Current ASOS National and Southern Workload as of June 10, 1993*

Region	Estimated Workload Standard (years/unit)	Workload FY92 (per unit)	Workload FY93 (incl. Overhead & Facility)
National	.050	.098	.084
Southern	.050	N/A	.136

*(NWS 1993)

2.2.1 Comparison Sites Reliability and Maintainability

West Palm Beach, FL

From October 1992 to 10 June 1993, only two failure reports have been written for the ASOS unit at West Palm Beach, FL. Neither of these failures were classified as a major failure. The first failure was a defective fiber optics output board which caused a drop-out of precipitation accumulation information. The unit had to be replaced. The other failure was a chipped mirror on the temperature/dew point sensor which also had to be replaced.

Tulsa, OK

Problems encountered with the ASOS hardware at Tulsa, OK included:

- Present weather (e.g., light rain, snow, etc.) being reported under fair weather conditions, and
- Wind sensor (direction) became stuck during periods of ice/extreme cold.

All cases of present weather being reported under fair weather conditions were a result of some type of obstruction on the present weather indicator lens. In the fall, spider webs were a particular problem and several times, dust and dirt produced the same results. The wind equipment problem was identified early and the field sites were retrofitted to solve this problem. This solution made a significant improvement in the quality of the wind data; however, continued investigation revealed more subtle problems which are still being evaluated (Devore and Teague 1993).

Sterling Research & Development Center

The Extended Reliability Test performed at the Sterling Research & Development Center in Sterling, VA, focused primarily on reliability. Results of the LEDWI's precipitation identification reliability test indicated that the insecticidal paint used on the LEDWI sensor head as part of Systems Management Incorporated's (SMI, a subsidiary of AAI Corp.) insect abatement program was not totally effective. Approximately three months after the application, spider activity was observed near the sensor head and resulted in false sensor reports of snow.

During the reliability test, an excessive number of dew point data quality failures occurred. One failure resulted from the reported dew point temperature exceeding the ambient temperature by more than two degrees. Another failure caused a dew point temperature jump of nine degrees in one minute, which exceeded the data quality limit of six degrees in one minute. An investigation of the problem resulted in a revised optical loop adjustment procedure for the hygrothermometers which was subsequently validated during the ASOS test at Sterling, VA and also at several remote test sites.

Also during the reliability test, there were two cases where the wind direction parameter was reported erroneously by ASOS. Another report documented erratic performance in the wind direction sensor. Subsequent disassembly and inspection of the wind direction bottle revealed that moisture was present. The bottle was returned to SMI in late April 1992 for examination (NOAA/NWS 1993).

In the March 1993 issue of the *ASOS Progress Report*, Ulinski states in his article 'Near Term ASOS Changes' that "the wind speed and direction sensor will be improved to circumvent moisture penetration which causes the sensors to seize up and to improve performance and reliability. Corrosion makes the wind speed and direction sensor bottles difficult to remove from the wind cross arms. As a result, a change in design was made for the sensor bottle and wind sensor bearing. Currently, the fixes are being tested before the changes are fielded."

No pressure problems were reported during the reliability test, however, each pressure sensor was connected into one manifold. The proper configuration according to the Federal Siting Standards, includes independent venting for each sensor with separate outside vents (NOAA/NWS 1993).

The reliability of the two ASOS systems at the Sterling Research & Development Center during the test period from 6 March 1992 to 2 April 1993 are shown in Table 2.9. The Multiple Sensor system and the Single Sensor system contain the same instruments with the exception that the Multiple Sensor system has two ceilometers and two visibility sensors instead of just one. The computation of Mean Time Between Failures (MTBF) is based on the ratio of total number of system operational hours to the total number of failures. The MTBF estimates include only those failures which resulted in the replacement of Field Replaceable Units (FRU) to restore the ASOS to normal operation.

Table 2.9. Sterling Research & Development Center System Reliability*			
System	Operational Hours	Number of Failures	MTBF (Hours)
Multiple Sensor	9408	11	855
Single Sensor	9408	13	724

*(NOAA/NWS 1993)

Table 2.10 is an example of the Optional NWS Maintenance Policy of Maximum Outage Times for a major hub site. A major hub is defined as a high traffic airport with centralized activity, (e.g., Atlanta, Miami, Tampa, Nashville, and Dallas/Ft. Worth). The maximum outage times listed in Table 2.10 are the maximum times the equipment will be inoperative starting from the time the technician receives notification or discovery of a failure until the time the equipment is back to full operation. If the decision is made to purchase an ASOS system, NASA has the option of contracting with the NWS or the Range Technical Services (RTS) personnel to maintain the ASOS unit(s). In either case, maintenance materials can be obtained from the NWS. If desired, it is likely the NWS maintenance plan could be tailored to meet NASA's requirements.

Table 2.10. NWS Maintenance Policy of Maximum Outage Times*			
Type of Airport	Priority	Outage Times (hours)	Sensors and Components Included
Major Hub	1	12	Pressure, Wind, Visibility, Ceilometer, Data Collection Packages (DCP), Acquisition Control Unit(ACU), Freezing Rain occurrence
	2	24	Liquid & Frozen Precipitation Accum, Snow Depth, Other Present Weather Terminals
	3	72	Sunshine Switch, Printer, Snow Depth, and Freezing Rain (when it cannot occur)

*(NWS 1992)

One potential advantage of having the NWS provide maintenance would be the NWS has a staff of technicians who specialize in ASOS maintenance. However, the technician who would be responsible for providing service to the KSC ASOS is located in West Palm Beach.

Two advantages of having the RTS contractor provide maintenance would be:

- They currently provide maintenance for most of the meteorological equipment on the Range, and

- Outage times could be reduced because the contractor is on-site and can respond more quickly.

In addition to the major hub site definition, the NWS maintenance plan includes two other types of ASOS installations, towered and small. The priority items along with the sensors and components are the same for the towered and small as for the major hub. However, the maximum outage times may differ among the three different classifications.

