Integrated Terminal Weather System (ITWS) 1994 Demonstration Phase OT&E Final Report

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16. Abstract

The Integrated Terminal Weather System (ITWS) will produce a fully automated, integrated terminal weather information system to improve safety, efficiency, and capacity of terminal area aviation operations. The ITWS will acquire data from Federal Aviation Administration (FAA) and National Weather Service (NWS) weather sensors as well as aircraft in flight to provide FAA air traffic personnel with products that require no meteorological interpretation. These products include current terminal area weather and near-term predictions of significant weather phenomena (e.g., microbursts, wind shear, gust fronts, precipitation, lightning, terminal winds, etc.).

A Demonstration/Validation (DEMVAL) of ITWS prototypes was conducted at Memphis and Orlando International Airports (MEM)(MCO) and the Memphis and Jacksonville Air Route Traffic Control Centers (ARTCC) during the summer of 1994. ITWS products were evaluated for operational suitability, usefulness, and meteorological validity. Questionnaires were completed by air traffic controllers, supervisors, and traffic managers at the completion of the DEMVAL.

This report summarizes the results of the meteorological data analysis and questionnaire results, as determined by ACT-320. The resolution of Critical Operational Issues (COI) are also discussed.

The results of these analyses indicated that during the DEMVAL:

1. The ITWS products (a) were useful during operationally significant weather, (b) were displayed without the need for meteorological interpretation, and (c) enhanced supervisor effectiveness in traffic planning/management during adverse weather;

2. Terminal airspace and runways were utilized more efficiently when the ITWS was operational; and

3. The ITWS reduced perceived controller workload during adverse weather conditions in the terminal area.

17. Key Words
Integrated Terminal Weather System (ITWS)
Demonstration/Validation (DEMVAL)
Operational Test and Evaluation (OT&E)

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EXECUTIVE SUMMARY

The Integrated Terminal Weather System (ITWS) is a development program initiated by the Federal Aviation Administration (FAA) to produce a fully-automated, integrated terminal weather information system to improve the safety, efficiency, and capacity of terminal area aviation operations.

The ITWS will acquire data from FAA and National Weather Service (NWS) sensors as well as from aircraft in flight in the terminal area. The ITWS will provide products to FAA air traffic (AT) personnel that are immediately usable without further meteorological interpretation. These products include current terminal area weather and short-term (0-30 minutes) predictions of significant weather phenomena.

The Operational Test and Evaluation (OT&E) that is the subject of this report, occurred during the Demonstration/Validation (DEMVAL) Phase of the acquisition cycle as defined in FAA Order 1810.1F, and the Demonstration Phase of Test and Evaluation (T&E). The ITWS program is funded by the Aviation Weather Development Program (AND-460); Air Traffic (AAT-1) is the program sponsor. The ITWS prototype was developed by Massachusetts Institute of Technology Lincoln Laboratory (MIT/LL). The DEMVAL Operational Test and Evaluation (OT&E) was conducted by the FAA Technical Center, Weather Branch, ACT-320.

During the summer of 1994, a DEMVAL of the ITWS prototype was conducted at Memphis (MEM) and Orlando (MCO) International Airports. ITWS graphics products were displayed on Situation Displays (SD) and text products were displayed on Ribbon Display Terminals (RBDT) in the tower and Terminal Radar Approach Control (TRACON) for AT personnel use and evaluation. SDs were also installed at the Jacksonville and Memphis Air Route Traffic Control Centers (ARTCC), NWS Memphis Weather Service Forecast Office (WSFO) and NWS Melbourne, FL Weather Service Office, as well as Delta Airlines (Atlanta) and Northwest Airlines (Minneapolis). The FAA Technical Center also had two SDs to monitor the real-time ITWS presentations for both MEM and MCO.

The ITWS products were evaluated for operational suitability, usefulness, and meteorological validity. The ITWS products were evaluated to determine whether AT personnel, without a meteorological background, could effectively use each product and whether the products were appropriate for AT personnel use.

The Critical Operational Issues (COI) from the ITWS OT&E Test Plan for the 1994 Demonstration were also addressed, and based on the data collected from the questionnaires, workload scales, and interviews, it was determined that for the current phase of testing:

1. The ITWS products were useful during operationally significant weather events,

2. The ITWS products were displayed without the need for meteorological interpretation and are easily understandable,

3. The ITWS reduced perceived controller workload during adverse weather conditions in the terminal area,

4. The ITWS products enhanced supervisor effectiveness in traffic planning/management during adverse weather, and

5. Terminal airspace and runways were utilized more efficiently when the ITWS is operational.

Based on meteorological data collected and analyzed from the DEMVAL, it was determined that the ITWS products performed to an acceptable level relative to probability of detection (P_D) and false alarm rates. Several of the products (e.g., Microburst Prediction, Storm Cell Information attribute association techniques, Tornado detection, Lightning, and use of the TDWR to present the five nm precipitation range) require further evaluation against the performance standards of the ORD.

Several of the products neither enhanced air traffic planning and situational awareness nor hindered job performance. Storm Cell Information and Terminal Weather Text Message were rated to have had no significant input on situational awareness and planning. Responses to interviews and questionnaires indicated that users felt the Tornado and Lightning products were not effective for rerouting air traffic since pilots automatically avoid areas of severe weather. However, these products are useful for other purposes (i.e., evacuating the airport traffic control tower (ATCT) in the presence of a tornado, use of the lightning product for the safety of ramp operations (baggage handlers, fuelers, etc.)).

The results of the DEMVAL indicate that the ITWS is a valuable tool for air traffic planning and management, but some products require improvement. ACT-320 recommends that the ITWS program proceed to Key Decision Point (KDP)-3.

1. INTRODUCTION.

1.1 PURPOSE OF REPORT.

The purpose of this Demonstration/Validation (DEMVAL) Operational Test and Evaluation (OT&E) report is to discuss the conduct and present the results of the 1994 Integrated Terminal Weather System (ITWS) DEMVAL. The DEMVAL was conducted at Orlando (MCO) and Memphis (MEM) International Airports in the Airport Traffic Control Towers (ATCT) and Terminal Radar Approach Control (TRACON), and at the Jacksonville Air Route Traffic Control Center (ARTCC)(ZJX) and Memphis ARTCC (ZME). The DEMVAL report was prepared in accordance with FAA-STD-024b.

1.2 SCOPE OF REPORT.

This report contains the test system configuration, the DEMVAL description and the results (appendix A) of the DEMVAL conducted at Memphis and Orlando. It addresses the Critical Operational Issues (COIs) described in the ITWS Operational Test and Evaluation (OT&E) Plan for the 1994 Demonstration Phase (hereafter referred to as 1994 DEMVAL Plan). It also describes how these COIs were evaluated during the DEMVAL. Supporting data are included. The report also addresses the meteorological performance of the ITWS products and assesses the results of product performance (appendix B).

Some of the ITWS products presented during the 1994 demonstrations, such as microburst, gust front, hail, and tornado detection used enhanced or improved algorithms to present products significantly different from those previously implemented for Terminal Doppler Weather Radar (TDWR) and Next Generation Weather Radar (NEXRAD). This warranted a performance evaluation for each of the enhanced products. It was beyond the scope of the DEMVAL to make comparisons between ITWS products and existing products, such as ITWS Microburst Detection versus TDWR Microburst Detection or ITWS Machine Intelligent Gust Front Algorithm (MIGFA) versus TDWR Gust Front algorithm.

The FAA did not formally evaluate the ITWS in operation at the National Weather Service (NWS) and the airlines (Northwest and Delta); results of these evaluations are discussed in the Pre-KDP-3 ITWS Benefits Quantification, December 1994.

