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THE APPLIED METEOROLOGY UNIT – OPERATIONAL CONTRIBUTIONS TO SPACEPORT CANAVERAL

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1. INTRODUCTION

The Applied Meteorology Unit (AMU) provides technology development, evaluation and transition services to improve operational weather support to the Space Shuttle and the National Space Program. It is established under a Memorandum of Understanding among NASA, the Air Force and the National Weather Service (NWS). The AMU is funded and managed by NASA and operated by ENSCO, Inc. through a competitively awarded NASA contract. The primary customers are the 45th Weather Squadron (45WS) at Cape Canaveral Air Force Station (CCAFS), FL; the Spaceflight Meteorology Group (SMG) at Johnson Space Center (JSC) in Houston, TX; and the NWS office in Melbourne, FL (NWS MLB).

This paper will briefly review the AMU's history and describe the three processes through which its work is assigned. Since its inception in 1991 the AMU has completed 72 projects, all of which are listed at the end of this paper. At least one project that highlights each of the three tasking processes will be briefly reviewed. Some of the projects that have been especially beneficial to the space program will also be discussed in more detail, as will projects that developed significant new techniques or science in applied meteorology.

2. AN OVERVIEW OF THE AMU

The AMU was established in 1991 based on recommendations from a "blue-ribbon" NASA advisory panel (Theon 1986) and the National Research Council (NRC) (National Research Council 1988). In accordance with those recommendations it was co-located with the Air Force operational forecasters at CCAFS to facilitate continuous two-way interaction between the AMU and its operational customers. It is operated under a NASA, Air Force, and NWS Memorandum of Understanding (MOU) by a competitively selected contractor. The contract, which is funded and managed by NASA, provides five full time professionals with degrees in meteorology or related fields, some of whom also have operational experience. A broad range of expertise is maintained including mesoscale meteorology, numerical weather prediction, radar meteorology, thunderstorm and associated hazards prediction, applied statistics, instrumentation, computer visualization, and management of meteorological information. NASA provides a Ph.D.-level NASA civil service scientist as Chief of the AMU. The AMU Chief manages the AMU for the Government and participates actively in its technical work. The Air Force provides office and laboratory space adjacent to Range Weather Operations in the Range Operations Control Center at Cape Canaveral Air Force Station. The NWS provides access to additional space at the Melbourne Florida NWS Office when required. Both Air Force and NWS personnel also collaborate with the AMU in its technical work.

The AMU is tasked by its customers through a unique, nationally recognized (Office of Naval Research 1996) process that is described in detail below. The tasks are limited to development, evaluation and operational transition of technology to improve weather support to spaceport operations and providing expert advice to the customers. The MOU expressly forbids using the AMU resources to conduct operations or do basic research. The AMU may be tasked to perform any or all of the following technology transition services

- Evaluating new technologies with the potential for immediate or near-term operational application
- Tailoring new or existing technologies to the specific requirements and capabilities of our customers and their infrastructure
- Assisting with the development of a concept of operations for effective use of new or existing technologies
- Developing training materials for the use of weather sensors, systems and techniques
- Assisting in the effective specification, acquisition, installation and testing of new weather systems and sensors

Examples of several of these kinds of work will be presented below.

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Once the AMU has been assigned a task, the AMU Program Manager assigns a principal investigator and other team members as appropriate. The team prepares a task plan that describes the work to be done, the methodology to be used, the deliverables to be prepared and the task schedule. This plan is reviewed with the customer(s) who proposed the task to ensure that the task has been correctly understood and that the deliverables are what the customer wants. Monthly progress reports and quarterly technical reports are provided to all customers and the quarterly reports are posted to a publicly accessible website (http://science.ksc.nasa.gov/amu). The customer is usually directly involved throughout the design and development of the work. At every critical decision point during the execution of the tasking, the customer is involved in the decision making process. Finally, before the deliverables are formally presented the customer is given an opportunity to review a draft or beta test version of each. This interactive task execution process has also been nationally recognized as a "best practice" (Office of Naval Research 1996).

In cases where the AMU's work may be of general interest to the scientific community, an appropriate conference paper or journal article will be prepared. A complete bibliography of AMU publications may be obtained from the website. Including papers currently in press, the total number is approaching one hundred.

3. THE AMU TASKING PROCESS

The first process is a formal, prioritized quasi-annual tasking that allocates the 5 contractor full-time equivalents (FTE) based on consensus of the three tasking agencies at a face-to-face meeting. The second process is 'option hours' tasking, where any of the tasking agencies may purchase additional FTE from the AMU beyond the NASA-funded five on a non-interference basis with the formally prioritized tasks. Finally, there is 'operational immediate' tasking, where technical consultation requiring the special skills of the AMU is needed immediately to support a time-critical operation. Though 'operational immediate' tasks are rare, the AMU provides at least one person to support all launches in case they are needed.

3.1 *Formal Prioritized Tasking*

Formal prioritized taskings are assigned by consensus of the AMU tasking group. The group consists of representatives from the Air Force, NASA and the NWS. A quasi-annual face-to-face meeting is convened at a location determined in advance by group consensus. About six weeks prior to the meeting, each of the three agencies submits proposals for taskings for the next 12 to 15 months. Each proposal includes at least the following

- A descriptive title
- A detailed technical description
- The operational benefit or requirement to be satisfied by undertaking the task
- A statement explaining why the AMU is the best organization to perform the work
- A list of deliverables and the customer(s) to whom they will be delivered
- An estimate of the AMU resources required to perform the work

After the proposals are received, the AMU contractor reviews them and makes its own independent assessment of the following

- The feasibility of the task
- The appropriateness of the task for the AMU
- The resources required to perform the task

Each proposal with the associated contractor review is provided to the three participating agencies for discussion and evaluation. Prior to the face-to-face meeting, email and telephone discussions take place to lay the groundwork for an efficient and effective face-to-face meeting.

The tasking meeting is designed to match the proposed work to the available resources. Inevitably, the sum of the resources required to do all of the proposed work exceeds the resources actually available. Unless proposals are modified or withdrawn, they must be prioritized and only those proposals with high enough priority to remain above a resource-determined "cut line" will be performed.

There are four phases of discussion at the meeting. In the first phase each agency presents its proposals and the group has the opportunity to ask clarifying questions. The goal of this phase is to ensure that every proposal is completely understood. The proposals are not critiqued or prioritized. Phase two provides each agency with the opportunity to critique the proposals and make suggestions for eliminating, modifying or combining proposals in order to get within the resource limitation. If phase two does not result in reducing the proposed workload to match the labor available, phase three begins in which the remaining proposals are ranked in priority order. The ranking is done by a consensus process with the possibility of a formal vote available as a backup if consensus cannot be reached. Since its inception, the AMU tasking process has always been able to achieve a consensus result, usually by additional modification or withdrawals of proposals to get within the resource limitation. The AMU contractor is an important contributor to finding ways of re-scoping and scheduling the work to maximize the opportunity to meet the requirements of all of our customers. After the proposals are ranked, the contractor presents a final analysis of the remaining tasks and advises where the cut line, if any, must be drawn. Phase four is the adoption of the tasks above the line as the formal prioritized work of the AMU for the following year.

3.2 *Option Hours Tasking*

Option hours tasking is available for work that was not accepted through the formal prioritized process or which is proposed between tasking meetings. A customer who is willing to pay for the service may request that their proposed task be undertaken using option hours. Under the terms of the AMU contract, the Government may buy up to two full time equivalents (FTE) (labor years) per year in addition to the five FTE base-funded by NASA. The use of option hours is subject to the following constraints

- The tasks must be consistent with the AMU MOU
  - May not undertake basic research
  - May not perform operational duties
  - Must relate to improvement of weather support to the Shuttle Program or national and commercial space program activities at the Eastern Range
- The tasks may not conflict with or impede the formal prioritized taskings
- The AMU must be the most appropriate facility for conducting the work

The Chief of the AMU, as NASA contract manager, makes the final decision as to whether a proposed option hours tasking is appropriate. If the tasking is approved the proposing organization provides the necessary funding to purchase the additional hours.

