7.1 WEATHER SYSTEM UPGRADES TO SUPPORT SPACE LAUNCH AT THE EASTERN RANGE AND THE KENNEDY SPACE CENTER

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1. INTRODUCTION

The Air Force's 45th Weather Squadron (45 WS) provides comprehensive operational meteorological services to the Eastern Range (ER) and the Kennedy Space Center (KSC). These services include weather support for resource protection, pre-launch ground processing, and day-of-launch operations for more than 30 space launches per year by the Department of Defense (DoD), National Aeronautics and Space Administration (NASA), and commercial launch customers. Launch vehicles present a unique challenge in weather support to ensure both mission success and safety of personnel. Beginning with the preparation for the first ER missile launch (Bumper 8) in July 1950, weather support requirements, and systems necessary to meet those requirements, have been under continuous review and improvement to ensure the safe processing and launch of these vehicles.

2. LAUNCH OPERATIONS

On the ER, weather support for resource (people and facilities) protection from lightning, winds, and hail, is little different from that required at any other semitropical area. However, there are several aspects to space launch weather support, which are unique. Possibly the most misunderstood by the general public is selection of launch time. Frequently, one hears "why launch on a summer afternoon during maximum occurrence of thunderstorms?" The launch window is defined as the time period that the launch vehicle can launch to achieve precise program requirements. The many factors that enter into determination of the launch window (as discussed below) prior to any weather consideration, combined with the very dynamic weather of Florida, lead to weather becoming a prime cause of launch delays and/or scrubs (see Table 2 following).

There are several factors that carry more weight than weather considerations in establishing the launch window. For example, for Shuttle missions, if a launch hold would cause the crew day to exceed 18 hours, the timeline must permit rescheduling of activities to achieve mandatory payload objectives and limit the crew to 18 hours. Also, the launch window must accommodate mandatory payload objectives and other factors such as collision avoidance, and for interplanetary missions, planet alignment. Furthermore, climatology ranks below such factors as the following for determining Space Shuttle launch windows: available days, minimum duration, daylight landing opportunity, daylight launch, daylight landings at abort sites, and daylight return to launch site.

3. WEATHER SUPPORT REQUIREMENTS

Two items contribute to the difficulty of weather support by the 45th Weather Squadron: (1) the location of the Cape Canaveral Air Force Station (CCAFS)/KSC complex and (2) the extreme weather sensitivity of the mission combined with high cost of error. The area of maximum thunderstorm occurrence in the United States is in Central Florida, not far from the CCAFS/KSC complex. Consequently, thunderstorms represent the single greatest threat to operations on CCAFS/KSC, bringing deadly lightning and damaging winds. Table 1 shows monthly frequency of thunderstorms for the Shuttle Landing Facility (SLF) in 3-hourly increments, rounded to the nearest whole percent (- indicates less than 0.5 percent) based on 25 years (1973-1997) of hourly observations at the SLF (AFCCC, 1998). These climatological data clearly show a thunderstorm maximum in the summer afternoons, reaching 25 percent of hourly observations for 1500 to 1700 Local Standard Time (LST) in July. Days with thunderstorms (as opposed to hourly data) exceed 50 percent in both July and August. The number of cloud-to-ground strikes per year is widely variable within the CCAFS/KSC complex. The annual average ranges from 5 to 13 flashes per km^2 (Boyd et al., 1995).

Weather presents a significant hazard to all phases of spacelift operations (Boyd et al., 1995). During the processing phase, launch vehicles and their payloads are prepared for flight. These activities, which often occur outdoors, can involve propellants, ordnance, and sensitive electronic systems, all at risk from lightning strikes, winds, and precipitation.

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Table 1
Percent of Hourly Observations with Thunderstorms at the KSC Shuttle Landing Facility (1973-1997)

LST	APR	MAY	JUN	JUL	AUG	SEP
00-02	-	1	1	2	2	2
03-05	-	1	1	1	1	1
06-08	-	-	2	-	1	1
09-11	2	1	4	2	4	4
12-14	2	3	17	13	15	10
15-17	3	8	23	25	20	15
18-20	4	6	12	13	10	9
21-23	1	3	8	7	7	6

During the launch phase, the booster and its payload are more at risk due to the possibility of the vehicle triggering a lightning strike, or adverse changes in upper level winds that exceed the booster's structural capability. To assess the triggered lightning threat, the United States Air Force and NASA jointly developed a complex set of weather launch commit criteria (LCC) (Boyd et al., 1993). Upper-air data are provided to each customer, who assesses the impact to their launch vehicle. Smith and Adelfang (1992), and Tiwari and Schultz (1996) detailed how this is accomplished for the Shuttle and Titan IV, respectively. Impact of weather on launches is shown in Table 2, which clearly shows that weather is the leading cause for launch scrubs. Categories, other than weather, include "user", defined primarily as vehicle problems and "range" which includes all range instrumentation and/or safety concerns independent of the weather systems.