1.3 BACKGROUND.

The ITWS program is funded by the Aviation Weather Development Program Office (AND-460) and is sponsored by Air Traffic (AAT-1). Previous ITWS demonstrations have been conducted in 1992 (Orlando) and 1993 (Orlando and Dallas/Fort Worth). The results of the 1993 demonstration is documented in the Final Report for the Air Traffic Control (ATC) Operational Evaluation of the Prototype Integrated Terminal Weather System (ITWS) at Dallas Fort/Worth and Orlando Airports (May-September 1993). These demonstrations provided useful data that Massachusetts Institute Of Technology/Lincoln Laboratory (MIT/LL) used to refine various ITWS algorithms; they also provided valuable user feedback to aid in the conduct of the 1994 DEMVAL. The products demonstrated were requested by ATR-400 in a memorandum dated May 13, 1994.

In 1993, the ITWS program commissioned the ITWS Users Group, a small working group which included air traffic controllers. Some of these controllers had worked with ITWS prototypes and recommended the design of the human interface throughout the development cycle. This group has had significant input into the human interface, particularly, the ITWS display design and product options.

2. REFERENCE DOCUMENTS

NAS-SS-1000	NAS System Specification, Vol 1, 1/94
FAA-STD-024b	Content and Format Requirements for the Preparation of Test and Evaluation Documentation, 8/94
FAA Order 1810.1F	Acquisition Policy, 3/93
FAA Order 1810.4B	FAA NAS Test and Evaluation Policy, 10/92
	ITWS Operational Requirements Document (ORD), Draft, 9/94
	ITWS Architecture Alternatives Analysis, 3/94
	ITWS Test and Evaluation Master Plan (TEMP), Draft, 9/94
	ITWS OT&E Plan for the 1994 Demonstration Phase, 4/94
	ITWS OT&E Procedures for the 1994 Demonstration Phase
	ATR-400 ITWS Products Memorandum, dated May 13, 1994
	Final Report for the Air Traffic Control (ATC) Operational Evaluation of the Prototype Integrated Terminal Weather System (ITWS) at Dallas/Fort Worth and Orlando Airports (May-September 1993)
	Description of ITWS Weather Products, MIT/LL, March 1994

3. SYSTEM DESCRIPTION.

3.1 MISSION REVIEW.

The ITWS is a terminal area weather system which will provide an integrated set of safety and planning products to air traffic control (ATC) personnel in towers and TRACONs. Enhancing flight safety, maintaining aviation capacity during operationally significant weather, reducing weather-related delays, and decreasing controller workloads will be realized with the use of the ITWS. Other users (ARTCC, Traffic Management Unit (TMU), NWS, airlines, etc.) should also benefit due to increased terminal weather information and common situational awareness, when dealing with tower/TRACON ATC personnel.

The ITWS will receive and process inputs from the various FAA and NWS sensors and integrate them into a single display which requires little or no further meteorological interpretation by the user. ITWS will output its products to the various Situation Displays (SD) and ribbon display terminals (RBDT) associated with each ITWS host processor, which will be housed in the TRACON building. The ITWS will be deployed to 34 TRACONs covering 45 TDWR serviced airports, Oklahoma City (two) for training and program support facilities, and the FAA Technical Center.

3.2 TEST SYSTEM CONFIGURATION.

The product suite for the DEMVAL (table 3.2-1) was comprised of the ITWS products as defined in the ATR-400 ITWS products memorandum dated May 13, 1994. The approach of the 1994 ITWS DEMVAL was to present products to the user that are planned to be available at Initial Operational Capability (IOC).

ITWS SDs were located in the tower and the TRACON at the MCO and MEM airports, and in the TMU and Center Weather Service Unit (CWSU) at ZME and ZJX. An SD was also installed at Northwest Airlines headquarters in Minneapolis, MN, and Delta Airlines in Atlanta, GA. Data from Northwest and Delta users was collected by MIT/LL, who were involved in a Benefits Assessment Study. Two SDs were monitored at the FAA Technical Center.

The ITWS product algorithms that were used during the DEMVAL were developed by MIT/LL. These algorithms generated the products listed in table 3.2-1 and described later in this section. These algorithms will be provided as Government Furnished Equipment (GFE) to the ITWS production contractor. The software that MIT/LL utilized to run the algorithms and display the products will be provided to the production contractor as Government Furnished Information (GFI).

The operating software used during the DEMVAL was engineering level software; four different programming languages were used. The ITWS contract will specify that a single higher order computer language will be used in the production ITWS system. Since the algorithms will be GFE, product performance of the production ITWS should approximate the DEMVAL results. A Science Panel was convened in December 1993, to evaluate the science behind the ITWS product algorithms. The algorithms were given the panel's approval. The DEMVAL system consisted of weather sensor and product inputs to the MIT/LL Lexington office and DEMVAL field sites, where ITWS products were generated and subsequently displayed on the ITWS SD.

TABLE 3.2-1. ITWS DEMVAL PRODUCT LIST

1.	storm motion and extrapolated position
2.	storm cell information
3.	airport lightning with warning light
4.	microburst detection with countdown timer
5.	microburst prediction
6.	wind shear (ITWS microburst, ITWS gust front)
7.	terminal winds (Memphis only)
8.	ITWS precipitation with anomalous propagation (AP) removed
9.	ASR-9 precipitation with AP flagged
10.	tornado detection
11.	terminal weather text message (TWTM)
12.	long range reflectivity and long-range storm motion

The future-state ITWS may include additional products as required by AT; it is an adaptable system, capable of expansion as additional products are developed.

3.2.1 ITWS DEMVAL Product Description.

A brief description of the ITWS DEMVAL products is contained in the following sections. Additional product information is contained in the MIT/LL document "Description of ITWS Weather Products."

3.2.1.1 Storm Motion and Extrapolated Position.

The ITWS storm motion product provides estimates of speed and direction for significant storm cells containing level three or greater precipitation. The data source for this product is the

Airport Surveillance Radar Model 9 (ASR-9) radar. Anomalous propagation (AP) echoes are edited from the ASR-9 precipitation prior to application of the storm motion product (section 3.2.1.8). This minimizes the possibility of tracking AP.

The ITWS storm extrapolated position (SEP) product projects future locations of the leading edge of storm cells containing level three or higher precipitation. The current leading edge location, and the 10- and 20-minute projected leading edge locations are displayed.

The data source for this product is the ASR-9 radar. Input data are subjected to AP editing prior to SEP processing, minimizing the possibility of projecting leading edges of AP.

3.2.1.2 Storm Cell Information.

The Storm Cell Information (SCI) product provides information on the presence of detected lightning, hail, and mesocyclones that are associated with individual storm cells. The SCI product also provides echo top information associated with storm cells. The hail and mesocyclone products were developed by the National Severe Storms Laboratory (NSSL) in Norman, OK, and are implemented by MIT/LL for use with the ITWS. Both products are intended as replacements for the hail and mesocyclone products that are currently part of the NEXRAD product suite. When this replacement occurs, this product will become a "pass through" for ITWS. Lightning was detected by the National Lightning Data Network (NLDN).

3.2.1.3 Airport Lightning With Warning Light.

The airport lightning with warning light product alerts air traffic personnel to the presence of lightning in the airport vicinity. The range is site adaptable; for the DEMVAL, a 10-nm range was used. When lightning is present (as detected by the NLDN) within 10-nm of the airport, the lightning warning light is illuminated.

3.2.1.4 Microburst Detection With ATIS Countdown Timer.

The ITWS microburst detection product provides locations, areal extent, and strength of windshear events. This product also provides runway oriented windshear alert messages on the RBDT. The data source for this product is the TDWR. When a windshear or microburst alert appears on any RBDT, the respective windshear or microburst alert box is illuminated and indicates "ACTIVE." When the alert is no longer present, the countdown timer (60 minutes for microburst, 20 minutes for windshear) is started within the warning box.