3.3 *Mission Immediate Tasking*

On rare occasions, the special expertise and experience of the AMU may be needed to assist the operational customers with a situation outside of their normal experience base under conditions where there is not time to go through either of the processes discussed above. This may happen, for example, during a launch countdown where unusual radar signatures are seen or remote sensing and in situ observations appear inexplicably inconsistent. Resolving the causes of these anomalies needs to be done immediately to assure success of the mission. The AMU Chief has the authority to assign a Mission Immediate tasking to the AMU if the following criteria are met

- The work does not constitute performing an operational role (because that would violate the terms of the MOU)
- The AMU has the necessary expertise to perform the work at the level of competence required
- The urgency of the situation precludes using the option hours process
- The scope of the work is small enough that any disruption or delay of other taskings will be small and transient.

4. A DECADE OF AMU PRODUCTS

Although the AMU has been in operation for nearly thirteen years, this paper focuses on the last decade. Products from the first several years were presented in a paper by Ernst and Merceret (1995). The products described in this section are not a comprehensive listing, but they do provide examples of the three tasking methods described above and the various product types that typify the AMU's service to the American space program. Some of the products requested by the AMU customers include written reports, training, sensor analysis, display software, data ingest software, statistical analysis, climatological analysis, forecaster aids, numerical weather prediction (NWP) model evaluation and improvement, data quality control, and operator training, a few of which are described in this section. In it's nearly 13 years of operation, the AMU has completed 53 tasks, only a few of which are described here.

4.1 *Anvil Forecast Tool – Formal Prioritized Tasking*

The 45WS and SMG identified thunderstorm anvil forecasting as one of their most challenging tasks when predicting the probability of a Launch Commit Criteria (LCC) violation or evaluating Space Shuttle Flight Rules (FR) due to the threat of natural and triggered lightning. In this case, the customers requested the AMU to develop a capability to display a thunderstorm anvil threat corridor on a satellite image6. The threat corridor is based on observed data from a rawinsonde or forecast data from an NWP model. The AMU delivered a product through which the forecaster can request the Meteorological Interactive Data Display System (MIDDS) (Schumann 1996) to generate an anvil threat corridor which is shown by dotted lines on the satellite picture in Fig. 1. If thunderstorms are forecast to occur in the threat corridor, the time until the resulting anvils would approach close enough to violate launch or landing constraints (Roeder et al., 1990) can be estimated from the dotted range rings on the threat corridor overlay. By developing this tool directly on MIDDS, the forecasters can use the capability in real-time on a system they use routinely in support of daily operations

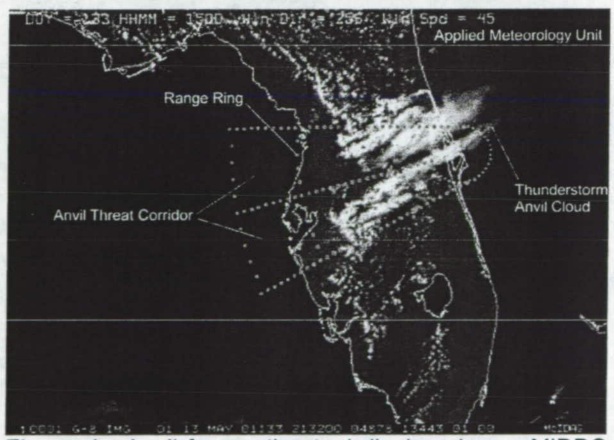

Figure 1. Anvil forecasting tool displayed on a MIDDS forecaster workstation

4. 2 *Microburst Prediction Tool – Formal Prioritized Tasking*

The 45WS wanted to improve their microburst forecast capability after a poorly forecast 33.5 m s^{-1} (65 Kt) microburst event occurred at the Shuttle Landing Facility on 16 August 1994. The 45WS tasked the AMU to develop an application forecasters could use daily to better forecast these severe wind events. The AMU developed a RAOB-based Microburst-Day Potential Index (MDPI) that provides an estimate of the probability downbursts each day. The product is displayed on MIDDS in a manner similar to that shown in Fig. 2. The MDPI performance includes a probability of detection of 97%, a false alarm rate of 28%, and a critical success index of 70% (Wheeler and Roeder 1996). As with the anvil forecasting tool, the MDPI is executed and displayed on MIDDS giving the forecasters direct access to this product for daily operations support. The tool also displays the Wind Index (WINDEX) developed by the National Severe Storms Forecast Center (now Storm Prediction Center). In addition to the MDPI, The AMU developed related radar-based tools for nowcasting downbursts using cell trends.

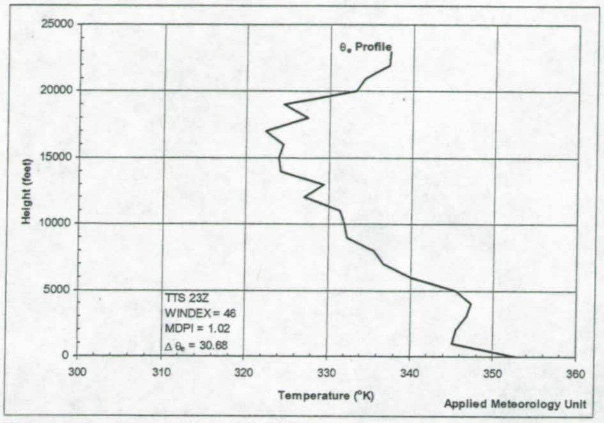

Figure 2. Example of MIDDS graphical MDPI/WINDEX display.

4.3 *Numerical Weather Prediction (NWP) – Formal Prioritized Tasking*

In an effort to improve NWP model capability, the AMU was tasked to improve the integration of local meteorological data sets into the analysis scheme for the Advanced Regional Prediction System (ARPS) NWP model. Most NWP models use national data sets but very few take advantage of any available local data. The KSC/CCAFS area has a high density of meteorological observations that could improve local short-term model forecasts if the data were assimilated properly into an analysis scheme. One example of a local data set integrated into ARPS is shown in Figs. 3 and 4 which depicts the forecast radar composite reflectivity without using radar data from the Melbourne, Florida Weather Surveillance Radar-1988 Doppler (WSR-88D) (Fig. 3) and with the WSR-88D data (Fig. 4). It is clear that the data from the local radar produced forecast radar reflectivity in east central Florida which was much closer to the observed values as seen within white circles. The assimilation of local data sets is a continuous process that runs with the ARPS analysis scheme thereby providing forecasters with better NWP model guidance for every forecast cycle.

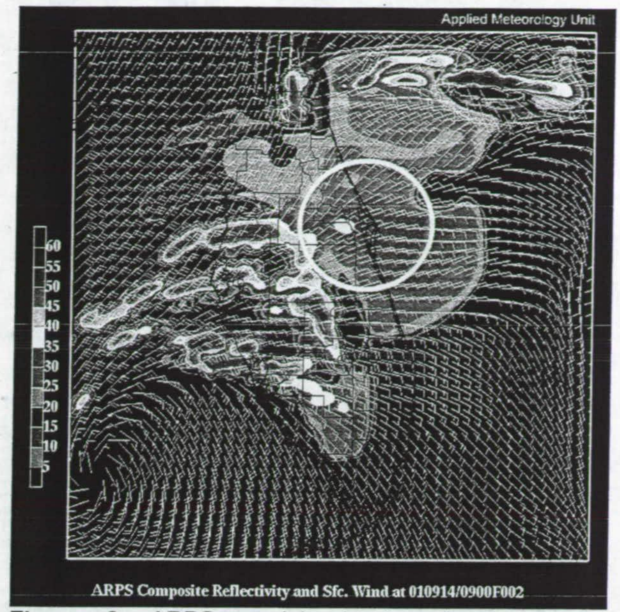

Figure 3. ARPS model showing forecast radar composite reflectivity without assimilating local radar data.