The ER Safety Office has multiple weather support requirements, including observation of the vehicle during ascent, toxic hazard forecasts (Parks, et al., 1996), potential blast effects of an explosion at the launch pad (Boyd and Wilfong, 1988), and debris fallout in case of an accident, all very weather sensitive.

Table 2
Eastern Range Launch Countdowns
(POR: 1 Oct 88-25 Aug 00)

Count-down	**Launch** (on time)	**Launch With *Delay***	***Scrubbed* Launch**
494 (100%)	173 (35%)	146 (30%)	175 (35%)
		Cause of Delay/Scrub	
		User 60 (12%)	User 74 (15%)
		Range 36 (8%)	Range 12 (2%)
		Weather 50 (10%)	Weather 89 (18%)

4. ER WEATHER SYSTEMS

The ER has the world's most dense operational network of weather instrumentation. Data from this network are used to assess and forecast weather conditions required to support space launch operations. Improvements and upgrades are made constantly to minimize the impact of weather while ensuring the safe processing and launch of space systems. Almost all of the current systems have been modified to some extent within the past decade.

4.1 Lightning Detection Systems

There are three primary ER lightning detection systems (Maier, et. al., 1995). The first of these is the Launch Pad Lightning Warning System (LPLWS)--a network of 31 field mills distributed in and around the launch and operations areas of CCAS and KSC, as shown in Figure 1. The network measures the electric field at the surface and also detects electric discharges. From the field measured at the surface, the charge aloft is inferred -- a key to evaluating danger of triggered lightning during launch.

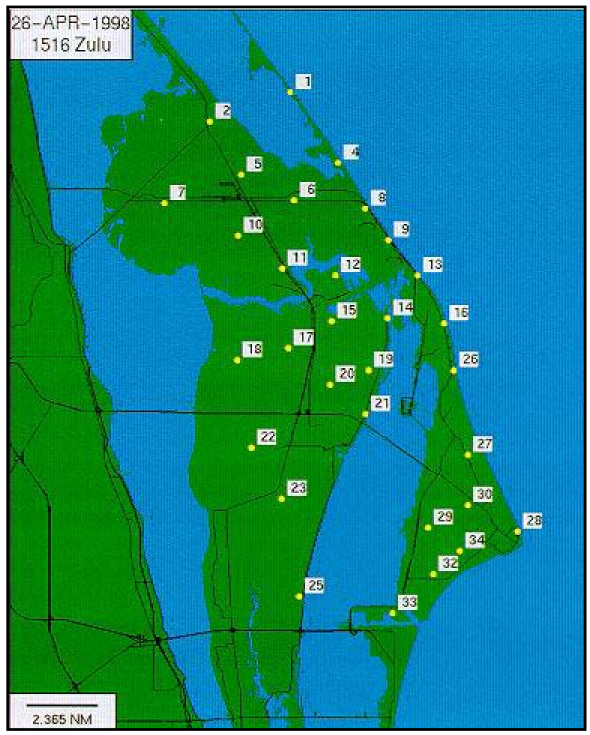

Figure 1. Field Mill Locations

The second ER lightning detection system is the Cloud-to-Ground Lightning Surveillance System (CGLSS) consisting of a network of six magnetic direction-finding and time-of-arrival (IMPACT) sensors deployed in and around the launch and operations area as shown in Figure 2. They are deployed on relatively short baselines and operate at low gain to ensure the requirements for high locating accuracy and detection efficiency of cloud-to-ground strikes are satisfied. This arrangement limits the CGLSS effective range to about 100 km.