3.2.1.5 Microburst Prediction.

The microburst prediction product attempts to detect precursors to microbursts before the event is detected by the microburst detection product. A prediction made prior to a detection provides a longer lead time to a microburst event. The data sources for this product are the TDWR and Meteorological Data Collection and Reporting System (MDCRS) soundings.

3.2.1.6 Windshear (ITWS Microburst, ITWS Gust Front).

The ITWS windshear product detects the presence of windshears, microbursts, and gust fronts. It displays the location and strength of detected windshears and microbursts on the SD; it provides location and strength to the RBDTs for events detected on active runways.

The gust front detection product provides current locations and estimated future detection of gust fronts. The product also provides an estimate of wind speed and direction behind the gust front. The data sources for this product are the TDWR and Low Level Windshear Alert System (LLWAS).

3.2.1.7 Terminal Winds.

The ITWS terminal winds product provides wind speed and direction at several altitudes and airport terminal corner posts. It is a combination of data from several sources: NEXRAD, TDWR, MDCRS, LLWAS, Automated Surface Observing System (ASOS)/Automated Weather Observing System (AWOS), and Mesoscale Area Prediction System (MAPS). This product was demonstrated at MEM only. Winds at MCO during the demonstration time period typically lack adequate variability.

3.2.1.8 ITWS Precipitation with Anomalous Propagation (AP) Removed.

The AP edited precipitation product is the six-level ASR-9 precipitation product with AP removed (as determined by the NEXRAD). AP is a phenomenon that causes false echoes to appear in the ASR-9 radar data. These false echoes mimic precipitation cells.

3.2.1.9 ASR-9 Precipitation with AP Flagged.

The ITWS short-range precipitation product is the ASR-9 radar weather channel six-level precipitation with detected areas of AP displayed in black on the SD.

3.2.1.10 Tornado Detection.

The tornado product provides the location of detected tornadoes. An alert message is also displayed on the RBDT. The data source for this product is the NEXRAD. The tornado product is a pass through product.

3.2.1.11 Terminal Weather Text Message.

The terminal weather text message product provides a summary description of terminal area weather. The text messages that can be selected for display on the SD are a textual representation of the Terminal Weather Information for Pilots (TWIP) product that can be uplinked to an aircraft cockpit. The message consists of precipitation intensity, location, and motion for cells within 15 nm of the airport; microburst and windshear alerts with losses, gains, and beginning times; and time and intensity of precipitation expected to impact the area within 15-nm of the airport.

3.2.1.12 Long-Range Reflectivity and Long-Range Storm Motion.

The ITWS long-range precipitation product is the six-level NEXRAD precipitation. It is considered to be a "pass through" product from the NEXRAD, and as such, has been previously tested and evaluated. The long-range storm motion product provides estimates of motion (speed and direction) for level three and greater storm cells, as detected by the NEXRAD for the 100- and 200-nm ranges.

3.2.2 Test System Changes.

The MEM portion of the DEMVAL was delayed due to a schedule slip in TDWR reliability testing and replacement of the TDWR computer. The TDWR remained unavailable at the time of the new DEMVAL start date. Since the training of the AT personnel had been completed, ATR-400, AND-460, and ACT-320 agreed to start the DEMVAL without the TDWR available. (See appendix C for ITWS operating times in Memphis.) The last 10 days of the Memphis DEMVAL were also conducted without an operational TDWR, due to TDWR hardware problems unrelated to the ITWS DEMVAL.

In addition, there were some modifications to the ITWS software just prior to the start and during the first week of the DEMVAL. Some of these changes were made as a result of the decision to start the DEMVAL without an operational TDWR in Memphis. All decisions to change products or displays were made in conjunction with AND-460, ATR-400, ACT-320, and MIT/LL. These changes are explained in the following paragraphs.

a. Change the response of the display in the absence of windshear information. Prior to May 20, 1994, if the display system could not satisfactorily acquire the windshear products it showed a red X across the SD and indicated that the RBDTs were impaired, meaning that the ITWS should not be used. A change was required to allow use of the ITWS without TDWR (and hence, without the red X). The red X was removed in this situation and the windshear products were added to the blue "unavailable products" stripe.

b. Display a clear indication that the system is not to be used. When the system was in a warm-up mode (just prior to the start of each day's activities), test windshear data sets were often passed through the system to check that software and hardware were functioning correctly. Products and messages were displayed on the SD and RBDT in this case. Likewise, when the ITWS was in the process of failing (during the course of normal operations), a mechanism was required to ensure this failure information was displayed.

In both cases, a red X was placed in the large display window of the SD (in place of the small, but not so obvious blue stripe at the bottom of the SD).

c. Improve the visibility of the Memphis tower SD. AT personnel had difficulty viewing the SD in the Memphis tower under certain ambient light conditions. The TDWR monitors that were being utilized lacked contrast control. A higher contrast, controllable graphics display was substituted for the TDWR monitor to correct the problem.

d. Change the RBDT text on the active runway lines when no windshear is available. Text was changed from "ITWS IMPAIRED" to "MBA/WSA OTS" (microburst alert/windshear alert out of service) on all active runway lines of the RBDT. The purpose was to reflect the message that no valid windshear products were available, but that the remainder of the ITWS system was functional, including LLWAS winds information.

e. Update the tornado alert line independent of d. above. The tornado alert line was changed to update regardless of the status of the windshear products. The previous change made it clear that the ITWS was still functioning (regardless of TDWR status) and that tornado alerts displayed on the RBDT were valid.

f. Update the status line independent of d. above. This line contains the LLWAS information (2-minute running average of the centerfield winds and the gust report) and a time stamp. LLWAS continued to update this information as long as LLWAS data was valid. If invalid, the LLWAS portion would display "CF 999 99" and report no gust information. The time updated whenever new data for the runway lines or status line was received. No time was reported if both LLWAS and TDWR were impaired.

g. Signal when a complete failure of the RBDT occurs. A communications failure was indicated whenever all RBDT information was lost (windshear, tornado, and LLWAS). This was indicated by "RBDT COMM FAILURE" displayed on all active runway lines.

h. Change in microburst prediction algorithm. When the ITWS was presented to the Science Panel in December 1993, it was recommended that further development was required to meet the ITWS functional requirement for a low probability of false alarm (P_{FA}). Based on raw TDWR data from MCO, MIT/LL felt that the probability of detection (P_D), (56 percent) and the P_{FA} (3 percent at 15 kts), (10 percent at 30 kts) were representative of expected results. Therefore, the Orlando DEMVAL was conducted with the microburst prediction algorithm in "unrestricted mode." Minimal historic TDWR data was available to evaluate the microburst prediction algorithm performance for MEM prior to the start of the DEMVAL; therefore, the algorithm was run in "restricted mode." In restricted mode, the algorithm waited a longer period of time before declaring a microburst prediction. This served to present more accurate predictions, given the uncertainty of algorithm performance due to the lack of prior data. This decreased the false alarm rate but also decreased the amount of lead time, prior to the actual microburst.

i. Correction of reported echo tops in Storm Cell Information box. It had been noted by both the NWS Forecast Office in MEM and the CWSU at ZME that the echo tops reported by the Storm Cell Information Product were lower than those provided by NEXRAD. Two deficiencies were found: (1) the ITWS reported echo tops were 5000 ft. low due to a software error, and (2) the ITWS echo tops for storms with small areas of level four or greater precipitation were sometimes low because the maximum storm top could be outside the boundary of the highest level of reflectivity within the cell. The echo top algorithm searched for the highest cloud top within the area of heaviest precipitation. This was corrected by increasing the minimum search area for maximum echo top to 64 km^2. A detailed discussion of this problem is found in section 5.2.6.10 and in appendix B.