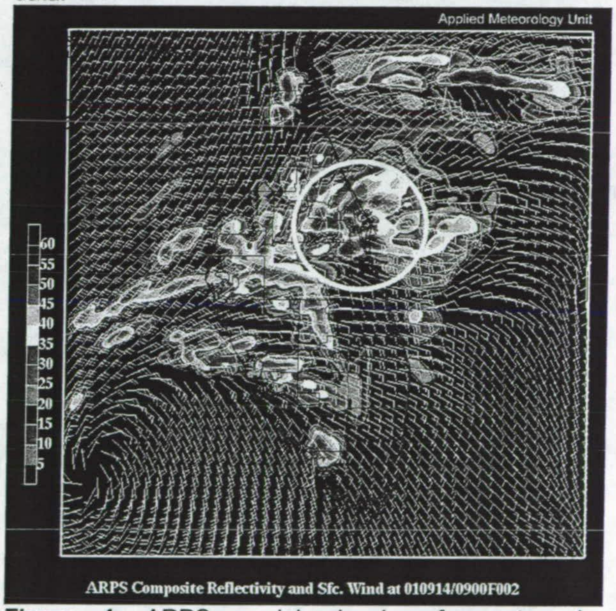

Figure 4. ARPS model showing forecast radar composite reflectivity with assimilating local radar data.

4.4 *Sensor Evaluation – Formal Prioritized Tasking*

The networks of meteorological sensors in and around KSC/CCAFS play a critical role in support of space launch operations. Forecasters rely on the accuracy and consistency of these sensors to produce accurate forecasts. When the balloon-borne sensor system or Meteorological Sounding System (MSS) was to be replaced after about two decades of operation, the AMU was tasked to compare the data from the MSS with the new Automated Meteorological Profiling System (AMPS). The purpose of the AMU study was to determine the nature of relative humidity differences between the AMPS and MSS, and to evaluate the impact of any such differences on the diagnosis of tropospheric stability and thunderstorm forecasting indices10. Because local experience and thunderstorm forecast rules-of-thumb are based on a long history of stability indices computed from MSS observations, it was important that forecasters become familiar with any changes in the relative humidity data that may accompany the transition to AMPS and the resultant impact on the tools used for analysis and forecasting of thunderstorm activity.

Figs. 5 and 6 show the vertical profiles of average relative humidity from both sensors for the cool season (Fig. 5) and the warm season (Fig. 6). The initial AMU sensor comparison indicated forecasters could expect the atmosphere to appear less stable when diagnosed with AMPS than with MSS, assuming that their temperature profiles were equal. However, the AMU determined that AMPS and MSS stability indices computed from the warm-season dual-sensor profiles were statistically indistinguishable. This apparent paradox was resolved by evidence of a weak systematic temperature difference between AMPS and MSS that counteracts effects of the relative humidity difference on stability indices. As a result of this analysis the AMU was able to recommend that AMPS products be used without modification thereby providing the forecasters with a high level of confidence in the new system.

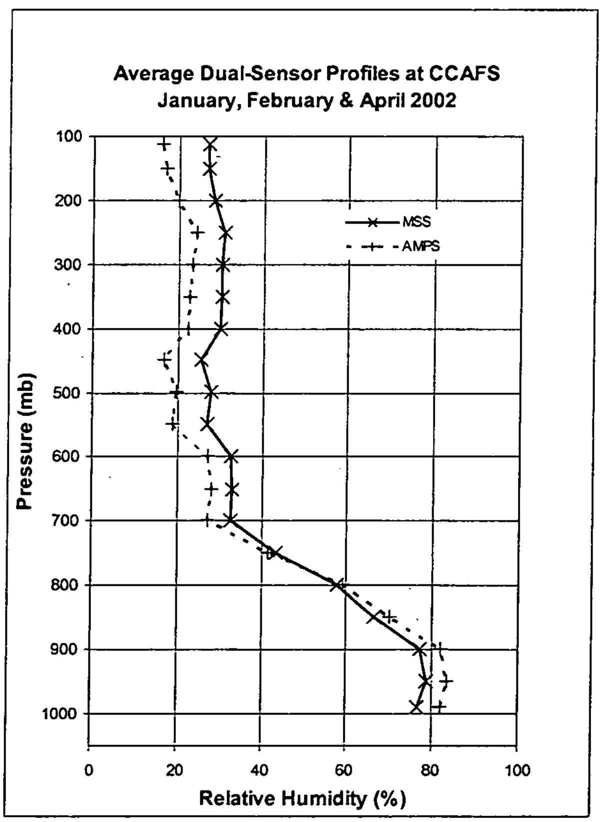

Figure 5. Vertical profiles of average relative humidity from the MSS (solid) and AMPS (dashed) sensors for twenty dual-sensor ascents taken in January, February and April 2002.

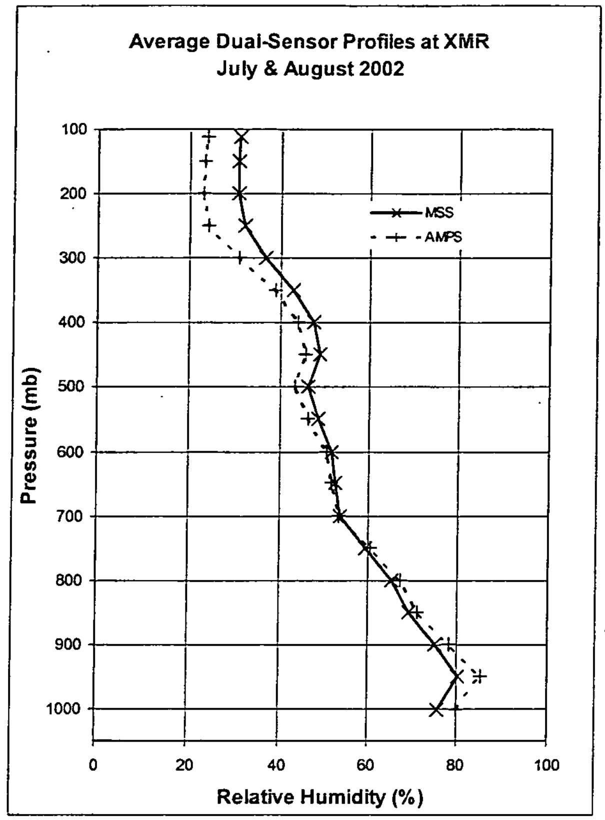

Figure 6. Vertical profiles of average relative humidity from the MSS (solid) and AMPS (dashed) sensors for twenty dual-sensor ascents taken in July and August 2002.

4.5 *Poorly Forecast Severe Weather Event – Mission Immediate Tasking*

The AMU was tasked to analyze and evaluate a poorly forecast severe weather event that affected a major portion of Brevard County including Patrick Air Force Base on 13 August 1996. The severe weather event occurred during the warm season and therefore the task was levied as "Mission Immediate" to quickly ascertain why the event was not forecasted and what could be done to improve forecasting of similar events for the rest of the season. The primary purpose of the analysis was to evaluate relevant meteorological data from the event in order to glean lessons learned and to better understand the contributing factors that caused the damaging weather. From this analysis recommendations were derived to assist forecasters in recognizing these contributing factors more readily when they occur. Results and recommendations were provided for the benefit of future warning operations at both the 45WS and the National Weather Service in Melbourne (NWS MLB).