System Status and Plans

Since ASOS is a new system and is still in the early stages of the program, improvements, modifications, and updates are a continuing occurrence. Listed below is the status of the ASOS system and the plans for 1994 presented by Mr. Richard Reynolds, ASOS Program Manager, at the Fifth Conference on Aviation Weather Systems on 5 August 1993.

2.3 System Status

- Software Version 2.0
  - Field test underway, plan to implement 1 August 1993
  - Contains FAA ATC modifications and specials logic
- Visibility
  - Data quality has been fixed and currently working on heater
  - Available Fall 1993
- LEDWI
  - Improving performance in heavy snow
  - Available Fall 1993
- Rain Gauge
  - Insufficient catch, currently being tested
  - Available Fall 1993
- Hygrothermometer
  - Testing Review Board approval, 19 July 1993
- Wind
  - Redesigned to correct problems
- Pressure
  - Maintenance note distributed on venting blockage
- Freezing Rain
  - Sensor approved for operational test

2.4 Plans for 1994

- Install Software Version 2.1 (winter load):
  - Add daily and monthly summary message to AFOS
  - Complete Standard Hydrometeorological Exchange Format (SHEF) output change requests

- Incorporate and test freezing rain algorithm changes
- Dial backup for Alaska and Hawaii

- Meteorological Discontinuity and Backup Algorithms make observations more representative (visibility, sky conditions)

- Complete FAA final tower equipment development and test

- Initiate data continuity study (follow-on for commission sites)

- Add hot keys for augmentation-aviation parameters

- Complete freezing rain sensor operational test and commission sensors

3.0 Requirements Analysis

This section discusses the surface observation requirements for the support of shuttle launch and landing operations, airfield operations, and the SMG's shuttle weather support simulations and shows its relationship to ASOS' capabilities. After the unfulfilled requirements are known, the means to satisfy some requirements without the use of human augmentation are described. The use of human augmentation to satisfy the remaining requirements is described in Section 5, Proposed Concepts of Operations for ASOS at the SLF.

The surface observation requirements were obtained from the Joint Operating Procedures for Meteorological Support Between the Eastern Space and Missile Center and the John F. Kennedy Space Center (1990) and the Launch and Landing Program Requirements Documentation (1992). ASOS' capabilities were obtained from the ASOS User's Guide (1992).

The requirements were compared to ASOS capabilities to determine which components of the observation requirements could be satisfied by ASOS and which components must be met by other means (e.g., human augmentation, additional sensors, etc.). Tables 3.1, 3.2, and 3.3 contain comparison results of ASOS capabilities versus surface observation requirements for the various operations and simulations. The following conventions are used in the comparison tables:

√ :The requirement is satisfied by ASOS.

√- :The requirement is partially satisfied by ASOS.

\- :The requirement is not satisfied by ASOS.

3.1 Unsatisfied Requirement Remedies

It was shown in the previous section that the standard ASOS configuration does not satisfy all observation requirements at the SLF. This subsection describes ASOS enhancements that can reduce the number of unsatisfied requirements.

- **Ceilings and Sky Conditions above 12 000 Feet**

The ASOS ceilometer is currently configured to determine the ceiling and sky conditions up to 12 000 feet. One solution for reporting ceiling and sky conditions above 12 000 feet is to replace ASOS Vaisala CT12K ceilometer with the Belfort Model 7013C laser ceilometer. This instrument is capable of detecting cloud heights from 50 to 25 000 feet and has a reported accuracy of ±25 feet (Belfort Instrument 1992). This, coupled with the idea of implementing multiple ceilometers, is a potential solution for a more precise reporting of ceiling and sky conditions up to 25 000 feet. The ASOS meteorological discontinuity algorithm (planned for 1994) incorporates the use of multiple sensors (ceilometers and visibility sensors) to provide better representation of the surrounding sky conditions. The replacement of the 12 000 foot ASOS Vaisala ceilometer with the 25 000 foot Belfort ceilometer would not require any modification of the ceiling and sky condition algorithm. However, this sensor change would require minor engineering changes to the software that displays the observation reports (e.g., CLR BLO 250 instead of CLR BLO 120).

Table 3.1. Relationship of ASOS and Manual Observing Capabilities To Airfield Operations Surface Observation Requirements*

Airfield Operations Observation Requirements	Manual	ASOS	Comments
Standard:			
Observations when Aircraft / Missile Mishap Occurs	√	√-	ASOS provides all standard SAO information every minute. However, any specific information relevant to a mishap may not be available without the use of human augmentation
Ceiling	√	√-	ASOS can report ceilings up to 12 000 feet only
Sky Conditions	√	√-	ASOS can report sky conditions up to 12 000 feet only
Prevailing Visibility	√	-	ASOS can determine (point) visibility at the sensor location only
Present Weather	√	√-	ASOS cannot differentiate between haze and smoke, rain and rain shower, and light rain and drizzle
Temperature & Dew Point	√	√	
Wind Direction & Speed	√	√	
Altimeter Setting	√	√	
Remarks	√	√-	ASOS remarks include varying conditions (wind direction, cig, sky condition, vis), pressure changes, max/min temp, hrly & accum precip
Special:			
Tornado, Funnel Cloud, or Waterspout	√	-	Cannot be detected by ASOS
Thunderstorm	√	-	Cannot be detected by ASOS (algorithm development in progress)
Wind Shifts and Peaks	√	√	
Precipitation Begins or Ends	√	√	
Hail Begins or Ends	√	-	ASOS cannot detect hail and will generally report hail as heavy rain
Freezing Precipitation Begins or Changes	√	√-	ASOS will report freezing precipitation as either rain or snow depending on scintillation pattern

* Assessment assumes standard ASOS configuration. Many of the ASOS observation deficiencies can be remedied by hardware and/or software additions/modifications as discussed in Section 3.1.