3.3 INTERFACES.

This DEMVAL was not an integration test of the interfaces between the ITWS and other National Airspace Systems (NAS); it was an evaluation of the ITWS products and displays, and their utility to AT personnel. However, to understand the flow of ITWS DEMVAL inputs and outputs, the interfaces are discussed below.

In addition to the sensor interfaces discussed below, other inputs to the ITWS during the DEMVAL included satellite feeds to MIT/LL Lexington, MA, from the NLDN and Forecast Systems Laboratory (FSL). The FSL provided the AWOS, ASOS, MAPS, and MDCRS information. These DEMVAL system interfaces are depicted in figures 3.3-1 and 3.3-2. Figure 3.3-3 shows the anticipated ITWS production data flow.

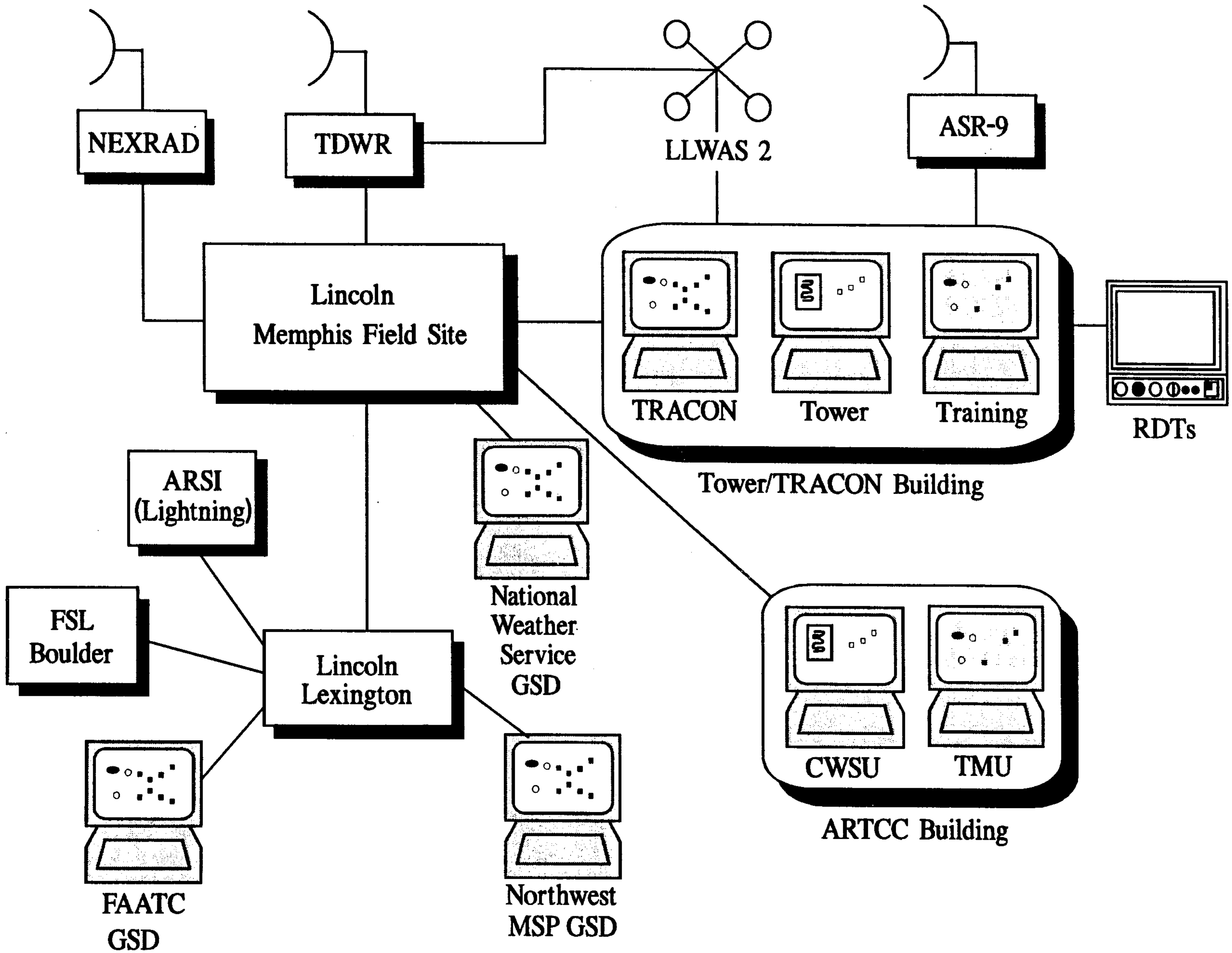


FIGURE 3.3-1. MEMPHIS ITWS DEMVAL CONFIGURATION

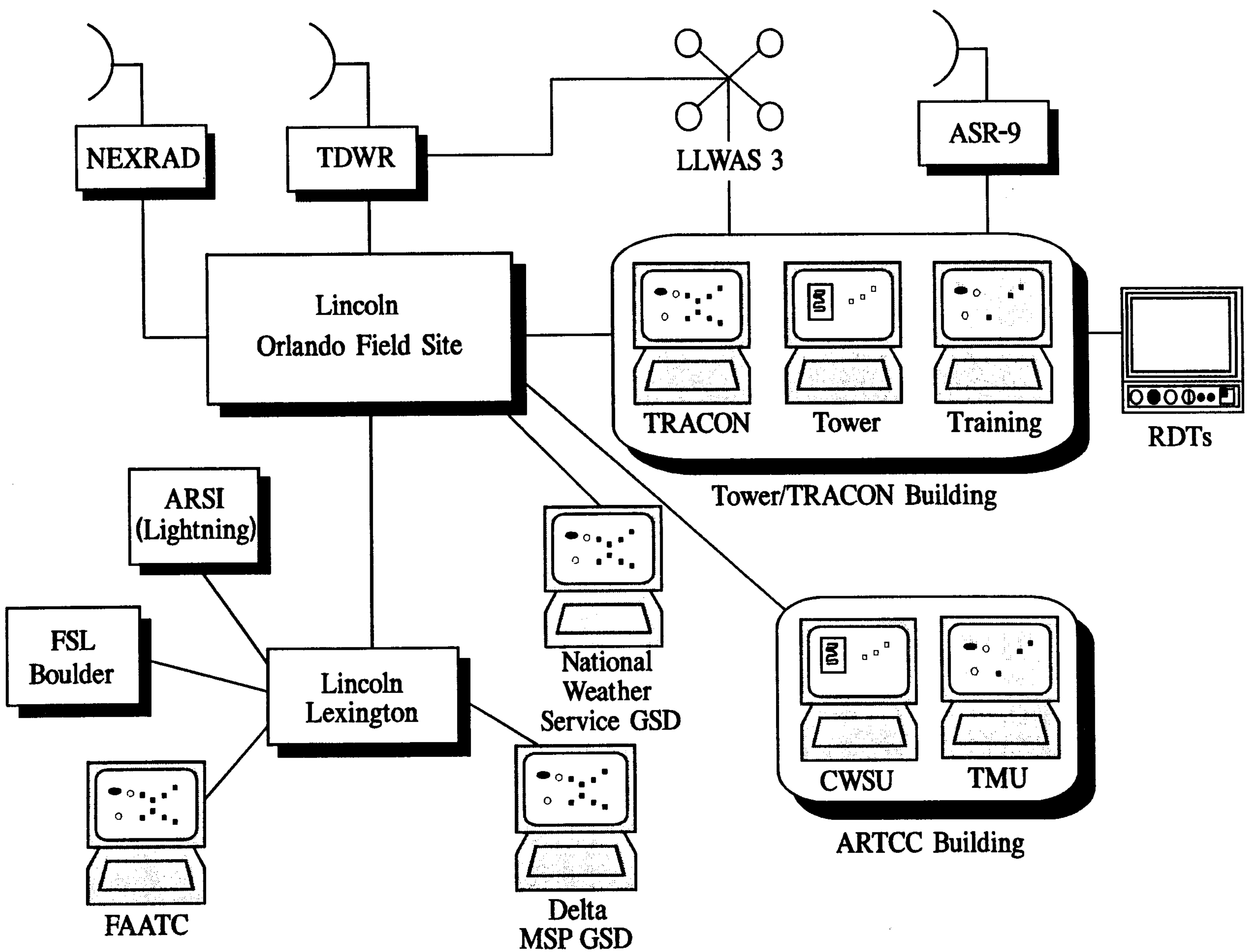


FIGURE 3.3-2. ORLANDO ITWS DEMVAL CONFIGURATION

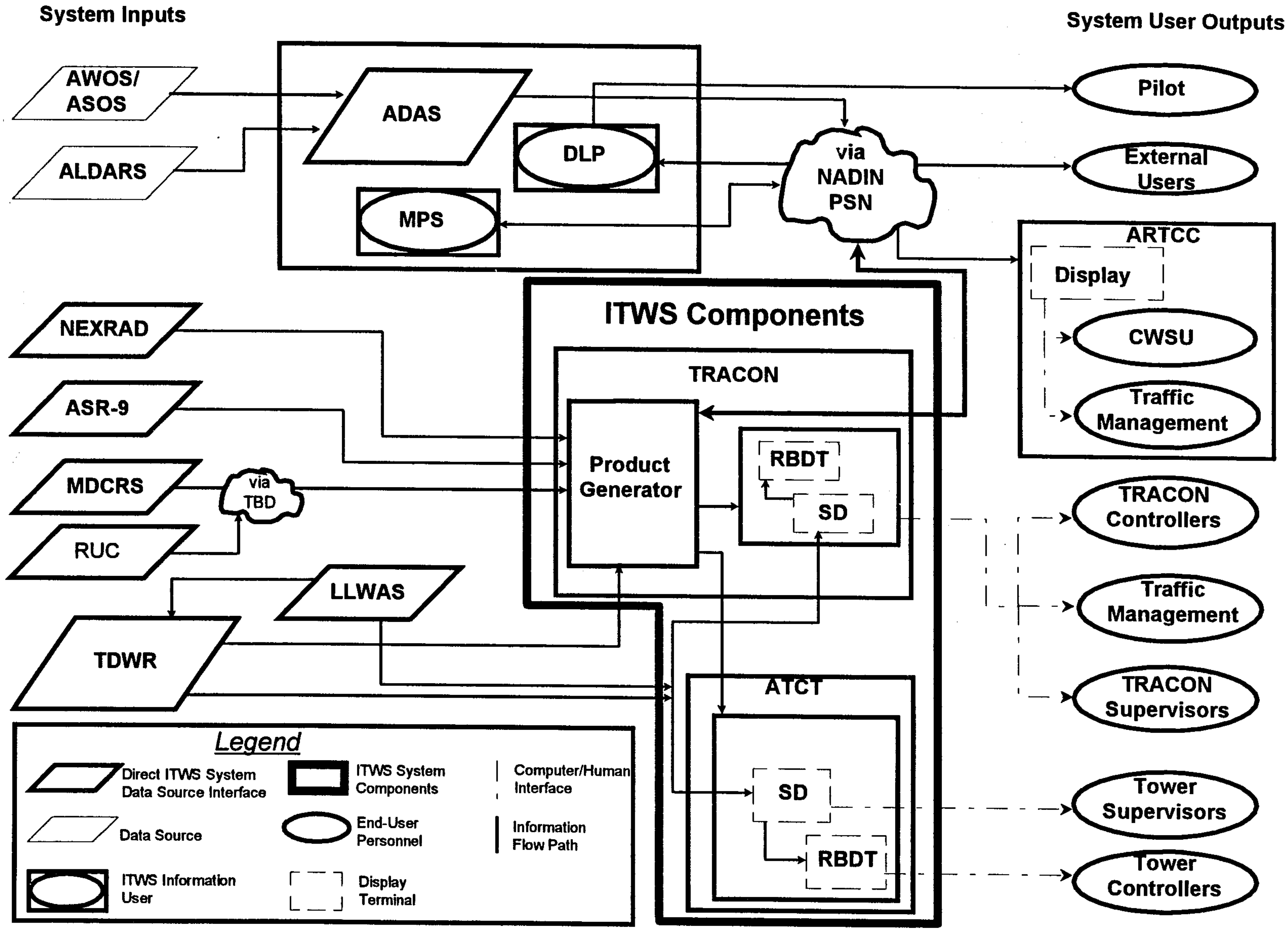


FIGURE 3.3-3. ITWS PRODUCTION DATA FLOW

Since this was an ITWS test bed to evaluate products, all algorithm processing and product generation occurred at the MIT/LL Lexington office (rather than a TRACON-based ITWS processor). Generated products were passed through the field sites at MEM and MCO prior to their distribution to the users listed in table 3.3-1.

TABLE 3.3-1. ITWS 1994 DEMVAL SD LOCATIONS

Memphis Tower, TRACON, and training room [1]
Orlando Tower, TRACON, and training room [1]
FAA Technical Center [2]
Memphis (ZME) ARTCC-TMU/CWSU
Jacksonville (ZJX) ARTCC-TMU/CWSU
Northwest Airlines, Minneapolis, MN [3]
Delta Airlines, Atlanta, GA [3]
NWS, Memphis Weather Service Forecast Office (WSFO) [3]
NWS, Melbourne, FL [3]

Note 1: Not operational ITWS SDs. These were used for training purposes only.

Note 2: Non-AT site. Real-time SDs that displayed the current weather conditions at MEM and MCO.

Note 3: Operational SDs that were not included in AT-sponsored DEMVAL.

3.3.1 TDWR Interface.

Base (raw sensor) data from the TDWR radars at MEM and MCO were used to generate all windshear, microburst, and gust front products. TDWR base data were also inputs to the terminal winds and terminal weather text message products.

3.3.2 NEXRAD Interface.