Finally, the Lightning Detection and Ranging (LDAR) system, consisting of a network of seven receiver sites, which detect: inter-cloud, intra-cloud, and cloud-to-ground lightning, thus providing a 4-D representation of lightning in and around the CCAFS/KSC area. Each site receives VHF radiation at

66 MHz, logarithmically amplifies the received signal, and then transmits the signal to a central site using dedicated microwave links. Each site operates autonomously and is powered by solar-charged batteries. LDAR was developed, and is still operated and maintained, by NASA KSC. The 45 WS receives and evaluates LDAR data 24 hours per day, 7 days per week.

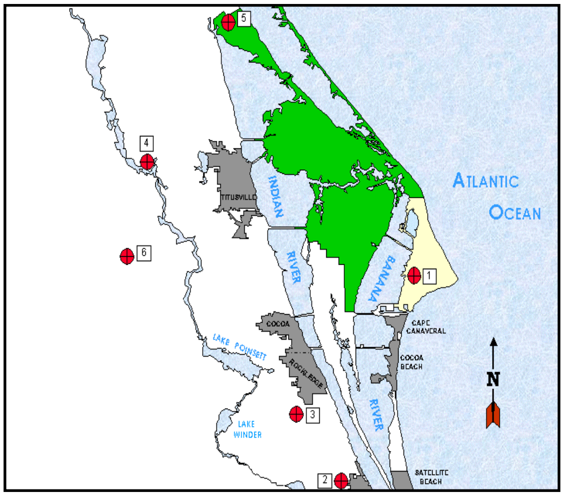

Figure 2. CGLSS Sensor Locations

4.2 Upper-Air Systems

The upper-air system is possibly the most critical single weather system on the ER. The high cost of space vehicles and payloads demands careful monitoring and evaluation of vehicle loading caused by in-flight winds. Modern launch programs, including Shuttle and Titan IV, develop a steering profile from actual observations and uplink to the vehicle as close as possible to launch. Essentially the launch vehicle's payload capability must be reduced by the loading uncertainties, thus reducing launch productivity (Wilfong, et. al., 1996). Various authors, Wilfong and Boyd (1989), Smith and Adelfang (1992), and Adelfang et al. (1993), have described these models and the impact of upper air variability on launch operations. The ER upper-air system, as described in detail by Wilfong et al. (1996) has recently been replaced by the Automated Meteorological Profiling System (AMPS), which uses the Global Positioning System (GPS) as described by Divers et al. (2000), and briefly summarized below.

4.2.1 Automated Meteorological Profiling System (AMPS)

AMPS consists of a ground element and two types of flight elements. The ground element includes an equipment cabinet, housing the meteorological processing equipment, a personal computer for control and data display, and an antenna tower for receiving the RF signals from the flight elements and GPS.

AMPS is designed to track up to six flight elements of either type simultaneously. The flight element telemeters raw GPS information for winds, temperature, and humidity (PTU) data on a 403 MHz downlink to the ground element. Pressure is computed by AMPS. A narrow band RF system is employed which can be tuned to any of 16 discrete frequencies to permit the simultaneous tracking of multiple flight elements within the 401 to 406 MHz band. Omni-directional 403 MHz antennas provide for all-aspect tracking without any steerable elements. A single low aspect angle antenna and a high aspect angle antenna continuously feed RF signals through pre-amplifiers to the 6-way RF splitter in the equipment cabinet. GPS signals needed for the differential corrections are provided via a microstrip patch antenna that also feeds a signal splitter system. In the equipment cabinet, the RF signals are fed to each of the individual tracking units, referred to as Signal Processing Subsystems (SPS). Each SPS contains three primary components - a processor module, a GPS module, and a 403 MHz receiver module plus the associated power supply. RF signals from each 403 MHz antenna are fed continuously to the 403 MHz receiver module. The selection of which signal to use is made automatically based on signal strength.

The receiver's baseband output is fed to the GPS module, which contains serial interfaces to the processor module and to the 12-channel base station GPS receiver, mounted in a daughter board configuration. The 403 MHz data and local GPS differential corrections are then fed into the processor module for conversion to wind and PTU data. The processor module also controls the frequency selection within the 403 MHz receivers based on operator inputs.

There are six identical SPS units that can be individually assigned to track a specific flight element. Each SPS communicates with the System Computer (SC) via a single IEEE 803.3 10 Base T Ethernet LAN. The LAN hub is located in the equipment cabinet, with the SC as the server and six SPS units as the workstations. The System Computer receives the wind and PTU data packets from up to six flight elements simultaneously and generates the real-time displays and data outputs to the USAF data collection system. Data files for each profile are archived within the SC. All operator interface for command and control of the system is through the SC.