4.6 *Space Shuttle Optical Imaging – Option Hours Tasking*

The NASA/ KSC Weather Office tasked the AMU to: *"Identify and evaluate alternative methods for* *determining whether or not a sufficient number of Shuttle launch imaging cameras will have a field of view unobstructed by weather".* This task was based on the finding from the Columbia Accident Investigation Board (CAIB) Report11 for Space Shuttle return to flight. Since the CAIB Report dictated that the Shuttle could not return to flight before this capability was in-place it was imperative to quickly determine if it was possible to observe and forecast conditions allowing the cameras to have an unobstructed view of the Shuttle upon launch. The AMU determined what methods were available to mitigate cloud forecasting challenges.

Based on these results, the AMU was further tasked through the prioritized tasking process to develop a statistical model and forecast decision aid for the Space Shuttle Launch Weather Officer using both option hours and base-funded hours.

5. SUMMARY

The AMU has been an outstanding example of interagency cooperation and effective, practical technology transition. Its success is due to at least five factors:

- Its unique customer-driven tasking process
- Continuous end-to-end customer involvement in task planning and execution
- Co-location of the AMU with an operational customer
- The range and depth of education and experience of the AMU civil service and contractor employees
- Flexibility in the tasking process, adapting task design, or even canceling tasks as lessons are learned during the task

These factors have led the AMU to a remarkable record of delivering operationally useful products on schedule and on budget for over a decade. The appendix consists of three tables that lists and describes all of the AMU products delivered by the AMU during it's nearly 13 years of operation. Table 1 shows all of the Formal Prioritized Tasking products, Table 2, all of the Mission Immediate Tasking products, and Table 3 all of the Option Hours Tasking products.

6. REFERENCES

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APPENDIX

TABLE 1. All Formal Prioritized Tasking products delivered by the AMU since beginning operation in 1991.

AMU Task	Weather Support Problem	AMU Product	Customer/Operational Benefit	Delivery Date
0.2 Cloud Cover Flight Rule Evaluation	• Rule Based on Limited Ability to Accurately Forecast at SLF • Rule May be Unduly Restrictive	• Flight Rule Modification Recommendations • Weather Data Bases for Decision Assistance	• Flight Rule Change Increased Availability of SLF for Shuttle Landings	Jun 93
50 MHz Radar Wind Profiler Algorithm	• Uncertified Instrument • Data Quality/Reliability not proved adequate for wind persistence as required by ascent community	• Operational MSFC Algorithm Software • User's Manual • Maintenance Manual • Software Requirements Specification	• System Acceptable For Day of Launch Use – Titan using DRWP for Loads – Shuttle Uses for Persistence • Data Refresh Increased from 30 Minutes to 5 minutes • Result: Increased Vehicle Safety	Feb 94
ASOS Evaluation	• Cost of 24 Hour Weather Observations at SLF • Non-COTS System	• ASOS Deployment Options	• Detailed Quantitative Information to Aid in Decision-Making Process	Mar 94
SLF Wind Tower Siting Assessment	• Potentially Unrepresentative Wind Observations for Shuttle Landing Due to Sheltering Effect and Distance from Runway	• Assessment • Methodology for Evaluation • Recommendations for Fix	• Trees Removed Adjacent to Runway Resulting in Increased Orbiter Safety • Improved Use of Wind Data in Engineering Analysis of Vehicle Response to Winds on Landing	May 94 (Spacing) Apr 95 (Sheltering)
SLF Fog Development Evaluation	• Limited Ability to Accurately Forecast Fog Development at SLF -- reduces availability of KSC for landing • Each Landing Diverted to EAFB Encurs $1M in Ferry Flight Costs	• Fog Forecast Decision Trees • MIDDS Display Programs • Weather Data Bases for Decision Assistance	• More Confidence in Forecast – Increased Likelihood of Landing Shuttle at SLF – Increased Landing Safety	Jun 94

AMU Task	Weather Support Problem	AMU Product	Customer/Operational Benefit	Delivery ate
NEXRAD/McGill Scan Strategy Comparison	• Cost of Continuing to Operate and Maintain PAFB WSR 74C/McGill Radar • Inadequate Understanding of Radars' Beam Coverage Impacted FR and LCC Evaluations	• Determined and Compared Effective Beam Coverage of MLB WSR 88D and PAFB WSR 74C/McGill Radars over KSC/CCAS Vicinity	• More Accurate Evaluation of FR & LCC • Increased Vehicle Safety • Improved Weather Warnings • Potentially Reduced Costs for Shuttle FR & LCC Evaluation	Jul 94
MIDDS Exploitation	• MIDDS Greatly Under Used • MIDDS User Hostile – Not Designed for Operations – Designed for Research	• F-key Menu System Documentation • Operational Macro Programs • Maintain Menus	• MIDDS Used More Effectively -- significant increase in access to data • Reduced Number of Keystrokes for Typical Command by Factor of 83 • Reduced Training Costs • Reduced System Maintenance Costs	Feb 96
MASS Model Evaluation	• Insufficient Ability to Forecast Local Wx Hazards Affecting Launch, Landing, and Ground Operations	• Determined Accuracy / Reliability of MASS Model • Recommended Model Not Be Implemented for Operations	• Saved Implementation, Certification, and Operations Costs	Dec 95
MDPI and WINDEX Evaluation	• Limited Ability to Forecast • High False Alarm Rate	• Operational Macro Program and Forecast Index	• More Accurate & Timely Microburst Warnings & Advisories	May 96 Nov 97 (update)
LDAR Evaluation and Transition	• Lack of Ability to Detect Cloud-to-Cloud and Within Cloud Lightning -- unacceptable ability to observe / forecast lightning hazard	• Computer-Based Training Course	• Increased Forecaster Accuracy Resulting in – Avoidance of Lightning Hazard (Natural / Triggered) – Safer / More Efficient Day-to-Day Ground Operations – Less Ground Operations Downtime	Jul 96

AMU Task	Weather Support Problem	AMU Product	Customer/Operational Benefit	Delivery Date
Mid-Tropospheric Wind Change Climatology	• Unable to Quantify Risk Avoidance Benefit of Doppler Radar Wind Profiler • Quantified Benefit Required for 50 MHz DRWP Cost Benefit Analysis by Shuttle/Titan	• 0.25, 1, 2, and 4 Hour Wind Change Climatology • Probability of Exceedance Curves for Wind Change Magnitudes	• Understanding of Risks of Unacceptable Wind Change as a Function of Time • Operational Risks can be Assessed for Design of Launch Constraints	Jul 96
I&M and RSA Support	• Upgraded/New Weather Systems Must Meet Customer Needs	• Review Vendor Briefings, Documents, Products • Review System Interoperability/Data Communications • Test Vendor Products/Prototypes • Provide Technical Advice, Comments, Suggestions	• Ensure Proposed Systems are Operationally Useful and Satisfy Customer Requirements – MIDDS Upgrade Support – Proposed Move of False Cape Profiler – Requirement for Additional Weather Radar – Collaborated on Removing Requirement for 449 MHz Profiler and Additional 915 MHz Profiler – Saved $1.3M	Ongoing since Aug 96