The NEXRAD radar located in Melbourne, FL, was used as input to the Orlando ITWS. The NEXRAD at Millington, TN, provided input data to the Memphis ITWS. NEXRAD data were used in the generation of the long-range storm motion, storm cell information, terminal winds, AP edited precipitation, long-range precipitation, tornado, and terminal weather text message products.

3.3.3 ASR-9 Interface.

The ASR-9 radars located at the MEM and MCO provided data used in the generation of the short-range precipitation, storm motion and extrapolated position, storm cell information, and terminal weather text message.

3.3.4 LLWAS Interface.

LLWAS sensors located at the airports were used to provide centerfield and boundary threshold wind information on the RBDT and to generate winds behind the gust front.

4. TEST AND EVALUATION DESCRIPTION.

4.1 TEST SCHEDULE AND LOCATIONS.

Scheduled operating hours for the DEMVAL were from 12 noon until 7:00 p.m. local time, Monday through Friday. Operations during weekends and other times were coordinated between the participating facilities and local MIT/LL personnel, as weather conditions dictated.

All ITWS products were monitored by MIT/LL personnel at field sites in Memphis and Orlando, as well as from the main laboratory in Lexington, MA. ITWS products were monitored by FAA Technical Center personnel via SDs at the Technical Center and visits to FAA and MIT/LL facilities at MEM, MCO, ZJX and ZME.

4.1.1 Memphis Schedule.

The Memphis portion of the DEMVAL took place from May 23 through July 15, 1994, at the MEM ATCT/TRACON and the Memphis ARTCC (ZME). The Demonstration was scheduled to commence on May 2, 1994, but was delayed as described in section 3.2.2. The ITWS was scheduled to operate from Monday to Friday, noon to 7:00 p.m. local time; additional ITWS operations were to be on as required basis, as dictated by the weather and MIT/LL personnel support availability outside these hours. Due to the frequency and severity of the weather in Memphis during the DEMVAL, and the useful of the ITWS, the ITWS was operational 11 of the 16 weekend days and numerous hours outside the prescribed scheduled time period. The ITWS was operational for all but these 5 days of the 8-week Memphis portion of the DEMVAL.