Table 3.2. Relationship of ASOS and Manual Observing Capabilities To Shuttle Operations & Simulations Surface Observation Requirements*

Shuttle Operations & Simulations Surface Observation Requirements	Manual	ASOS	Comments
Standard:			
Cloud Amount / Heights	√	√-	ASOS cannot report tenths of cloud cover nor can ASOS report cloud information above 12 000 ft; cloud information is updated once each minute
Visibility	√	√-	ASOS detects point visibility rather than prevailing visibility
Restriction to Visibility	√	√-	ASOS reports restrictions to visibility as either fog or haze
Sea Level Pressure	√	√	
Temperature & Dew Point	√	√	
Wind Direction & Speed	√	√	
Altimeter Setting	√	√	
Properly Identified Wind Data from each Runway Sensor	√	-	Cannot be performed by ASOS
Sector Visibility	√	-	Cannot be determined by ASOS
Cloud Cover that can Impact Landing Field / Runway	√	-	Cannot be determined by ASOS
Cloud Description, Position and Movement	√	-	Cannot be determined by ASOS
Cloud Cover in Tenths for all Layers	√	-	Cannot be determined by ASOS
Special:			
Tornado, Funnel Cloud, or Waterspout	√	-	Cannot be detected by ASOS
Ceiling falls below 8000 feet	√	√	
Visibility falls below 7 miles	√	√	
When Thunder Begins	√	-	Cannot be detected by ASOS (algorithm development in progress)
When any Precipitation Begins or Ends	√	√	

* Assessment assumes standard ASOS configuration. Many of the ASOS observation deficiencies can be remedied by hardware and/or software additions/modifications as discussed in Section 3.1.

Table 3.3. Relationship of ASOS and Manual Observing Capabilities To Spaceflight Meteorology Group & Flight Director's Surface Observation Requirements*

Spaceflight Meteorology Group & Flight Director's Surface Observation Requirements	Manual	ASOS	Comments
Standard:			
Ceiling	√	√-	ASOS detects ceilings up to 12 000 feet only
Sky Conditions	√	√-	ASOS reports sky conditions up to 12 000 feet only
Prevailing Visibility	√	-	ASOS can determine (point) visibility at the sensor location only
Present Weather	√	√-	ASOS cannot differentiate between haze and smoke, rain and rain shower, and light rain and drizzle
Temperature & Dew Point	√	√	
Wind Direction & Speed	√	√	ASOS computes and updates the 2-minute average wind every 5 seconds
Altimeter Setting	√	√	
Remarks	√	√-	ASOS remarks include varying conditions (wind direction, cig, sky condition, vis), pressure changes, max/min temp, hrly & accum precip
Tenths of Cloud Cover below 10 000 feet	√	-	Cannot be determined by ASOS
Special:			
Tornado, Funnel Cloud, or Waterspout	√	-	Cannot be detected by ASOS
Thunderstorm	√	-	Cannot be detected by ASOS
Wind Shifts	√	√	
Precipitation Begins or Ends	√	√	
Hail Begins or Ends	√	-	ASOS cannot detect hail and will generally report hail as heavy rain
Freezing Precipitation Begins or Changes in Intensity	√	√-	ASOS will report freezing precipitation as either rain or snow depending on scintillation pattern

* Assessment assumes standard ASOS configuration. Many of the ASOS observation deficiencies can be remedied by hardware and/or software additions/modifications as discussed in Section 3.1.

Another method for determining ceilings and sky conditions above 12 000 feet is to incorporate a complementary system that detects cloud height and fractional cloud amount for mid and upper levels using GOES data. Information from GOES-7 will be used to provide mid and upper clouds to support 100 ASOS sites by the end of 1993. In addition, the satellite derived cloud cover data is planned as a standard product when the GOES-I becomes operational. In the case of a GOES-7 failure, a backup technique that uses Meteosat-3 water vapor data is being developed at the University of Wisconsin (Schreiner and Ellrod 1993).

The results of a 30 day NWS reliability evaluation of this satellite-derived cloud cover data indicated that total sky cover for clouds above 12 000 feet was correct in 60% to 75% of the cases with respect to the cloud cover category (CLR, SCT, BKN, OVC), and the difference between satellite and manual observations was one category or less in 90% to 95% of the cases. Significant errors of two or more categories occurred in only 5% to 10% of the cases (Schreiner and Ellrod 1993).

- **Tenths of Cloud Cover Below 10 000 Feet**

Currently, tenths of cloud cover are not reported by ASOS. Communications with several ceilometer vendors indicated that no available ceilometer reports tenths of cloud cover. It was suggested that this information could be retrieved through higher level algorithms. Indeed, the ASOS sky condition algorithm internally computes tenths of cloud cover which is then degraded to category of cloud coverage (CLR BLO 120, SCT, BKN, OVC). However, only the category and cloud layer height for the three (if necessary) cloud layers is displayed in the SAO report. Modification of the software could be performed to report the tenths of cloud cover for the three available layers. However, the accuracy of the tenths of cloud cover is unknown.

- **Sector and Prevailing Visibility**

With the current configuration of ASOS, point visibility is the only type of visibility information reported. A suggested solution for reporting sector visibility and partial solution for prevailing visibility is the use of multiple sensors. One method of providing sector visibility and information similar to prevailing visibility is to place ASOS visibility sensors near the approach ends of the runway and one to the west of the SLF (or some other triangle configuration) and then process the data using the ASOS meteorological discontinuity algorithm (planned for 1994).

- **Thunderstorm, When Thunder Begins**

A thunderstorm algorithm currently exists for the ASOS system but has not yet been implemented and tested. When ASOS is interfaced to the FAA's AWOS Data Acquisition System (ADAS), ASOS will not only provide ADAS with minute by minute updates of weather conditions, but it will also retrieve lightning data from the NWS's nationwide lightning detection network via ADAS (Sessa 1993). ASOS will examine the ADAS data every minute for an indication of a thunderstorm within the past minute and store that data for 12 hours. When three or more lightning strikes are reported within 10 miles of the station during the preceding 15 minutes, a special observation is issued which contains a "T" and a thunderstorm onset remark. If fewer than three strikes have been reported during the last 15 minutes, the "T" will be removed and the thunderstorm ending remark will be included (NOAA 1993). It is not yet known when this thunderstorm reporting capability will be added to ASOS.