AMU Task	Weather Support Problem	AMU Product	Customer/Operational Benefit	Delivery ate
NEXRAD Exploitation	• NEXRAD Under-Exploited – High False Alarm Ratio in NEXRAD Severe Weather Algorithms – NEXRAD Algorithms Tuned to Midwestern Environment – Limited Ability to Recognize Convection Initiation and Severe Storm Signatures in NEXRAD Products – Limited Understanding of Capability of VAD Wind Profile	• Determination of Severe Weather and Convection Initiation Signatures	• Enhanced User Understanding of NEXRAD Products which Best Display Signatures Important to Convection Initiation and Severe Storm Detection – Reduced False Alarms – Reduced Failure to Detect Severe Weather – Safer / More Efficient Day-to-Day Ground Operations – Less Ground Operations Downtime • VAD Wind Profile Evaluation Transferred to NWS Saving Evaluation Costs	Jan 97
LDAR Data Compression/Filtering	• LDAR's High Data Rates Make it Difficult to Ingest and Process LDAR Data in MIDDS	• Investigated Data Compression/Filtering Techniques • Identified Options for Less Data-intensive Display	• Information Necessary for Making a Technical Decision	Mar 97
Radar/PIREP	• Unable to Resolve Cloud Top Difference Between Radar and Pilot Reports (Number One Operational LCC Issue at Start of Task)	• Determined Cause of Inconsistency • Alerted Users to Potential Problems with Radar-estimated Cloud Tops	• Improved LCC Evaluations	Mar 97
National Mesoscale Model Evaluation (29 km Eta)	• Insufficient Ability to Forecast Local Wx Hazards Affecting Launch, Landing, and Ground Operations	• Determined Most Effective Ways to Visualize, Interpret, and Use 29 km Eta Model for Short Range Forecasting	• Improved Short-range Forecasts for Ground, Launch, and Landing Operations	Jun 97 Apr 98 (Update)

AMU Task	Weather Support Problem	AMU Product	Customer/Operational Benefit	Delivery ate
Warning Decision Support System (WDSS) Evaluation	• Assimilation of Radar Data • High False Alarm Ratio in Severe Weather Detection	• NSSL's Algorithms Tuned to Central FL Weather Environment • Evaluation was a joint effort of the AMU and NWS MLB	• Improved Public Safety & Increased Accuracy • System for Convection Analysis and Nowcasting (SCAN, which includes WDSS) Included in 45 SW I&M Budget	Jun 97
Cell Trend Comparison of WATADS Vs. WSR-88D	• Limited Understanding of Capabilities of New WSR-88D Products • Forecaster Data Overload	• Recommendations for Use of the New Products	• Improve Lead Time in Issuance of Wx Warnings and Advisories • Improve Forecaster's Understanding of Thunderstorm Structure	May 98
915 MHz Wind Profiler Evaluation	• Limited Ability To Access Boundary Layer Winds • Data Quality/Reliability Not Proved Adequate for Wind Persistence as Required by Ascent Community	• Collaborated on Site Selection • Assist in Development of System Requirements • Review of Vendor Designs/Products • Documentation Sufficient for Certification	• Improved Thunderstorm and Toxic Diffusion Forecasts Resulting in – Increased Vehicle Safety – Safer / More Efficient Ground Operations – Less Ground Operations Downtime • Collaborative Efforts Resulted in Elimination of Need for Additional Profilers	Apr 96
915 MHz Wind Profiler Data Quality Control (QC)	• No QC Performed on Data; Contaminated Data Displayed with Accurate Data	• Acquire/Develop/Test QC Routines for Real-time and Post-analysis Use • Quality/Reliability of Wind Data Sufficient for Operational Use	• Forecaster Ability to Distinguish Between Good and Bad Data • Forecaster Knowledge of Data Contaminants, Including Certain Meteorological Conditions	Jun 98
MIDDS-X Transition	• Limited Understanding of Capabilities/Functionality of MIDDS-X	• Technical Expertise • Recommendations for Use/Display of Satellite and Graphic Products	• Improved Forecaster's/LWO's Understanding of System	Nov 98

AMU Task	Weather Support Problem	AMU Product	Customer/Operational Benefit	Delivery Date
AMU MIDDS-X Conversion	• Weather System Functionality Moved to New Platform	• Programs – Conversions • New Displays/Products	• Improved Speed and Display Characteristics	Dec 98
ERDAS RAMS Evaluation	• Insufficient Ability to forecast fine Scale Weather Affecting Launch, Landing, and Ground Operations • Upgraded RAMS Configuration in ERDAS Required Formal Evaluation	• Interim and Final Evaluation Reports of RAMS Model Errors and Benchmark of Results Against the National Eta Model	• Improve Specific Short-term Forecasts for Ground, Launch, and Landing Operations • Determine Added Value of ERDAS RAMS	Jun 00 (Interim) Jun 01 (Final)
Extend ERDAS RAMS Evaluation	• Need for Improved Forecasting of Fine-Scale Weather Affecting Launch, Landing, and Ground Operations • Need to Evaluate RAMS Forecasts in Real-time	• Tools to Evaluate RAMS Quality in Real-Time • Training on Use of Tools • Evaluation of Performance for Various Weather Elements • Recommendations on Improving RAMS • Final Report Documenting All of the Above	• Knowledge on the Quality of RAMS Forecasts for Range Safety • Tools to Evaluate RAMS in Real-Time	Aug 01
WSR-74C IRIS Exploitation (Phase 1)	• Need to Evaluate Capabilities of the IRIS Radar Product Generator	• Final Report Recommending Prioritized List of IRIS Products • Recommendation for a Revised Radar Scan Strategy	• Fully Exploit Integrated Radar Information System (IRIS) Capabilities • Reduce Vertical Gaps in Radar Coverage by 37% over KSC/CCAFS	Apr 00
WSR-74C IRIS Exploitation (Phase 2)	• Need to Customize Products and Tools for Operational Forecasting	• Memorandum Describing Seasonally Varying Radar Scan Strategies • Information on Special Purpose Radar Products	• Capability to Optimize Radar Scan for Seasonally Varying Conditions • Information to be Used for a Request for Quotation to a Software Vendor	Apr 01

AMU Task	Weather Support Problem	AMU Product	Customer/Operational Benefit	Delivery ate
Improve Anvil Forecasting (Phase 1)	• Anvil Forecasting is a Difficult Task Predicting Triggered Lightning Launch Commit Criteria / Flight Rules. • No Techniques Exist that Forecast Anvil Formation or Determine Anvil Length	• Report on Technical Feasibility of Forecasting Anvils • Consultation on Decision to Proceed with Phase 2	• Determination Whether or Not Development of an Anvil Forecasting Technique is Feasible	Mar 00
Improve Anvil Forecasting (Phase 2)	• Need to Develop Observations-based Operational Tools for Anvil Forecasting	• Objective Anvil Forecast Tools for 0-3 Hours Ahead • Training on Use of the Forecast Tools • Final Report Documenting Tools and Training	• Improved Short-Range Forecasts of Anvil Clouds for Prediction of Triggered Lightning Launch Commit Criteria and Flight Rules	Apr 02
Improve Anvil Forecasting (Phase 3)	• Need to Develop Model-based Operational Tools for Anvil Forecasting	• Objective Anvil Forecast Tools for 0-72 Hours Ahead • Training on Use of the Forecast Tools • Final Report Documenting Tools and Training	• Improved Long-Range Forecasts of Anvil Clouds for Prediction of Triggered Lightning Launch Commit Criteria and Flight Rules	Dec 02
Anvil Transparency Relationship to Radar Reflectivity	• Anvil Opaqueness is a Critical Element in Evaluating Flight Rules and Launch Commit Criteria • Surface/Pilot/Satellite Obs Currently Used, but All Have Limitations	• Threshold dBZ Value that Corresponds to the Anvil Transparency Threshold • Final Report Describing Analysis and Results	• Objective Method that Uses Current Radar Data to Analyze Anvil Transparency	Jun 04
Statistical Short-range Forecast Tools	• Need for Short-range (0-6 hr) Guidance in Forecasting Winds and Cloud Cover for Launch/Landing/Ground Operations	• Statistical Forecast Guidance Equations and Charts • Database of all Data Used in Task • Final Report Describing Development and Use of Tools	• Improved Short-range Forecasts of Cloud Ceilings and Peak Winds	Aug 01 (Ceiling) Jun 02 (Winds) Jun 03 (SLF Winds)