4.1.2 Orlando Schedule.

The Orlando portion of the DEMVAL was conducted from July 11 through August 19, 1994, at MCO ATCT/TRACON and ZJX. The ITWS was operational every day during the 6 week Orlando portion of the DEMVAL.

4.2 PARTICIPANTS.

Participants in the DEMVAL included:

a. AND-460, Aviation Weather Development Program Office; directed, funded, and managed all DEMVAL efforts. The Program Manager prepares and approves Program Directives (PD) and other appropriate agreements delineating organizational activities, resources and funding, and the DEMVAL Plan and Procedures.

b. ATR-400, Air Traffic Requirements, Program Sponsor's Representative; set AT operational requirements. Coordinated participation of AT personnel during the DEMVAL, including arrangements for those personnel administering the evaluations at the FAA Technical Center. Reviewed and coordinated National Air Traffic Controllers Association (NATCA) approval of questionnaires. Participated in product evaluation and gave final approval for the operational use of products.

c. AND-420, TDWR Program Office; coordinated maintenance of the TDWR radars with the Airway Facilities Sector Field Office (AFSFO), for the noncommissioned systems.

d. ACT-320, Associate Program Manager for Test (APMT); responsible for the overall conduct of the DEMVAL. The test team, under the direction of the test director, was responsible for data collection, monitoring the DEMVAL, and reporting results. Provided meteorologists, AT, and human factors personnel for on-site observations of ITWS products in operational setting; developed and administered post-test questionnaires. Responsible for configuration control over the system architecture and ITWS products. Reviewed all changes to products prior to their release for field evaluation. Developed the DEMVAL Plan and Procedures.

e. ASD-140, responsible for coordinating all Test NAS Change Proposals (NCP) to support the DEMVAL.

f. MEM ATCT AT personnel evaluated the ITWS products and displays.

g. Memphis ARTCC AT personnel evaluated the ITWS products and displays.

h. MCO ATCT AT personnel evaluated the ITWS products and displays.

i. ZJX AT personnel evaluated the ITWS products and displays.

j. ATQ-3, Office of Independent Test and Evaluation Oversight, responsible for independent oversight of major acquisition programs, providing an independent assessment of system performance and suitability.

k. MIT/LL supplied the ITWS prototype and operating hardware and software, maintained the equipment, supplied intermediate products and base data to ACT-320 for product evaluation; operated Memphis and Orlando field sites; and provided safety monitoring of the ITWS products.

4.3 TEST AND SPECIALIZED EQUIPMENT.

The equipment used during the DEMVAL included the RBDTs and TDWR displays in the tower and TRACON. ITWS SDs (supplied by MIT/LL) were used at the ARTCCs. The TDWR SD located in the Memphis tower was replaced by an ITWS SD, which provided additional contrast control required under certain lighting conditions.

MIT/LL coordinated the installation of all data lines and input sensor feeds. Additional SDs were maintained by MIT/LL at the field sites and Lexington in order to provide safety monitoring of ITWS products and to provide base (raw sensor data) and intermediate product outputs for product performance analysis.

The FAA Technical Center monitored ITWS output to the users via SDs at the Technical Center. MIT/LL operated temporary field sites at both Memphis and Orlando, which served as data collection sites, where personnel observed and recorded ITWS and input sensor base data.

4.4 TEST OBJECTIVES/COMPLETION CRITERIA.

The objective of the DEMVAL was to evaluate ITWS products in operational settings. Of particular interest were user interface and ITWS product utility, specifically, the interaction of AT personnel with the ITWS, how they utilized the products to perform their job tasks, the ease with which they used the ITWS SD, and how they understood the displayed products, as well as whether the products were operationally useful. Operationally useful is defined as whether the ITWS products enhanced the capability of AT personnel to perform their jobs. User data were collected via questionnaires and interviews by ACT-320.

COIs were developed and used to evaluate the ITWS. The following COIs are stated in the DEMVAL Plan and were the focus of the ITWS evaluation:

a. Are the ITWS products useful during operationally significant weather in terms of their availability, timeliness, and suitability for air traffic use? Are detections and false alarm rates acceptable to users?

b. Are the ITWS products displayed without the need for further meteorological interpretation? Is the displayed information understandable?

c. Does the ITWS reduce (perceived) controller workload during adverse weather conditions in the terminal area?

d. Do ITWS products enhance the effectiveness of traffic planning/management during adverse weather conditions in the terminal area? Are terminal airspace and runways planned for and used more effectively?

e. Does the unavailability of interfacing systems/sensors adversely affect the ITWS operations?

In addition, the following completion criteria were to be satisfied, per the DEMVAL Plan:

a. In Memphis, 10 cases of convective activity over 4 different days, which impacted an inbound push;

b. Also in Memphis, 10 windshear events over 4 days, to allow for adequate evaluation of microburst detection, microburst prediction and windshear products (ITWS microburst and gust front);

c. In Orlando, 15 cases of convective activity over 4 different days. (There are no clearly defined "push" times at Orlando as there are in Memphis.);

d. Also in Orlando, 15 windshear events over 4 days for adequate evaluation of microburst and windshear products; and

e. Approximately 75 percent usage of the ITWS by qualified AT personnel during a significant weather event.

The COIs and the completion criteria were developed by ACT-320 in conjunction with AND-460, ATR-330, ASD-140, and MIT/LL. Historical meteorological data indicates that MEM typically experiences 15.5 thunderstorms during the months of June and July; Orlando typically experiences 9.5 thunderstorms during July and August.

As stated in the DEMVAL Plan, a maximum mean score of 2.75 (on a scale of 1-5, 1 indicating the product consistently enhances the user's job tasks) on the questionnaire rating scale was required to consider a product acceptable. Additionally, the same criteria were set to determine the acceptability of ITWS functionality.

Workload scale data were collected to compare perceived user workload without the ITWS versus workload while utilizing the ITWS. Success criteria was an outcome that demonstrated a statistically significant decrease in perceived operator workload while utilizing the ITWS.

In terms of the first COI, meteorological performance was expected to meet the requirements in the ITWS Operational Requirements Document.

4.5 TESTING DESCRIPTIONS.

MIT/LL personnel performed all hardware setup prior to the start of the DEMVAL, and maintained the equipment throughout. The DEMVAL was conducted in accordance with the DEMVAL Plan and Procedures. For samples of the questionnaire administered to AT, see appendices C-D of the ITWS OT&E Procedures for the 1994 Demonstration.

AT personnel were observed using the ITWS in the course of performing their daily job tasks. Informal discussions during the DEMVAL period and structured interviews and questionnaires after the formal DEMVAL ended were used to formulate user opinions of ITWS product utility, availability, accuracy, timeliness, ease of access, and interpretation.

Meteorological data were collected and analyzed for accuracy by comparing base (raw sensor) data and intermediate products with ITWS displayed products, as outlined in the DEMVAL Plan and Procedures. MIT/LL recorded all data received and provided this data to an ACT-320 meteorologist as requested. These data sets were then used to provide an independent evaluation of product performance. Additionally, meteorological products were monitored by ACT-320 at the FAA Technical Center on real-time SDs in order to evaluate overall display performance and characteristics. Product monitoring and evaluation was also conducted by ACT-320 at the MIT/LL field sites.