Another approach to the requirement to report when thunder begins is to ingest data from a local lightning system and then process the data using the ASOS algorithm. Examples of local lightning systems include the Lightning Location and Protection (LLP), Lightning Detection And Ranging (LDAR), or the National Lightning Detection Network.

4.0 Meteorological Sensors in the St. Johns River Valley

The Applied Meteorology Unit's preliminary report on fog developing at the SLF (Wheeler et al. 1993) suggested the need for Automated Weather Stations (AWS) in the St. Johns River Valley. The majority of the fog events analyzed in that report indicate that fog or stratus develops at the SLF or is advected in from the southwest, west, or northwest. With limited data (wind direction and speed) coming from the region west of the Indian River, the suggestion was made to install additional instrumentation to the existing towers and also install AWS west of Interstate Highway 95.

There are two approaches to providing this information. One solution would be to install one or more ASOS units in the St. Johns River Valley. A standard ASOS production unit would provide real-time information on cloud conditions, visibility with weather restrictions, present weather, temperature, dew point, pressure and wind direction and speed. Alternatively, an ASOS could be comprised of just a ceilometer and visibility sensor to provide cloud conditions and visibility with weather restrictions. However, another solution which may be more cost effective, is to take advantage of the upgraded Weather Information Network Display System (WINDS) network.

Until recently, the wind towers to the west of the Indian River (Figure 4.1) only contained wind direction and speed sensors. However, the WINDS is being upgraded and instrumentation to measure temperature and relative humidity has been added to most of the towers. The upgraded WINDS will provide forecasters with important information to facilitate and improve fog forecasting (e.g., light/calm winds, small dew point depression).

In addition to the ongoing WINDS upgrade, installing visibility sensors at several of the towers west of the Indian River would be beneficial. The upgraded WINDS will have the capability of supporting additional sensors at the mainland towers. One approach would be to purchase and place four visibility sensors in the St. Johns River Valley. Possible locations of these sensors could be towers 0819, 2016, 2202, and 1000, northwest, west, southwest, and south-southwest, respectively, of the SLF. Figure 4.1 shows a map of the surrounding area with labeled towers and the suggested locations for the sensors identified by the large, bold numbers.

These visibility sensors would provide the Spaceflight Meteorology Group (SMG) and Range Weather Operations (RWO) forecasters real-time information on visibility conditions to the west of the SLF. This information would allow the forecaster to detect fog development over the St. Johns River Valley and improve fog forecasting skill in support of Shuttle operations.

The biggest technical problem foreseen in installing the sensors is upgrading the solar power subsystem at each site to accommodate the increased power demands of the visibility sensor. In addition to upgrading the power subsystem at the site, the Remote Transmission Unit (RTU) software would need to be modified as well as the base station software to collect and broadcast the data on various output formats (MIDDS, MARSS, etc.) (Maier 1993).

In addition to the visibility sensors, ceilometers could also be added to the WINDS network. This would further enhance fog forecasting skill plus provide cloud conditions to the forecaster. One potential problem with adding ceilometers to the WINDS towers is the large power requirements of the ceilometers.

For any of the above suggestions, a site survey would need to be performed before exact locations are chosen for the visibility sensors and/or ceilometers.