AMU Task	Weather Support Problem	AMU Product	Customer/Operational Benefit	Delivery Date
Data Integration Model/ Data Deficiency (LDIS Phase I)	• No Automated Tools to Assimilate Mesoscale Data in Central Florida • Limited Availability of Nowcasting Tools • Forecaster Data Overload	• Prototype Analysis System • Evaluation Report Identifying Mesoscale Data Sources & Describing Proof-of-Concept Analysis System	• Proof-Of-Concept System Demonstrating – Improved Short-term Forecasts for Ground, Launch, and Landing Operations – Improved Weather Warnings & Advisories	Jan 99
Local Data Integration System Extension (Phase 2)	• Need for Real-time Assimilation of Mesoscale Data in Central FL • Limited Availability of Nowcasting Tools • Forecaster Data Overload	• Configuration and Simulation of Prototype Analysis System with Real-time Data for a 2-week Period • Evaluation Report Discussing System Performance, Data Influence, and Forecaster Tools	• Improved Nowcasting Capabilities • Knowledge of Hardware Necessary for a Real-time Analysis System • Understanding Utility of All Operationally-available Data	Aug 99
Local Data Integration System (Phase 3)	• Need for Real-time Mesoscale Data Assimilation in Central FL • Limited Availability of Nowcasting Tools • Forecaster Data Overload	• Assistance in Installing and Configuring LDIS at Customer Offices • Memorandum Detailing the Procedures for Implementing the Mesoscale Data Analysis System	• Customers Have Access to Timely High Resolution Meteorological Analyses for Launch/Landing Support and Routine Forecasting Operations	Apr 01
Local Data Integration System (Phase 4)	• Incorporate Additional Data Sets into the Real-time LDIS • Fine-tune and Improve the Continuity of Analyzed Weather Features	• On-site and Remote Assistance to Ingest New Observational Data Sets • Memorandum Summarizing the Improvements and Fine-tuning of LDIS	• Improved Real-time Analysis Products for Launch/Landing Support and Routine Forecasting Operations	Oct 01

AMU Task	Weather Support Problem	AMU Product	Customer/Operational Benefit	Delivery Date
Local Data Integration System Optimization and Training	• Incorporate Additional Data Sets into the Real-time LDIS • Need for Training on the Maintenance of the Real-time LDIS • Explore Advanced Features and Techniques not Currently Implemented or Available	• On-site and Remote Assistance to Ingest New Observational Data Sets • Memorandum Summarizing Training and Feasibility for Implementing Advanced Features	• Improved Real-time Analysis Products for Launch/Landing Support and Routine Forecasting Operations. • Training Manual to Help Customers Maintain Real-time LDIS	Mar 03
Detecting Chaff Source Regions	• Limited Understanding of Weather Radar Interference During Launch Support • Chaff Echoes could Mask LCC-Related Weather Echoes	• Report Documenting Source Regions of Chaff Affecting Radars Around KSC During the Winter Months	• Documentation Provides Operational Resource Showing Known Chaff Source Regions	Jun 00
Neumann-Pfeffer Replacement	• Inaccurate Performance of the Current Neumann-Pfeffer Thunderstorm Probability Index (NPTPI) Prompted the Air Force Institute of Technology (AFIT) to Develop a More Reliable Algorithm • 45 WS Requested New AFIT Software be Implemented for Forecaster Use Before the 2001 Warm Season	• Converted and Commented AFIT code that Operates on a PC in the RWO • Memorandum Explaining How to Use the Code	• Improved Thunderstorm Probability Forecast Tool that will Calculate/Display Current Day's Probability of Occurrence and Time of Occurrence	Jun 01
Operations Research Support	• Organizations Doing Weather Research Lacked Convenient Access to AMU Databases	• Provide Data and Software Developed Internally by the AMU. • Provide Copies of Previously Published AMU Reports. • Review Documents, Write Memoranda, and Provide Technical Consultations as Requested.	• AMU Databases Available to All Weather Organizations Doing Research	Ongoing Since Jul 99

AMU Task	Weather Support Problem	AMU Product	Customer/Operational Benefit	Delivery Date
Advanced Meteorological Profiling System (AMPS) Moisture Profiles	• AMPS is Scheduled to Replace MSS as the Operational System. • Differences in RH Profiles Between AMPS and the Meteorological Sounding System (MSS) may cause change in values of stability indices.	• Analysis of Cool-Season Dual-Sensor RH Profiles from AMPS and MSS • Report on Impact of RH Differences on Thunderstorm Forecasting Indices Used by 45 WS. • Interim Operational Recommendations based on Projection of Cool-Season Results to Warm-Season	• Interim Operational Procedures for Correcting AMPS derived Thunderstorm Forecasting Indices. • Prevent Potential Degradation of Thunderstorm Forecasting Skill Due to Impact of Systematic Difference in AMPS RH Profiles on Thunderstorm Forecasting Indices.	Jul 02
Extend AMPS Moisture Analysis	• AMPS Moisture Profiles in Previous Task May Not Represent Warm Season Profiles • Warm Season Profiles Created by Extrapolating Cool-Season Results	• Analysis of Warm-Season Dual-Sensor RH Profiles from AMPS and MSS.	• Operational Procedures for Correcting AMPS derived Thunderstorm Forecasting Indices.	Jun 03
Land Breeze Forecasting	• Impact of Nocturnal Land Breezes on Low-level Wind Direction, low temperatures, and Fog Development • Challenge in Predicting Occurrence, Onset Time, Duration, Speed, and Direction	• Comprehensive Climatology of Land Breezes and their Characteristics in the Wind-tower Network. • Final Report with Subjective Forecast Rules to Help Determine the Land Breeze Occurrence, Onset Time, and Movement	• Set of Forecast Rules that can be Used to Determine the Occurrence, Timing, and Movement of Land Breezes	Sep 02
Mini-SODAR Evaluation	• Quality of New Mini-SODAR Wind Speed/Direction Data at SLC 37 unknown. • The Mini-SODAR will be used to Evaluate Launch Pad Winds for Operations.	• Comparison of Mini-SODAR Wind Speed and Direction with Nearest Tall Tower. • Final Report on Performance Characteristics of Mini-SODAR as a Replacement for a Tall Tower.	• Ability to assess Mini-SODAR Wind Speed and Direction Data Quality Used for Critical Go/No Go Launch Decisions by 45 WS Forecasters and Launch Weather Officers.	Sep 03

AMU Task	Weather Support Problem	AMU Product	Customer/Operational Benefit	Delivery Date
Mesonet Temperature and Wind Climatology	• Anecdotal Evidence Suggests Certain Mesonet Towers Show Biases in Temperature and Wind Speed/Direction – No Objective Study Ever Done. • Forecasters Need to be Aware of Biases When Issuing Warnings/Advisories, and Evaluating LCC and FR.	• Collective and Individual Tower Temperature and Wind Climatologies in Tabular/Geographical Form • Individual Tower Biases in Tabular/Geographical Form • Final Report Describing Analysis and Results • Training and Assistance in Transitioning Product into Operations.	• The Objective Analysis of the Climatologies and Biases are Desired for Mission Planning Decisions, Forecaster Training, and as an Aid in Evaluating Flight Rules and Launch Commit Criteria.	Jul 04
Objective Lightning Probability Forecast	• Current Lightning Probability Forecast Made Using Subjective Techniques • Forecasters Desire an Objective Technique Based on Statistical Analysis of Historical Data	• Objective, PC-Based Tool that Calculates the Probability of Lightning Occurrence for the Day • Final Report Describing Analysis and Results • Training on Use of Tool	• Increased Objectivity in Daily Lightning Probability Forecasts	Aug 04
Severe Weather Forecast Decision Aid	• Process for Making Forecasts of Severe Weather Potential has Not Been Updated to Reflect Current Knowledge	• A Forecast Decision Aid (e.g. Flow Chart, Nomogram, Decision Tree) • Final Report Describing Analysis and Results • Training on Product Use	• A More Objective Method for Assessing Severe Weather Potential Based on Current Knowledge and Practices	Sep 04

TABLE 2. All Mission Immediate Tasking products delivered by the AMU since beginning operation in 1991.