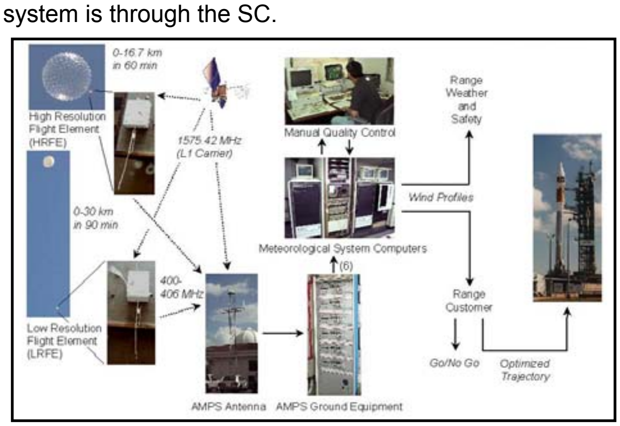

Figure 3. AMPS Flow Diagram

The AMPS low-resolution flight element (LRFE), used for measurement of atmospheric winds and pressure, temperature, and humidity (PTU), is lofted by a standard weather balloon. The high-resolution flight element (HRFE), for wind measurements only, is carried by a 2-meter Jimsphere. An inverse differential GPS approach is used for calculation of the wind.

4.2.2 Doppler Radar Wind Profiler

The evaluation of radar wind profilers to directly improve structural stress analysis support started at the ER in 1987, when NASA awarded a contract to design and build a demonstration super-profiler system (Smith, 1989). The NASA/KSC Doppler Radar Wind Profiler (DRWP), commonly referred to as the 50 MHz DRWP, operates at 49.25 MHz with an average power-aperture of 10^8 Wm^2. The system was installed adjacent to the north end of the Shuttle Landing Facility (SLF) on KSC in 1989 in a low power configuration (4 kW). The system was completed in 1990 with the installation of a high power amplifier (250kW) that significantly extended the vertical range of the system (although the system is normally operated at 125kW). The system provides estimates of the horizontal wind components directly above the radar AT 5-minute intervals. A wide range of parameter settings provides complete flexibility in the radar operating characteristics. Nominal settings are shown in Table 3.

Soon after its installation in 1989, Marshall Space Flight Center (MSFC) identified problems with the single cycle and consensus wind algorithms supplied with the DRWP. To improve the quality and time resolution of the DRWP wind profiles, MSFC developed a new wind algorithm to replace the single-cycle and consensus techniques within the DRWP. The Applied Meteorology Unit (AMU) (Ernst et al., 1995) at KSC successfully transitioned the new wind algorithm, known as the Median First Guess (MFFG) wind algorithm, to an operational status in 1993 (Wilfong et. al, 1993).

Table 3
50 MHz DRWP Nominal Settings

Peak Power	250 kW
Antenna Type	Electronically steered phased array, 2 oblique beams at 15° from vertical and one vertical beam
Antenna Area	15,600 m^2
Pulse Width	1.0 μs
Pulse Repetition Period	160 μs
Maximum Radial Velocity	± 26-29 m/s
Number of Gates	112 (2.0 - 19.0 km)
Gate Spacing	150 m
Wind Algorithm	median filter first guess
Number of Spectral Points	256
Cycle Time	30 min

4.3 Boundary Layer Sensors

Boundary layer sensing is accomplished by two major systems: a network of five 915 MHz DRWPs with Radio Acoustic Sounding Systems (RASS), and a network of (currently) 44 towers with wind/temperature/dew point sensors, referred to as the Weather Information Network Display System (WINDS).

A network of five 915 MHz boundary layer profilers with RASSs (Heckman et al., 1996 and Lucci et al., 1998) was installed to fill the data gap from the top of the wind towers to the lowest gate of the 50 MHz DRWP. The network is arranged in a diamond-like pattern over the area with an average spacing of 10-15 km. Capabilities of the profilers are summarized in Table 4. Lockheed Martin modified the 915 MHz profilers in 1999 under the Range Standardization and Automation (RSA) program (see paragraph 5). Antenna aperture and power were increased significantly to improve altitude coverage.