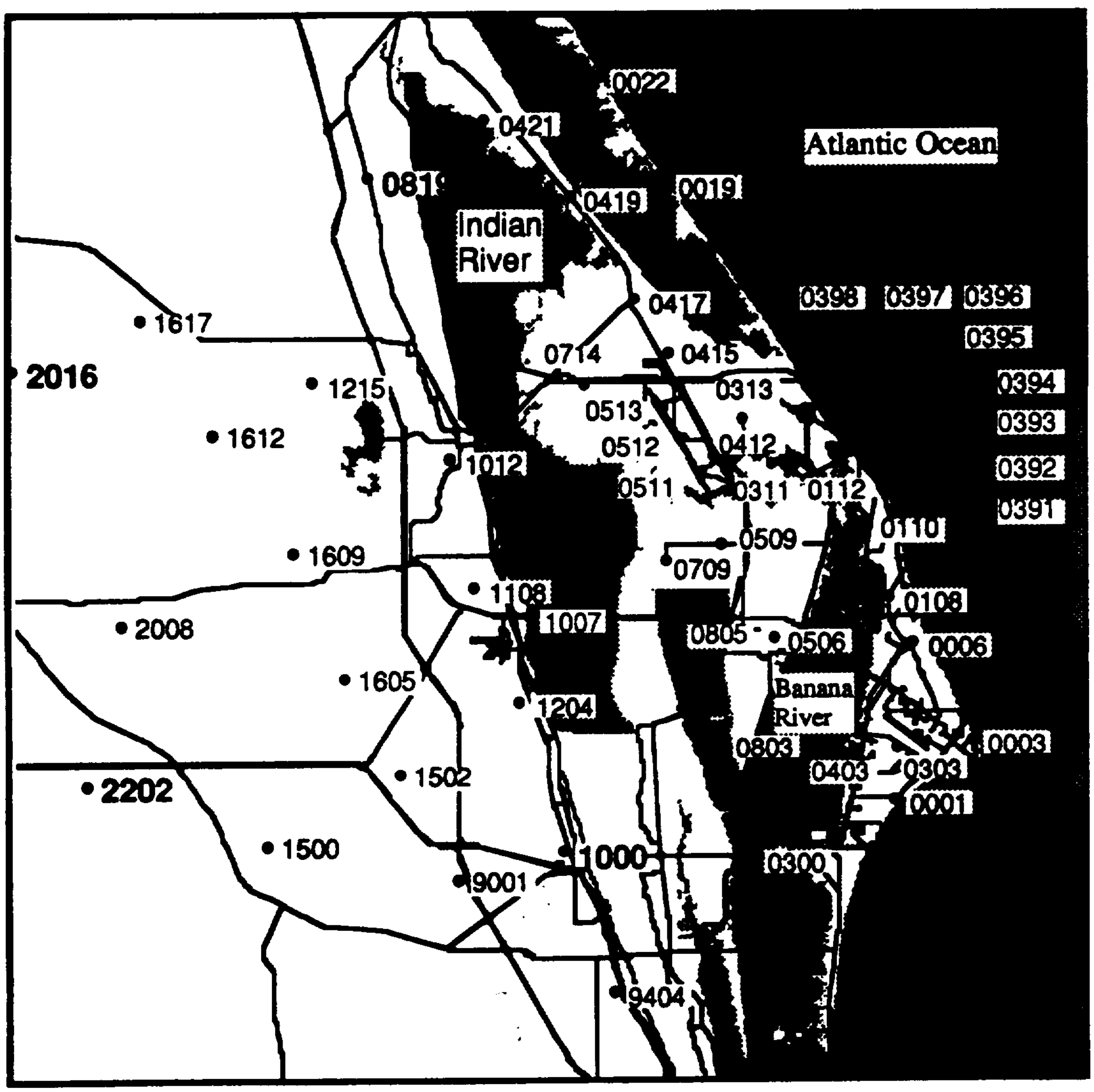

Figure 4.1. Map of Local Tower Network and Suggested Locations for Additional Sensors Identified with Large, Bold Numbers

5.0 Proposed Concepts of Operations for ASOS at the SLF

This section describes the optimum ASOS configuration for use at the SLF. This configuration includes some modifications/enhancements to the standard ASOS configuration which were described in more detail under the Unsatisfied Requirement Remedies, Section 3.1. This section also presents the proposed concepts of operations for ASOS at the SLF.

It is important to note the AMU is not recommending whether to deploy ASOS at the SLF or not. The AMU is only recommending how to configure and use ASOS if it is deployed at the SLF.

5.1 Recommended ASOS Configuration for use at SLF

The recommended ASOS configuration is based on the standard ASOS production unit and includes modifications to enhance its capabilities with respect to SLF observation requirements. In addition, the recommended configuration contains suggestions for placement of sensors and display terminals.

Standard ASOS Production Units (illustrated in Figures 1.1 and 1.2)

The ASOS Combined Sensor group consists of the following sensors:
- Temperature
- Dew Point
- Ceilometer
- Visibility sensor
- Wind Direction and Speed
- Precipitation Accumulation and Identification
- Pressure sensors

The ASOS Touchdown Sensor group consists of the following sensors:
- Ceilometer, and
- Visibility sensor

Recommended ASOS Sensor Group

Recommended ASOS sensor group for use at SLF consists of (at a minimum):

- Two ASOS Combined Sensor group units plus one Touchdown Sensor group unit.
- Enhancements include:
  - Modification of the Touchdown Sensor group to include wind instrumentation.
  - Modification of the ASOS sky condition algorithm to append tenths of cloud cover to the observation report.
  - Replacement of the current ASOS ceilometer (12 000 foot capability) with the Belfort ceilometer (25 000 foot capability).

This configuration would provide three ceilometers, three visibility sensors, and three wind sensors. One sensor could be used as the primary and two as secondary.

The recommended location for the two ASOS combined sensor group units is one at each of the approach ends of the runway. The recommended location for the ASOS touchdown sensor group unit is to the west of the SLF.

Other possible ASOS sensor groups for use at the SLF include:

- Three Combined Sensor groups.
- One Combined Sensor group and two Touchdown Sensor groups.

Recommended Locations for ASOS Input and Display Terminals

The recommended locations for the input and display terminals are:

- One input terminal located at the Landing Aids Control Building (LACB) on the south end of SLF runway.
- One input terminal at the SLF Control Tower (midfield on SLF runway).
- One display terminal in the RWO working location (can be a stand-alone display terminal or the data could be integrated into the Meteorological Monitoring System or into another display system).
- One display terminal in the SMG's working location.
- One input terminal in the ASOS CPU rack to be used for maintenance purposes only.

The recommended ASOS configuration cannot alone meet all the requirements to support airfield operations, shuttle launch and landing operations, and the SMG's shuttle weather support simulations. However, the recommended ASOS configuration satisfies more of the requirements than the standard ASOS configuration. Table 5.1 contains all requirements of the various operations and simulations, listed in Tables 3.1, 3.2, and 3.3, that were not satisfied by the standard ASOS configuration but are either partially satisfied or satisfied by the recommended ASOS configuration. Table 5.2 contains the requirements of the various operations and simulations that still remain unsatisfied or only partially satisfied with the recommended ASOS configuration.

5.2 Proposed Concept of Operations #1

The proposed concept of operations is based on having an ASOS system at the SLF and using LACB personnel to augment the ASOS observations. This concept of operations would require the LACB personnel, who would be tasked to augment ASOS observations, to be trained as certified weather observers. Another key component of this concept of operations is to move the weather instrumentation from Weather Station B to a location at or near the LACB. This instrumentation would then be used as backup in the case of a partial or complete ASOS failure. If this occurred, LACB personnel would be required to take manual observations of the missing weather elements. This concept of operations would not require any weather observers at Weather Station B. This concept of operations would fulfill all of the SLF surface observation requirements 115.5 hours per week.

Key components of this concept of operations include:

- Installing the recommended ASOS sensor group at the SLF.

- Installing the ASOS input and display terminals at the recommended locations.