Mission Requirement	Weather Support Problem	AMU Product	Customer/Operational Benefit	Delivery Date
Improve Detection of Low Level Clouds for Launch / Landing Operations and Range Optics	• Limited Ability to Detect Low Level Clouds in Low Light Conditions as Required to Evaluate LCC/Flight Rules	• Developed Satellite Enhancement to Resolve Low Level Clouds	• Improved RTLS, AOA, EOM & Range Optics Forecasts	Oct 91
After Hurricane Andrew, 45 WS Tasked to Provide Warnings, Advisories, and Aviation Forecasts to Federal Emergency Personnel in South Florida	• Within 24 Hours, Reconfigure AF Equipment to Provide Totally New Support to Large Area with Diverse Requirements	• Set up National Lightning Detection Network in RWO • Configured MIDDS Workstation in RWO • Trained RWO Forecasters on Equipment use • Provided Guidance on South Florida Forecast Techniques	• During Andrew Recovery – – Increased Forecast Lead Time / Accuracy for South Florida – Improved Response Time – Enhanced Safety of People in Perilous Situation	Aug 92
Determine Frequency of Low Visibilities at SLF Near Sunrise	• Sudden Fog Development at SLF Could Endanger Shuttle Landings	• Developed Graphs Depicting Frequency of Low Visibilities at SLF	• Improved RTLS, AOA, EOM & Range Optics Forecasts	Oct 92
Understand Effect of Various Wind Averaging Techniques on Displayed SLF Winds	• Lack of Confidence in Wind Measurements Resulting from Different Averaging Techniques Used by Different Meteorological Systems	• Analytical and Observational Analysis of Averaging Effects Resolving the Major Issues	• Enhanced Confidence in Measured SLF Winds	May 93
Determine Cause of Weather Radar Interference During Launch of STS-56	• Cause of Weather Radar Interference During Launch Unknown - Could Mask LCC Related Weather Echoes	• Radar Cross-section Analysis Indicated Interference Cause by Chaff • Operational Technique for Chaff Diagnosis	• Reduced Frequency of Occurrence of Weather Radar Interference by Chaff During Operations • Saved over $250K in Cost Avoidance for Chaff Study • Minimize Uncertainty of Cause of Weather Radar Interference	Jun 93
Understand Electrostatic Discharge Detected by LDAR During Launch of STS-55	• Cause of Electrostatic Discharge Detected by LDAR Unknown • Concern About Potential for Damage to Orbiter	• Determined Moisture Content of Atmosphere Near Vicinity of Discharge • Helped Understand STS-55 LDAR Event	• Confidence that Current LCC Adequate	Jun 93

Mission Requirement	Weather Support Problem	AMU Product	Customer/Operational Benefit	Delivery Date
13 August 1996 Case of Severe Storms at Patrick Air Force Base (PAFB)	• Severe Thunderstorm that Caused Extensive Damage At PAFB Was Not Forecast	• Memorandum Describing the AMU Analysis of the Radar Data and Recommendations on How to Interpret the Radar Data to Determine Difference Between Severe/Non-Severe Storms	• Techniques for Radar Data Analyses to Improve Thunderstorm Forecasts	Mar 97
February 2000 Anvil Rain During an Atlas Launch Countdown	• Determine the Nature of Unusual Radar Echoes Approaching the KSC/CCAFS area from the West	• Determined that the Radar Echoes did not Exhibit Signature Typical of Chaff, but Appeared to be Anvil Rain	• Additional Information for Launch Weather Team Decision-Making Process • Permitted On-Time Launch Despite a Complex Weather Situation	Feb 00

TABLE 3. All Option Hours Tasking products delivered by the AMU since beginning operation in 1991.

Mission Requirement	Weather Support Problem	AMU Product	Customer/Operational Benefit	Delivery Date
PROWESS Model	• Insufficient Ability to Forecast Local Wx Hazards Affecting Launch, Landing, and Ground Operations	• System Checkout/ Acceptance Test • Identified Weather Infrastructure Deficiencies • Recommended No Further Action Until Deficiencies Removed	• Saved Implementation, Certification, and Operations Costs	Apr 96
50 MHz Radar Wind Profiler QC Display Upgrade	• Difficult to Interpret and View Profiler Data Display • Display not Adequate for Operational QC	• Test Plan and Report • Operator Training • Upgraded Display Software	• Easier Comparison of Profiler and Jimsphere Data • Easier to Detect Dangerous Changes in Winds	May 96
Cost Benefit Study of Options to Modify or Replace the SLF Weather Equipment	• Weather Instrumentation, Data Collection/Processing Equipment at SLF Becoming Obsolete and Un-Maintainable • Need Recommendations on How to Replace the System	• Report Describing Weather System Replacement Options and Associated Costs • Briefing to SLF Data Users	• SLF Data Users Have Knowledge on Which to Base Decision for Replacing the Obsolete System	Sep 96
Emergency Response Dose Assessment System (ERDAS) Evaluation	• Current Toxic System is 2D & is Only a Diagnostic Model • Current Toxic System is Grossly Deficient	• Evaluation Report • Transition ERDAS to Operations • Implement Prognostic 3D Dispersion Analysis System for Range Safety	• Improved Toxic Diffusion Corridors/Dosages • Safer Ground Operations	Oct 96
Model Validation Program	• Toxic Diffusion Models' Capabilities & Limitations Poorly Understood • Mesoscale / Diffusion Models Need Verification for Varying Meteorological Conditions	• Mesoscale Model (RAMS) Output Data • Diffusion Model (HYPACT) Output Data • Data Produced for 3 Field Sessions (~ 60 Releases) • Evaluation of Toxic Model Performance	• Enhanced Understanding of Toxic Models' Capabilities & Limitations Resulting in – Greater Safety for Ground and Launch Operations – Increased Launch Availability	Jan 99