The WINDS is operated and maintained by the 45 SW Range Technical Services Contractor, who supplies the data to the 45 WS for their evaluation.

The locations of the WINDS platforms cover an area of approximately 1200 km^2 for an average spacing of 27 km^2. Sensors are located at various heights from 2 to 165 m (one platform is 165 m high and three others are 67 m), and report wind, temperature and dew point either each minute or every five minutes.

Table 4
915 MHz Radar Wind Profiler Nominal Operating Parameters

Peak Power	2 Kw
Antenna Type	Electronically steered phased array, 4 oblique beams at 21° from vertical and one vertical beam
Antenna Area	2.76 m^2
Pulse Width	0.4, 0.7, 1.4, or 2.8 μs
Pulse Repetition Period	23 μs
Maximum Radial Velocity	± 10 m/s
Number of Gates	25 (0.117 - 2.437 km) 22 (0.221 - 4.280 km)
Gate Spacing	97 m (0.7 μs pulse) 193 m (1.4 μs pulse)
Wind Algorithm	Consensus averaging (3 or 5 beams)
Number of Spectral Points	64
Averaging Time	9 min

4.4 Weather Radar

In 1983, the ER purchased and installed a WSR-74C (5-cm wavelength) weather radar to replace the FPS-77. A project was immediately started to incorporate a volume scan processor to produce data sets from 24 elevation angles between 0.6 and 35.9 degrees sampled over five minute intervals.

In 1987, the volume scan project was completed, with the WSR-74C radar control and display consoles (one for the Applied Meteorology Unit (AMU) and one for Range Weather Operations (RWO)) located at CCAFS and the transmitter/receiver antenna located at Patrick Air Force Base (AFB) (Austin, et al., 1988). Data digitization allowed forecasters to construct and display Constant Altitude Plan Position Indicators (CAPPIs), vertical cross-sections, and echo tops, animate displays, and extract point information such as maximum tops and radial location. The CAPPI function is especially useful during launch countdowns to allow interrogation at any desired level. Figure 4 below shows an example of a CAPPI during the scrub of STS-108 on 4 Dec 01 due to light rain showers in the area.

In 1998 a project was completed which upgraded the system to the IRIS/Open software (Boyd et. al., 1999). That system increased the update rate from a complete volume every five minutes to one every 2 ½ -minutes. It provides the capability to display reflectivity over any user-defined range with user defined color-coding. These new features enable routine detection and display of weak reflectivity features such as nonprecipitating clouds and mesoscale boundaries (e.g. fine lines and sea or river breeze) close to the radar. The radar reflectivity field can be displayed in standard plan position indicator (PPI) or range height indicator (RHI) format in real–time. Additionally, following each 2 ½ -minute volume scan build cycle, the system generates the following products, each available for display: Vertical Cross Sections, Maximum Reflectivity, Maximum Echo Top, Vertically Integrated Liquid (VIL), Track/Forecast Product Display (TRACK), Constant Altitude PPI (CAPPI), and Warn/Centroid Product Display (WARN).

The volume scan strategies (figure 5) were further refined over the next two years by the AMU to better support operations (Short, et al., 2000).

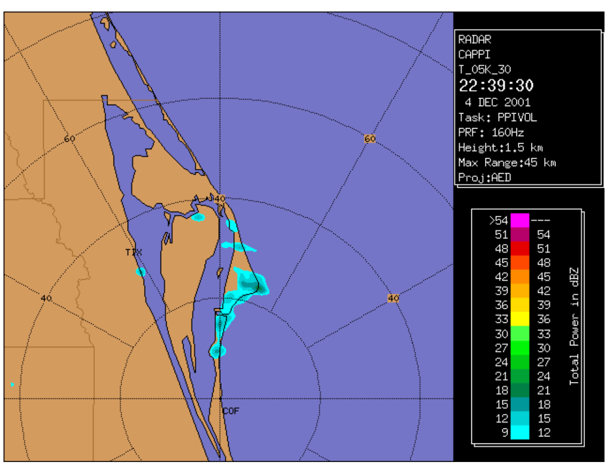

Figure 4. CAPPI Display

The third of the first five nationally procured “NEXRADs” (WSR-88Ds) was installed in Melbourne in 1989. The ER has access to that National Weather Service WSR-88D via three Principal User Processors (PUPs); one each located at the RWO and AMU at CCAFS, and one at the Patrick AFB weather station.