- Moving the weather instrumentation from Weather Station B to a location at or near the LACB.
- Monitoring the data from three SLF wind towers on MIDDS or dedicated equipment. In the current procedure, the data from three SLF wind towers are manually added to the remarks section of the observation during shuttle launch and landing operations.
- Having LACB personnel augment the hourly and special ASOS observations during their normal operating hours (0600 to 2230 local time, 7 days/week) in addition to their regular duties and during shuttle operations to include cloud tenths, type and height, prevailing visibility, present weather, and additive remarks. In addition to these elements, the LACB personnel should be capable of taking observations of the elements listed in Tables 3.1, 3.2, and 3.3, if the need should arise (i.e., failure of an ASOS component).

Table 5.1. Observation Requirements Now Partially Satisfied or Satisfied by the Recommended ASOS Configuration

Observation Requirements	Std ASOS	Recom ASOS	Comments
Ceiling	√-	√	The use of the 25 000 ft ceilometer will help to satisfy this requirement
Sky Conditions (incl. cloud amount and height)	√-	√	The use of the 25 000 ft ceilometer will help to satisfy this requirement
Prevailing Visibility	-	√-	The use of multiple visibility sensors will provide more visibility information but will not satisfy the requirement
Sector Visibility	-	√	The use of multiple visibility sensors will help satisfy this requirement
Cloud Cover that can Impact Landing Field/Runway	-	√-	Multiple ceilometers will help satisfy this requirement but still cannot determine cloud type (Cu, CB, etc.)
Cloud Description, Position and Movement	-	√-	Multiple ceilometers will help indicate sky condition changes over the areas of the different ceilometers
Cloud Cover in Tenths for all Layers	-	√-	Modifying ASOS sky condition algorithm to append tenths of cloud cover to obs report will help satisfy this requirement but the accuracy of the tenths of cloud is unknown

Table 5.2. Observation Requirements that Remain Unsatisfied with the Recommended ASOS Configuration

Observation Requirements	Recom ASOS	Comments
Observations when Aircraft/ Missile Mishap Occurs	√-	ASOS provides all standard SAO information every minute. However, any specific info relevant to a mishap may not be available without the use of human augmentation
Prevailing Visibility	√-	Multiple sensors will not fully satisfy this requirement
Restriction to Visibility	√-	ASOS reports restrictions to visibility as either fog or haze
Properly Identified Wind Data from each Runway Sensor	-	Cannot be performed by ASOS
Present Weather	√-	ASOS cannot differentiate between haze and smoke, rain and rain shower, and light rain and drizzle
Remarks	√-	ASOS remarks include varying conditions (wind direction, ceiling, sky condition, visibility), pressure changes, max/min temperature, hourly and accumulated precipitation
Cloud Cover that can Impact Landing Field/Runway	√-	Even with multiple ceilometers, ASOS cannot determine cloud type (Cu, CB, etc.)
Cloud Description, Position and Movement	√-	Multiple ceilometers will indicate changing sky conditions over the different ceilometers but still cannot determine cloud type
Cloud Cover in Tenths for all Layers	√-	Modifying ASOS sky condition algorithm to append tenths of cloud cover to obs report will help to satisfy this requirement but the accuracy of the tenths of cloud is unknown
Tornado, Funnel Cloud, or Waterspout	-	Cannot be detected by ASOS
Thunderstorm or When Thunder Begins	-	Cannot be detected by ASOS
Hail Begin or Ends	-	ASOS cannot detect hail and will generally report hail as heavy rain
Freezing Precipitation Begins or Changes	√-	ASOS will report freezing precipitation as either rain or snow depending on scintillation pattern

An additional recommended component of this concept of operations includes:

- Having the RWO observer gather weather observations from observers stationed at the Range Operations Control Center (ROCC), Weather Station A, and Vehicle Assembly Building (VAB) during shuttle launch and landing operations (from the VAB only during launch operations). The observer would then enter the observations into a text file on MIDDS for distribution to SMG and MSFC. An example of the type of data contained in the text file follows:
  - ROCC: cloud tenths, type and height, present weather and additive remarks.
  - VAB: cloud tenths, type and height, present weather and additive remarks.
  - Weather Station A: complete observation including additive remarks.

  A reduction in Air Force weather observers is scheduled and may impact the RWO's ability to perform this procedure.

Advantages of Concept of Operations #1

- The proposed concept of operations provides a reduction in cost since no weather observers would be required at Weather Station B. Weather observations are currently being taken by the Range Technical Support Contractor personnel at Weather Station B. These weather observers maintain a continuous weather watch 24 hours a day, 365 days a year.

- The LACB provides a better view of the SLF runway than Weather Station B. The LACB is located next to the SLF runway and an observer at the LACB can see a portion of the runway. Weather Station B is located approximately 3000 feet east of the SLF runway and low bushes and trees prevent an observer at Weather Station B from seeing the SLF runway.

- The proposed concept of operations provides supplemental data 16.5 hours/day, 7 days a week. A certified weather observer will be at the LACB for 16.5 hours a day, 7 days a week and during shuttle launch and landing operations to input human observations of:
  - Cloud tenths, type and height
  - Prevailing visibility
  - Present weather
  - Additive remarks.

- The proposed concept of operations provides a consolidated text file of local weather observations (Weather Station A, VAB, and ROCC) on MIDDS during shuttle launch and landing operations.

- The use of multiple sensors will provide a more complete depiction of the meteorological conditions at the SLF. The current algorithm for multiple ceilometers assumes the use of two or more ceilometers separated by a distance of at least three miles. The current algorithm for multiple visibility sensors assumes the use of three visibility sensors separated by a distance of at least two miles (NOAA 1993).

- The use of the recommended ASOS units provides:
  - Consistent observations.
  - Sky conditions up to 25 000 feet.
  - Tenths of cloud cover.

Deficiencies/Disadvantages of Concept of Operations #1

- The cost of acquiring and maintaining the ASOS system.

- There would be an additional cost associated with training LACB personnel to become certified weather observers.

- The cost of moving the weather instrumentation from Weather Station B to a location at or near the LACB.

- The accuracy of ASOS tenths of cloud cover is unknown when used as a stand-alone unit (every day from 2230 to 0600 local time; 52.5 hours per week).