4.6 DATA COLLECTION AND ANALYSIS METHODS.

Data were collected in order to evaluate the ITWS products and the COIs as they relate to both human factors and meteorological performance. In addition to the specific data collection methods discussed below, the following methods also were employed: informal discussions between AT users and ACT-320 personnel throughout the DEMVAL, direct observation/monitoring of an SD displaying real-time Memphis and Orlando ITWS products at the FAA Technical Center, and field site visits to monitor and evaluate ITWS products.

4.6.1 Human Factors Data Collection and Analysis.

The operational AT environment in which the DEMVAL occurred required human factors data collection to be unobtrusive to air traffic controllers performing job tasks. Therefore, several methods of data collection were utilized:

a. Evaluation Questionnaires,

b. Subjective Workload Scales, and

c. Structured Interviews.

The data collected were used to answer the COIs listed in section 4.4. Additionally, the questionnaires and structured interviews were used to obtain data on utility, effectiveness, performance, and display issues. The questionnaires and interviews also provided rating scale data on the functionality of the ITWS products. Results from the workload scales provided a measure of the impact that the ITWS had on reducing perceived user workload.

Structured interviews were conducted to better understand rating scale responses and enable users to expand upon their questionnaire responses. Further explanation of the techniques employed is contained in the following sections.

Since completing the questionnaire and participating in the interviews were voluntary, not all AT personnel that used the ITWS during the DEMVAL were formally polled. The number of respondents varied for each data collection method used as shown in table 4.6.1-1.

TABLE 4.6.1-1. PERCENTAGES OF ELIGIBLE RESPONDENTS

	MEMPHIS			ORLANDO		
	Memphis Tower Sups	Memphis Tower CICs	Memphis Center Sups/TMCs	Orlando Tower Sups	Orlando Tower CICs	Jackson-ville Center Sups/TMCs
Workload	60% (6/10)	36% (16/45)	38% (8/21)	41% (9/22)	26% (17/64)	63% (12/19)
Interview	60% (6/10)	36% (16/45)	38% (8/21)	32% (7/22)	26% (17/64)	63% (12/19)
Questionnaire	50% (5/10)	31% (14/45)	38% (8/21)	36% (8/22)	49% (31/64)	63% (12/19)

4.6.1.1 Evaluation Questionnaire.

The questionnaire is a subjective rating scale measure that was administered to the ATC personnel at the end of the DEMVAL. It was used to assess product utility, and human/computer interface issues related to the ITWS display design (color, graphics, text, overlays, etc.) and system functionality (response times, update rates, etc.).

Questionnaires were administered to users in both the Terminal area (TRACON and Tower) at MEM and MCO and at the ZME and ZJX. The Terminal area users consisted of Traffic Management Coordinators (TMC), Supervisors, and Controllers in Charge (CICs). ARTCC users consisted of TMCs and Supervisors. The questionnaires for both facilities (ARTCC versus Terminal area) were the same, except for the omission of the Tornado product and Microburst and Windshear Air Traffic Information System (ATIS) countdown timers in the ARTCC questionnaire. Figure 4.6.1.1-1 is the five-point scale that was used to rate the ITWS products as displayed on the SD.

TITLE	TITLE DESCRIPTION	RATING
CONSISTENTLY ENHANCES	CONSISTENTLY ENHANCES YOUR ABILITY TO PERFORM YOUR JOB TASK WHEN UTILIZING THE PRODUCT; LIKELY TO LEAD TO ENHANCED JOB PERFORMANCE.	1
FREQUENTLY ENHANCES	FREQUENTLY ENHANCES YOUR ABILITY TO PERFORM YOUR JOB TASK WHEN UTILIZING THE PRODUCT; MAY LEAD TO ENHANCED JOB PERFORMANCE.	2
NEUTRAL	ENABLES YOU TO DO YOUR JOB TASKS WHEN UTILIZING THE PRODUCT; DOES NOT LEAD TO DEGRADATION NOR ENHANCEMENT OF JOB PERFORMANCE.	3
FREQUENTLY HINDERS	FREQUENTLY HINDERS YOU TO DO YOUR JOB TASK WHEN UTILIZING THE PRODUCT; MAY LEAD TO DEGRADATION OF JOB PERFORMANCE.	4
CONSISTENTLY HINDERS	CONSISTENTLY HINDERS YOUR ABILITY TO DO YOUR JOB TASKS; LIKELY TO LEAD TO DEGRADATION OF JOB PERFORMANCE.	5
NA	YOU HAVE NEVER USED THE PRODUCT IN QUESTION.	-

FIGURE 4.6.1.1-1. EVALUATION QUESTIONNAIRE RATING SCALE

Due to the number of Supervisors and TMCs that completed the questionnaire, the responses from these positions were combined in the interest of meaningful data analysis, even though controller positions were identified in the questionnaires from the Tower/TRACON facilities. This methodology is consistent with all data analysis for each data collection method used.

4.6.1.2 Workload Scales.

Reduction in workload is one critical operational component of the ITWS to be investigated. The original intention of ACT-320 was to address this COI by means of direct observation of AT personnel performing specific job tasks. Data were to be collected prior to the ITWS installation and compared to similar data collected towards the end of the DEMVAL. However, after collecting this information in MEM prior to the start of the DEMVAL, it was determined that there was no logical way to compare these data.

Consequently, it was decided to administer the Modified Cooper-Harper (MCH) Workload Scale to measure the impact of the ITWS on perceived controller workload. The MCH Workload Scale was administered before and after the OT&E DEMVAL in Orlando. The MCH was also administered in Memphis, although the Memphis DEMVAL had already started. Memphis users were asked to rate tasks and workload based on how they felt they were affected prior to the start of the DEMVAL (without the ITWS) and during the DEMVAL, with the ITWS. Comparison of the results from Memphis did not vary significantly from those received in Orlando.

This scale measures perceived workload using an ordinal rating scale from 1-10 denoting gradients of user perceived difficulty and demand level (1 = easy to 10 = impossible) while performing specific tasks. Figure 4.6.1.2-1 depicts an example of the MCH Scale.

DIFFICULTY LEVEL	OPERATOR DEMAND LEVEL	
VERY EASY, HIGHLY DESIRABLE	OPERATOR MENTAL EFFORT IS MINIMAL AND DESIRED PERFORMANCE IS EASILY ATTAINABLE	1
EASY, DESIRABLE	OPERATOR MENTAL EFFORT IS LOW AND DESIRED PERFORMANCE IS ATTAINABLE	2
FAIR, MILD DIFFICULTY	ACCEPTABLE OPERATOR MENTAL EFFORT IS REQUIRED TO ATTAIN ADEQUATE SYSTEM PERFORMANCE	3
MINOR BUT ANNOYING DIFFICULTY	MODERATELY HIGH OPERATOR MENTAL EFFORT IS REQUIRED TO ATTAIN ADEQUATE SYSTEM PERFORMANCE	4
MODERATELY OBJECTIONABLE DIFFICULTY	HIGH OPERATOR MENTAL EFFORT IS REQUIRED TO ATTAIN ADEQUATE SYSTEM PERFORMANCE	5
VERY OBJECTIONABLE BUT TOLERABLE DIFFICULTY	MAXIMUM OPERATOR MENTAL EFFORT IS REQUIRED TO ATTAIN ADEQUATE SYSTEM PERFORMANCE	6
MAJOR DIFFICULTY	MAXIMUM OPERATOR MENTAL EFFORT IS REQUIRED TO BRING ERRORS TO MODERATE LEVEL	7
MAJOR DIFFICULTY	MAXIMUM OPERATOR MENTAL EFFORT IS REQUIRED TO AVOID LARGE OR NUMEROUS ERRORS	8
MAJOR DIFFICULTY	INTENSE OPERATOR MENTAL EFFORT IS REQUIRED TO ACCOMPLISH TASK, BUT FREQUENT OR NUMEROUS ERRORS PERSIST	9
IMPOSSIBLE	INSTRUCTED TASK CANNOT BE ACCOMPLISHED RELIABLY	10

FIGURE 4.6.1.2-1. MODIFIED COOPER-HARPER WORKLOAD RATING SCALE

During the administration of the MCH Workload Scale, users were asked to rate their workload while performing these tasks under conditions with and without the ITWS. Both of these conditions consisted of (1) operationally significant weather, and (2) moderate to heavy AT flow. The six tasks that were rated included:

a. Planning AT flow
b. Planning airspace use
c. Decisions on rerouting aircraft
d. Avoidance of adverse weather
e. Changing runways
f. Choosing runways

4.6.1.3 Structured Interviews.

At the end of the DEMVAL, structured interviews were conducted with the users. The interview questions were designed to address human factors COIs. These issues included: effects on traffic management, planning and decision making, product utility, meteorological interpretability, availability, effectiveness, timeliness, and performance.