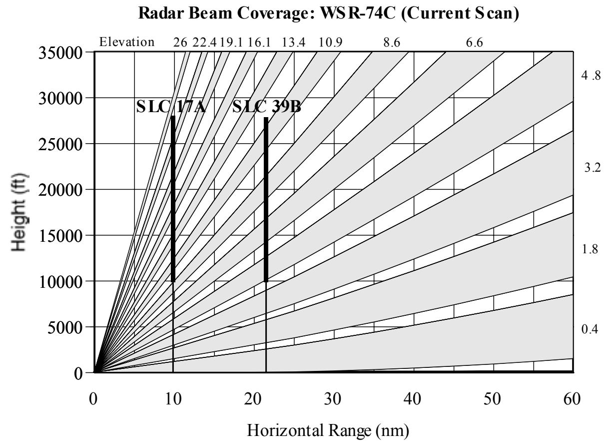

Figure 5. Scan strategy

Table 5
WSR-74C Characteristics

PARAMETER	SPECIFICATION
Antennas Assembly Type Azimuth travel Elevation travel	 Elevation over azimuth 360° continuous -1° to +85°
Parabolic Antenna Type Diameter Polarization Gain Beamwidth	 Horn-fed parabolic 3.65 m Linear, horizontal 43 dB, minimum 1.05° (3 dB)
Transmitter Frequency Peak power output Magnetron type Pulsewidth PRF	 5625 MHz (5.3 cm) 241 kW 5083 coaxial 4 μs nominal (1.0 μs selectable) 160 s^{-1} nominal (640 s^{-1} selectable)
Receiver Type Dynamic range Bandwidth IF Gain control Attenuation Sensitivity	 Logarithmic 76 dB, minimum 0.375 MHz (4 μs pulse) 30 MHz Fixed User selectable from 0 to 93 dB in 3 dB steps Capable of detecting rain rates of 0.25 mm/hr at 370 km

4.5 *Control and Display System (C&D)*

The current satellite receive and integrated display system, the Meteorological Interactive Data Display System (MIDDS), was installed in 1984/85 and first described by Erickson et al. (1985). Over the years it has undergone many modifications, but today is still a derivative of the University of Wisconsin Space Science and Engineering Center's (SSEC) Man-computer Interactive Data Access System (McIDAS). The original goal of MIDDS was to consolidate all meteorological data into a single data management and display system. Although that goal has yet to be fully reached, it remains valid today.

5. FUTURE IMPROVEMENTS

The ER has several ongoing projects to improve and modernize its weather systems. In addition, the Air Force Space Command, parent organizational command of the 45th Space Wing, is working to modernize both the Eastern and Western Ranges through a long-term program called Range Standardization and Automation (RSA).

5.1 Lightning Detection Systems

KSC signed a Space Act Agreement with Global Atmospherics, Inc. (GAI) for "Lightning Detection and Ranging (LDAR) Systems Dual Use Development and Commercialization Effort". That partnership resulted in development of "LDAR II" by GAI. Their first system was recently installed in the vicinity of the Dallas Fort Worth (DFW) International Airport (Demetriades et al., 2002), is made up of 7 sensors with 20 to 30 km baselines. The DFW LDAR II network can map lightning flashes in 3 dimensions within approximately 150 km of the center of the network. Lightning flash detection efficiency is expected to be greater than 95% within the interior of the network (a range of 30 km) and greater than 90% out to 120 km. The Air Force expects to take advantage of that development to procure and install that or a similar commercial off-the-shelf 4-D lightning detection system to replace the KSC "one-of-a-kind" proof-of-concept system still in use.

Also, under RSA, the original goal of MIDDS is to consolidate all lightning systems into a single integrated display is expected to be accomplished.

5.2 Upper-Air Systems

NASA continues to refine the 50 MHz profiler (Schumann et al., 1995 and Fitzpatrick et al., 2000), primarily for its application to improving stress analysis support. The Air Force has contracted through their Space Lift Range Systems Contractor (SLRSC) to make modifications, which will improve the operations and maintenance of the 50 MHz DRWP when it is transferred from KSC to the ER. These include: a Quality Control (QC) Conversion Processor upgrade and QC communications. Under a subcontract, the following will be accomplished: upgrade the high voltage power supply, replace the data/receiver with a Pentium-based Radar Computer with LAP-XM profiler data collection software, and ensure GPS timing to LAP-XM.