- The accuracy of ASOS tenths of cloud cover depends upon cloud movement and adequate spacing of the ceilometers.

- ASOS observations would not include information about prevailing visibility, hail, thunderstorms and additive remarks from 2230 to 0600 local time. However, point visibility would be available 24 hours a day from the three ASOS sensor groups at the SLF. If desired, thunderstorm reports could be included in ASOS observations by ingesting the National Lightning Detection Network, Lightning Location and Protection system, or possibly Lightning Detection and Ranging system data into the SLF ASOS unit.

5.3 Proposed Concept of Operations #2

The second proposed concept of operations is based on having an ASOS system at the SLF and using a Weather Station B observer with limited duty hours to augment ASOS observations. In the case of a partial or complete failure of ASOS, the instrumentation currently at Weather Station B will be used as backup for observations until the ASOS equipment is returned to operational status. This concept of operations would fulfill all SLF surface observation requirements 40 hours per week.

Key components of this concept of operations include:

- Installing the recommended ASOS sensor group at the SLF.

- Installing the ASOS input and display terminals at the recommended locations.

- Installing one ASOS input terminal at Weather Station B.

- Monitoring the data from three SLF wind towers on MIDDS or dedicated equipment. In the current procedure, the data from three SLF wind towers are manually added to the remarks section of the observation during shuttle launch and landing operations.

- Having an observer at Weather Station B with limited duty hours to augment/modify ASOS observations to include cloud tenths, type and height, prevailing visibility, present weather, and additive remarks. Observers would be used at the SLF for five 8-hour days Monday-Friday and during shuttle launch and landing operations. During non-operation times, the 8-hour shifts could be mission variable work hours depending on the next shuttle launch and landing times or have set times such as:

  - October through April: (fog season) — 0400 to 1300 local time
  - May through September: (thunderstorm season). — 1000 to 1900 local time

  During shuttle launch operations, the proposed weather observer hours would be from launch minus six hours to launch plus two hours from two days prior to launch through launch day. During shuttle landing operations, the proposed weather observer hours would be from landing minus 6 hours to landing plus 2 hours from one day prior to landing through landing day.

- Having personnel at the LACB and the Control Tower augment the ASOS observation only when a weather observer was not on duty at Weather Station B. The augmentation by LACB and Control Tower personnel would be limited to current observation duties and no additional training would be necessary. The current observation duties of the LACB and Control Tower personnel include reporting observed visibilities less than four miles, any rapid changes in weather phenomena that have not yet been reported (i.e., hail, lightning, tornado, and thunderstorm), and any relevant weather information contained in pilot reports.

An additional recommended component of this concept of operations includes:

- Having the RWO observer gather weather observations from observers stationed at the ROCC, Weather Station A, and Vehicle Assembly Building (VAB) during shuttle launch and landing operations (from the VAB only during launch operations). The observer would then enter the observations into a text file on MIDDS for distribution to SMG and MSFC. An example of the type of data contained in the text file follows:
  - ROCC: cloud tenths, type and height, present weather and additive remarks.
  - VAB: cloud tenths, type and height, present weather and additive remarks.
  - Weather Station A: complete observation including additive remarks.

A reduction in Air Force weather observers is scheduled and may impact the RWO's ability to perform this procedure.

Advantages of Concept of Operations #2

- The proposed concept of operations provides a potential reduction in cost since there would be a reduced number of hours of manual weather observations from Weather Station B. Currently, manual weather observations are taken at Weather Station B 24 hours a day, 365 days a year. In the proposed concept of operations, manual weather observations would only be taken 40 hours per week.

- The proposed concept of operations would not require additional weather observer training for LACB personnel. Proposed concept of operations #1 would require additional weather observer training for LACB personnel.

- The proposed concept of operations provides a consolidated text file of local weather observations (Weather Station A, VAB, and ROCC) on MIDDS during shuttle launch and landing operations.

- The use of multiple sensors will provide a more complete depiction of the meteorological conditions at the SLF. The current algorithm for multiple ceilometers assumes the use of two or more ceilometers separated by a distance of at least three miles. The current algorithm for multiple visibility sensors assumes the use of three visibility sensors separated by a distance of at least two miles (NOAA 1993).

- The use of the recommended ASOS units provides:
  - Consistent observations.
  - Sky conditions up to 25 000 feet.
  - Tenths of cloud cover.

Deficiencies/Disadvantages of Concept of Operations #2

- The cost of acquiring and maintaining the ASOS system.

- The cost of manual weather observations at Weather Station B would be greater for proposed concept of operations #2 as compared to proposed concept of operations #1.

- The number of hours per week of manual weather observations would be less for proposed concept of operations #2 (i.e., 40 hours a week at Weather Station B) as compared to proposed concept of operations #1 (115.5 hours per week at the LACB).

- The accuracy of ASOS tenths of cloud cover is unknown when used as a stand-alone unit (128 hours out of 168 hours per week).

- The accuracy of ASOS tenths of cloud cover depends upon cloud movement and adequate spacing of the ceilometers.

- ASOS observations would not include information about prevailing visibility, hail, thunderstorms and additive remarks from 2230 to 0600 local time. However, point visibility would be available 24 hours a day from the three ASOS sensor groups at the SLF. If desired, thunderstorm reports could be included in ASOS observations by ingesting the National Lightning Detection Network, Lightning Location and Protection system, or possibly Lightning Detection and Ranging system data into the SLF ASOS unit.

Additional Options for the Concept of Operations

Any or all of the following three options may be added to enhance concept of operations #1 or #2. Option A involves a transition period between the time an ASOS system is installed at the SLF and the time the ASOS provides the official weather observations for the SLF. Option B involves augmenting the ASOS observations during the off hours of the LACB personnel to ensure that all surface observation requirements are met 24 hours a day. Option C involves the use of mechanical instrumentation for backup purposes rather than the weather instrumentation from Weather Station B.