Mission Requirement	Weather Support Problem	AMU Product	Customer/Operational Benefit	Delivery Date
HyperSODAR Evaluation	• Lack of Sufficient Spatial/ Temporal Resolution in Wind Profile Measurements at the SLF to Support Engineering Analysis of Shuttle Response to Wind Gusts During Landing	• Report Documenting the Accuracy/Availability of HyperSODAR Data	• Assessment of HyperSODAR Data Accuracy/Availability Based on Data Collected at KSC and Comparison with Data Collected at White Sands Missile Range	Nov 99
50 MHz DRWP Quality Control Training	• Personnel Responsible for QC of DRWP Data Have No Formal Training or Written Guidelines on Proper QC Techniques • Proper QC Critical for Day-of-Launch Decisions	• One-Day Formal Training Session at Weather Station A • Electronic and Hard Copies of – MS PowerPoint Presentation – Documents Containing QC Checklist and Explanation of DRWP Variables and Algorithms Necessary for Proper QC of the Data	• Proper Training Helps Personnel Make Appropriate Decisions when Conducting Manual QC • Documents are Available to Personnel as a Guideline During the QC • More Reliable DRWP Output for End Users of the Data	Feb 00
Delta II Rocket Explosion Provided Opportunity to Evaluate the Models Used to Predict Toxic Plume Dispersion at CCAFS and Determine Utility of WSR-88D to Track Plumes	• No Knowledge on How Well the WSR-88D Detected and Tracked Explosion Plumes • No Knowledge of the Accuracy of RAMS, HYPACT, and REEDM Predictions of Toxic Plume Characteristics and Dispersion	• Report Documenting Results from the Delta II Case Study: – Analysis of Performance of WSR-88D, RAMS, HYPACT, and REEDM – Recommendations for Future Products and Use of WSR-88D and Models	• Guidelines Now Available for Guidance in Using the WSR-88D for Tracking Plumes, and on Model Performance in Predicting the Plume Trajectory, Thickness, and Concentration	Jul 00
HyperSODAR Software Specification	• Need to Obtain High Spatial and Temporal Resolution Wind Profiles over the Shuttle Landing Facility	• A Set of Software Specifications for the HyperSODAR that Were Used to Develop a Request For Proposal (RFP)	• Received a Valid Set of Specifications That Allowed the Shuttle Program to Develop an RFP	Mar 01

Mission Requirement	Weather Support Problem	AMU Product	Customer/Operational Benefit	Delivery Date
Extension/Enhancement of the ERDAS/RAMS Evaluation	• AMU Customers Outside of CCAFS Expressed Interest in Viewing RAMS in Real-Time • Systematic Low-Level Cold Bias Discovered in RAMS Forecasts • Tests Needed to Determine Impact of Large-Scale Model Boundary Conditions on RAMS Prediction Accuracy	• Memorandum Outlining the Technical Steps Needed to Send RAMS Data to SMG and NWS MLB in Real-Time • Re-ran Select RAMS Forecasts; Isolated Cause to be Excessive Fog in Model • Re-ran Select RAMS Forecasts; Found Little Impact on RAMS Accuracy	• Customers Understood Technical Requirements for Transmitting RAMS Data in Real-Time • Better Understanding of Strengths and Weaknesses in Real-Time RAMS Configuration; Information Helpful for RSA Modeling Solution Decision-Making • Better Understanding of Large-Scale Model Impact on Regional Numerical Forecasts	Jun 01
Airborne Field Mill Experiment (ABFM) Aircraft Track Overlay on Radar Data	• ABFM Program Designed to Collect Data in Thunderstorm Anvils to Determine if Lightning Launch Commit Criteria Should be Relaxed • Graphics Software Needed to Overlay Research Aircraft Track on WSR-74C Displays	• Software that Ingested Aircraft Location Data and Overlaid the Aircraft Track on the Radar Display • Real-Time Technical and Forecasting Support to NASA ABFM Project Scientists	• Ability for ABFM Scientists to Determine Location of Aircraft Relative to Existing Storms such that the Pilot Could be Vectored to Safely Collect Data	Jul 01
Low Temperature Recovery Forecast	• No Tool Exists to Help Forecasters Determine When or If a Recovery from a Shuttle Low Temperature LCC Violation Would Occur • Could Result in Possible Costly Delays to Shuttle Launches • New Tool Should be in Graphical, Easy-to-Use Form	• Shuttle Low Temperature Recovery Forecast Tool as a GUI in an MS Excel file • User's Guide Describing How to Use the Tool • Maintenance Manual Describing How to Interpret, Check Out, Troubleshoot, or Modify the Software	• Operational Forecasters Have an Automated Tool That Converts Wind, Humidity, and Temperature Forecasts Into a Forecast of the LCC Violation	Sep 01

Mission Requirement	Weather Support Problem	AMU Product	Customer/Operational Benefit	Delivery Date
Support for KSC Radar Analyses	• Classification of Daily Meteorological Regimes Needed for 915-MHz Radar Wind Profiler Study	• Identified Meteorological Regimes and Significant Precipitation Events during Period of Record of Study	• Confirmed Accuracy of Rainfall Quality-Control Algorithm for the 915-MHz Profilers	Aug 02
Analysis of Rain Measurements in Support of STS-107 Accident Investigation	• No Rain Climatology for Shuttle Exposure Existed • No Knowledge of Whether the Amount of Rain Experienced by STS 107 While on the Pad was Out-of-Family	• Charts of Rain Climatologies for Every Shuttle Mission – Total Rainfall During Exposure – Maximum Daily Rainfall During Exposure – Average Daily Rainfall During Exposure • Memorandum Describing the Charts and How to Interpret Them	• Information on Rainfall During All Shuttle Exposures to help Determine if STS-107 Rainfall Exposure was Out-of-Family • New Database and Climatologies of Rainfall During Each Shuttle Exposure Period Allows for Analysis of Future Shuttle Rainfall Exposures	Apr 03
Objective Verification of Numerical Weather Prediction (NWP) Models	• Traditional Objective Point Validation Not Adequate for High-Resolution NWP Models; Subjective Techniques Too Costly • Need for Objective Technique to Validate Weather Phenomena	• Joint Project With Dynacs / ASRC Aerospace Personnel • Technique for Objectively Identifying and Verifying Sea Breezes in Observed and Forecast Grid Fields	• Automated Model Verification Technique that can be Transitioned into Customer Operations as Required	May 03

Mission Requirement	Weather Support Problem	AMU Product	Customer/Operational Benefit	Delivery Date
Support to ABFM Field Program Scientists	• Visiting Scientists Not Familiar with Location or Operation of Equipment in AMU Lab • Help Needed for Training on Equipment, Software Maintenance, and Retrieving Local Data Sets	• Operation & Maintenance, Training, and Software Support for the AMU-Developed Aircraft Track Overlay Software (Jul 01) • Training and Consulting on Use of WSR-74C, LDAR, WSR-88D, MIDDS, and Other Equipment/Software in the AMU • Local Data Sets on Requested Media • Data Analysis Support for Technical Interchange Meetings	• Minimized Spin-Up Time for ABFM Scientists in Learning Location and How to Use Equipment • Access to Local Expertise in Thunderstorm Forecasting and Data Analysis • AMU Team Member Always Available in Person or On Call During Field Program to Troubleshoot Equipment or Software, Archive Data, and Advise on Local Forecasting or Data Analysis Issues	Nov 01
Severe High Wind Event on 4 March 2003	• Cause of Strong Wind Event over KSC Not Understood • Forecasters Needed Post-Analysis to Determine the Type of Event and Cause	• Memorandum Describing Sequence of Events and Contributing Factors in the Development of the Strong Winds	• Detailed Analysis of Weather Data Leading Up to the Event • Forecasters Understand What Caused the Strong Wind and How to Predict Such a Wind in the Future	Dec 03
Prior to Launch, Shuttle LWO Must Determine the Probability that the Forecast Cloud Cover will Allow the Optical Imaging System (OIS) to Obtain Three Useful Views of the Shuttle from Launch to Solid Rocket Booster Separation (SRBS)	• Clouds can Obscure Optical Imaging of the Shuttle During Launch • No Tool or Methodology Exists to Determine the Effect of Clouds on the OIS	• Concept Study to Determine if Technologies are Available to Produce a Valid Forecast Cloud Field • Statistical Model of Cloud Field to Simulate Viewing Conditions and Compute Probabilities of Three Useful Views by the OIS • Look-up Tables and Graphic Displays of Probabilities for LWO	• Ability for the LWO to Provide Objective Guidance to the Shuttle Launch Director Concerning Effects of Clouds on Viewing Conditions from Launch to SRBS	Oct 03 (Study) Mar 04 (Model)