5.3 Boundary Layer Sensors

5.3.1 SODARS

The Range Standardization and Automation program will fill the data void in the lower layers of the atmosphere by adding six mini-sodars. The mini sodar is designed to provide very high-resolution winds and reflectivity below 200m. The RSA implementation provides complete measurements every minute. The altitude coverage is from 15 meters to 200 meters in 5-meter increments. The mini sodars employ a phased array antenna of 32 elements designed to form three orthogonal beams. In each beam, the mini sodar measures the radial wind velocity and the reflected power each second. In addition to the average wind velocity, the systems also report the gust speed and direction, the standard deviation of the three wind components, and the signal to noise ratio.

Figure 6. A mini-sodar

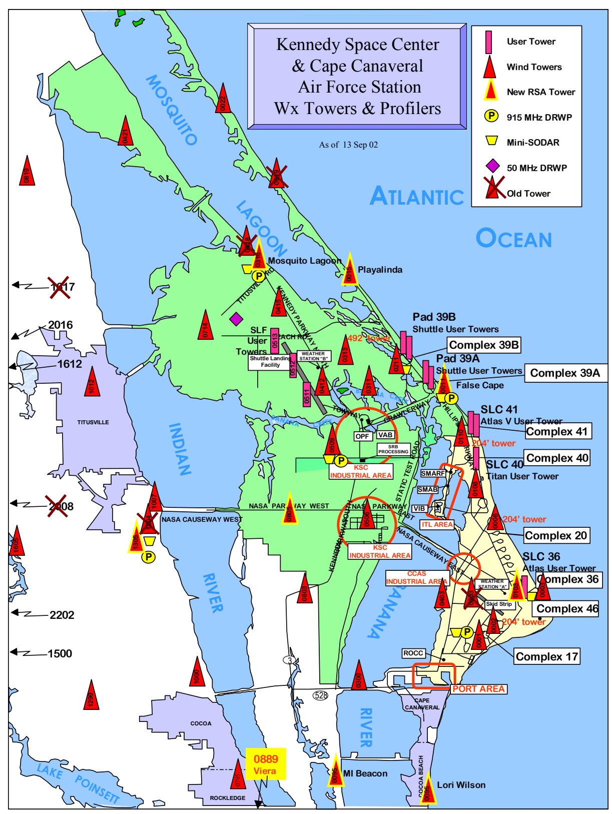

Figure 7. ER Instrumentation

5.3.2 915 MHz DRWPs

Building on the RSA modifications, SLRSC will complete those items required to ensure efficient operations and maintenance of the 915 DRWPs. These efforts include purchase of additional spares, development checkout procedures, software configuration controls, and documentation of logistics engineering procedures.

5.3.3 Other

The RSA contractor has already modified the tower network through deletion, addition, or relocation of some towers (Figure 7) to optimize the network for best coverage in support of the space launch mission. New sensors, including sonic anemometers have been installed. The new network is expected to become operational early 2004.

5.4 Weather Radar

A major radar improvement is in the planning stages. The plan calls for replacement of the current WSR-74C radar system. The new radar is planned to be a state-of-the-art, polarimetric, C-band (4 – 8 cm) Doppler radar system. The radar will be optimally sited and its data integrated into the RSA display system. Standard volumetric radar products will be updated and provided to forecasters every 2.5 minutes.

The system should provide two operationally significant capabilities that the current WSR-74C does not have. The first being the ability to retrieve three-dimensional vector wind fields. This will be accomplished by installing a network comprised of the active or single transmitting weather radar along with one or more bi-static receivers. The receivers for this network will be non-transmitting, non-scanning and remotely located from the active radar. This network of a single transmitting radar and multiple passive receivers will act much like a network of multiple transmitting radars, in that it will retrieve three-dimensional vector wind fields. The wind components will than be available for initialization of the local mesoscale model delivered as part of RSA.