Option A: Transition Period After Installing ASOS at the SLF

After the ASOS unit is installed and operating at the SLF, manual and ASOS observations would be taken concurrently at the SLF for a period of at least six months. This would provide data for comparison tests between human and ASOS observations and allow the weather support community to develop confidence in the quality and accuracy of the ASOS observations. In addition, it gives the weather support community time to evaluate the multiple sensors/multiple sensor algorithms of the ASOS at the SLF and, depending upon the transition time period, time to incorporate improvements in ASOS sensors and algorithms. The only disadvantage of this option is the increased cost associated with taking both manual and ASOS observations concurrently at the SLF.

Option B: Augmented ASOS Observations 24-Hours a Day

This option is based on using a Weather Station B observer to augment the ASOS observations during the off-duty hours of the LACB certified weather observer to ensure augmented ASOS observations 24 hours a day. The Weather Station B observer would augment the ASOS observations from 2230 local to 0600 local each day, 7 days a week from either Weather Station B or the LACB. Advantages to this option include:

- The fulfillment of all SLF surface observation requirements.

- Having augmented ASOS observations 24 hours a day that include cloud tenths, type and height, prevailing visibility, present weather, and additive remarks.

The disadvantage to this option would be the labor cost to provide these observations.

Option C: The Use of Mechanical Instrumentation for Backup Purposes

This option is based on using mechanical instrumentation (i.e., hand-held sensors) for backup purposes rather than the Weather Station B equipment. As a key component in the proposed concepts of operations #1, the weather instrumentation at Weather Station B would be moved to a location at or near the LACB and be used as backup in the case of a partial or complete ASOS failure. However, the cost of moving the weather instrumentation from Weather Station B to near or at the LACB and maintaining this equipment may outweigh the benefits of using the equipment for strictly backup purposes. Currently, mechanical instrumentation is used for backup purposes to Weather Station B. Advantages to this option include:

- The cost savings of disassembling and relocating the Weather Station B equipment and its associated communication lines.
- The cost effectiveness of using the mechanical instrumentation.
- A reduction in the maintenance cost of the Weather Station B equipment.

The disadvantage to this option would be the decreased accuracy of the mechanical instrumentation.

6.0 Summary and Conclusion

6.1 Summary

This evaluation has focused on how ASOS, in conjunction with other systems and procedures, could be used at the SLF to satisfy SLF surface observations requirements. These observation requirements include standard airfield operations requirements, shuttle operations and simulations requirements, and SMG and Flight Director requirements. These requirements were compared to ASOS capabilities to determine which components of the observation requirements can be satisfied by a standard ASOS configuration and which components cannot. A further evaluation of ASOS involved the acquisition of documentation concerning the performance characteristics, reliability, and maintainability of ASOS. The documentation contained results of previous evaluations of system performance including comparisons of ASOS data to the manual observations to help show data similarities and differences, and ASOS strengths and limitations.

The AMU developed recommendations for configurations and concepts of operations for the use of ASOS at the SLF. It is important to note the AMU is not providing a recommendation on whether to use ASOS at the SLF. Rather, we have recommended specific configurations and concepts of operations for its effective use. The ASOS configuration recommended for use at the SLF is based on the standard ASOS production unit and includes modifications to enhance its capabilities with respect to SLF observation requirements. The proposed concepts of operations are based on using an ASOS with limited supplemental manual weather observations to satisfy all SLF surface observation requirements for selected time periods. One of the proposed concept of operations is based on having an ASOS system at the SLF and using LACB personnel to augment the ASOS observations. The second proposed concept of operations is based on having an ASOS system at the SLF and using a Weather Station B observer with limited duty hours to augment ASOS. Ultimately, it is the user community that must assess ASOS merits and deficiencies in terms of meeting the stated requirements.

This evaluation has also produced recommendations for additional meteorological sensors in the St. Johns River Valley. Since there is limited meteorological data (wind direction and speed) collected in the St. Johns River Valley and fog or stratus is advected into the SLF from that region, the AMU recommends the installation of additional instrumentation in the St. Johns River Valley. One solution would be to install one or more ASOS units in the St. Johns River Valley. However, it is probably more effective to install visibility sensors on the existing WINDS towers in the St. Johns River Valley. These sensors would provide forecasters with real-time information on visibility conditions to the west of the SLF and help detect fog development to improve fog forecasting skill in support of Shuttle operations. In addition to the visibility sensors, ceilometers could also be added to the WINDS network. This would further enhance fog forecasting skill plus provide cloud conditions to the forecaster.

6.2 Conclusion

After reviewing ASOS' capabilities in relation to SLF surface observation requirements, it was determined that ASOS alone cannot fulfill all the surface observation requirements. However, many of the ASOS observation deficiencies can be remedied by hardware and/or software additions/modifications to the standard ASOS configuration. Some of these enhancements include upgrading the current hardware, modifying the production software, and making use of multiple sensors.

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13. ABSTRACT (Maximum 200 Words)

This report documents the Applied Meteorology Unit's (AMU) evaluation of the Automated Surface Observing System (ASOS) for KSC's Shuttle Landing Facility (SLF). This evaluation has focused on how ASOS, in conjunction with other systems and procedures, could be used at the SLF to satisfy SLF surface observation requirements.

The SLF observation requirements were compared to ASOS capabilities to determine which components of the requirements can be satisfied by a standard ASOS and which components cannot. Further evaluation of ASOS involved the acquisition of documentation containing results of previous evaluations of system performance including comparisons of ASOS to manual observations.

The AMU developed recommendations for configurations and concepts of operations for the use of ASOS at the SLF. It is important to note the AMU is not recommending the use of ASOS at the SLF. Rather, we have recommended specific configurations and concepts of operations for its effective use. The recommended ASOS configuration is based on the standard ASOS unit and includes modifications to enhance its capabilities with respect to SLF observation requirements. The proposed concepts of operations are based on using ASOS with limited supplemental manual weather observations to satisfy all SLF surface observation requirements for selected time periods.

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