The second capability the radar system should provide is dual-polarization measurements. By transmitting electromagnetic beams in both the vertical and horizontal directions, changes in signal properties can be used to estimate the size, shape, orientation, and type of hydrometeors. Two of the polarimetric measurements of particular interest are the Linear Depolarization Ratio (LDR) and Differential Phase Shift (KDP). Both of these products have been shown to be useful in identifying regions where high electrical charge is located within cloud areas (Illingworth and Hogan, 2002). The ability to identify electrified cloud regions will significantly improve the 45 WS's capability to forecast the onset and ending of lightning as well as the potential for triggered lightning. Research conducted using other polarimetric measurements have shown promise in providing more accurate rainfall estimations, unique hail detection capabilities, and estimating horizontal water vapor content within the boundary layer (Keeler et al., 2000).

5.5 Control and Display System (C&D)

As part of a modernization program, the National Weather Service (NWS) has spent many years creating an interactive analysis and forecasting tool for weather forecast offices. A major part of the RSA Program is modernization of the current C & D system. The RSA project leverages the NWS effort. Working with the National Oceanic and Atmospheric (NOAA) Forecast Systems Laboratory (FSL), the RSA project is expanding the capability of the Advanced Weather Interactive Processing System (AWIPS). Specifically, general-purpose functions are being expanded or created to visualize site-specific data. These functions will be integrated into the AWIPS baseline (Wilfong et al., 2002).

As shown in Figure 8, the weather infrastructure is implemented on two separate local area networks (LANs). The Operations Control Center (OCC) LAN interfaces to all local instrumentation and is used to acquire, quality control, and archive local data, as well as to distribute instrumentation data, mesoscale model data, and decision products. The AWIPS LAN is implemented in much the same way as the NWS installations and uses the new Linux based architecture. Local data acquired by servers on the OCC LAN are formatted and sent to the AWIPS LAN where they are combined with NOAAPORT and NEXRAD data acquired directly by the AWIPS.

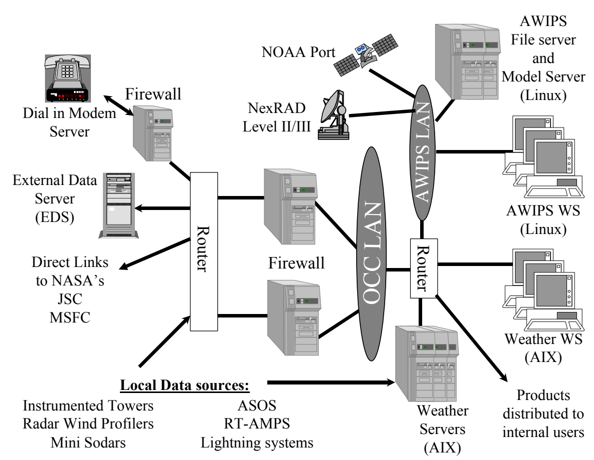

FIGURE 8. The RSA C & D System

The RSA implementation of AWIPS uses Linux PC and NFS servers. Mimicking the NWS' proposed hardware upgrades, the RSA program is implementing high-end IBM IntelliStation PCs for data display with an IBM eServer series 350 network file server for data ingest, decoding, and storage.

5.6 Local Mesoscale Model

The AWIPS LAN also supports a mesoscale model server used to run a local area analysis and forecast model (Shaw et al. 2002). Lockheed Martin in partnership with FSL has implemented an assimilation and forecast system using the Local Analysis and Prediction System (LAPS), (Albers et al. 1996). In principle, LAPS can be coupled with any mesoscale NWP model.

The NCAR/PSU fifth-generation mesoscale model (MM5), (Grell at al. 1995) has been selected for use as the forecast component for the RSA project. FSL's close working relationship with NCAR and extensive experience with the MM5 model, combined with its public domain nature, make it a logical choice. Additionally, the selection of MM5 as the forecast component places the RSA program on a direct track for upgrading to the emerging Weather Research and Forecast (WRF) model in the future.

MM5 Version 3, Release 4 (MM5v3-4) is the version implemented within the RSA program. It is a nonhydrostatic model utilizing a terrain-following pressure coordinate and offers a wide variety of boundary layer schemes, cumulus parameterizations, microphysical schemes, and longwave radiation formulations. Minor modifications have been made to accommodate the diabatic initialization technique. It has three interactive grids with the inter-most having a horizontal resolution of 1.1 km.

6. SUMMARY

With the help of many dedicated individuals in diverse organizations, the Air Force and NASA have established the world's premier instrumentation site for operational meteorology to support America's space program at the Eastern Range. Through the combined efforts of the United States Air Force, NASA, NOAA, and other organizations, weather support to our Nation's space program is continuously being improved.

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