There was some modification to the questions that were asked of the ARTCC users to accommodate differences between the ARTCC and Tower environments. Differences are noted in the results section.

4.6.2 Meteorological Data Collection and Analysis.

Meteorological data used in this report were obtained from two sources. The ACT-320 meteorologist who visited the test sites at Memphis and Orlando maintained a log of observed events and MIT/LL provided ACT-320 with base data and products in the form of color plots and operator logs for post-demonstration analysis.

At the test sites, MIT/LL maintained a series of displays of real-time base data and intermediate products in addition to the ITWS SD. With these displays, for example, it was possible for the meteorologist to check the TDWR base velocity and reflectivity displays for microburst, windshear, or gust front signatures to corroborate ITWS detections shown on the SD. This information also aided in the selection of data for post-demonstration analysis.

The meteorologist's log contained entries related to occurrences of meteorological events such as storm cells, microbursts, windshears, gust fronts, hail, and other pertinent weather phenomena. When possible, the meteorologist noted the type of event, time, strength, and location relative to the airport center or runways, and whether an ITWS event was evident in base data. The meteorologist also noted possible problems such as system failures and data source and product unavailability.

In order to facilitate an independent evaluation of product performance, ACT-320 requested that MIT/LL provide data and analysis tools in the same form or in a form similar to those they have used in their own evaluations of the products. Results of the ACT-320 evaluation of the meteorological performance are discussed in section 5.2.6. Appendix B contains a description of the analyses performed for each product evaluation.

5. RESULTS AND DISCUSSION.

The results of the data collection and analysis are discussed in this section. The completion criteria and the questionnaire/interview and meteorological evaluation results as they relate to the COIs are also discussed.

There were no major problems with the ITWS during the DEMVAL periods at either Memphis or Orlando. The readability of the tower SD in Memphis and the minor algorithm and display problems that occurred were discussed in earlier sections (section 3.2.2).

Appendix C contains a table of the operating times of the ITWS and the major input sensors during the Memphis DEMVAL. This table shows that the ITWS was operational for all but 5 weekend days of the DEMVAL period. Except for the start of the test (when it was known that the TDWR was unavailable) and the last week, when the TDWR was not operational, TDWR availability was acceptable. This table shows that overall availability of the TDWR during the 530 hours of ITWS operations was 71 percent. However, of the 13 days when TDWR was unavailable, there were 5 days when there was no significant weather; thus the availability of the TDWR during significant weather exceeded 82 percent. NEXRAD availability was 96 percent and ASR-9 weather channel availability was 100 percent. Both radars had excellent availability.

Appendix D contains a table of the operating times of the ITWS and the major input sensors in MCO. This table shows that the ITWS was operational every day of the 6 week DEMVAL period, for a total of 297 hours. The input sensor availability was excellent; 96 percent for TDWR, 94 percent for NEXRAD, and 100 percent for ASR-9.

5.1 COMPLETION CRITERIA.

The DEMVAL Plan set goals for minimum numbers of AT users and minimum occurrences of weather events to assure that users had ample opportunity to utilize the ITWS products. The completion criteria, as defined in the DEMVAL Plan, for each DEMVAL site were satisfied as discussed in the following sections.

5.1.1 Memphis Completion Criteria.

The requirement stated in the DEMVAL Plan was 10 cases of convective weather during inbound pushes and 10 windshear events in Memphis. During periods of ITWS operations in Memphis, there were 42 cases of convective activity during inbound pushes; an additional 42 cases of convective activity occurred during outbound pushes. These events occurred over 41 days. This exceeds the requirement for 10 convective events.

There were numerous windshear events in the TRACON area; a subset of these events contains the windshears, microbursts, and gust fronts that impacted the airport. There were 45 wind events that impacted the airport: 15 windshears, 4 microbursts, and 26 gust fronts. These numbers (from the more restrictive subset) satisfy the minimum requirement of 10 windshear events.

Another method of calculating the impact that weather had on the airport during the DEMVAL is to determine the number of runway arenas affected by windshears, microbursts, and gust fronts. An arena is defined as a critical region in the terminal area (e.g., final approach or departure corridor or runway). For example, if a microburst was present on runway 18L, two arenas would be affected; 18L arrival and 18L departure. If a microburst was at 1 mile final from the arrival end of the same runway, only one arena would be affected - 18L arrival. A single microburst that was situated over two different runways would affect four arenas - arrivals and departures for each runway.

In total, 550 arenas were affected during the MEM portion of the DEMVAL. Although there were no minimum criteria defined for runway arenas impacted, it is clear from this information that a sufficient quantity of weather was experienced during the Memphis DEMVAL period.

Seventy-five percent of qualified Memphis AT personnel were required to have used the ITWS during significant weather to satisfy the completion criteria. Greater than 95 percent of qualified MEM AT personnel used the ITWS during adverse weather; this number was based on observations and discussions with AT managers.

5.1.2 Orlando Completion Criteria.

There were 28 days during the MCO portion of the DEMVAL when convective activity impacted the airport (15 cases of convective activity was the minimum required). There was no requirement for weather events to occur during pushes, since Orlando does not typically experience defined pushes like MEM; MCO departures and arrivals occur at a more steady rate. (For purposes of this report, a push is defined as a period of intense arrival or departure activity, lasting from 1 hour to an hour and a half.)

A total of 121 wind events impacted the airport at MCO: 58 windshears, 17 microbursts, and 46 gust fronts. This satisfies the requirement of 15 windshears. A total of 1593 runway arenas (as defined in section 5.1.1) were impacted during the MCO DEMVAL. Greater than 95 percent of the qualified MCO AT personnel used the ITWS while adverse weather was present during the DEMVAL; this number was based on observations and discussions with AT managers.

5.2 CRITICAL OPERATIONAL ISSUES (COI) RESULTS.

The COIs stated in section 4.4 were answered by analyzing questionnaire and workload data and by analysis of the meteorological data and ITWS product performance. Meteorological performance of the ITWS products is also discussed. In the following sections, appropriate COIs are in boldface type. The meteorological analysis performed with respect to the first COI is addressed separately in section 5.2.6. Additional information from the interviews and questionnaires are included in appendix A; additional meteorological information is contained in appendix B.

5.2.1 Usability/Suitability/Timeliness COI.

Are the ITWS products useful during operationally significant weather in terms of their availability, timeliness, and suitability for AT use? Are detection and false alarm rates acceptable to users? (The second question is related to meteorological performance and is discussed separately in section 5.2.6.)

Data collected from the questionnaires relative to product utility were used to generate the mean rating scores found in figure 5.2.1-1 and table 5.2.1-1. Figure 5.2.1-1 is a bar graph of the mean scores of product utility for all responding users. The product utility is rated well below the maximum mean (2.75). Table 5.2.1-1 and figure 5.2.1-1 are based on a five-point scale, where 1 = product consistently enhances job performance and 5 = product consistently hinders job performance (figure 4.6.1.1-1).

As shown in table 5.2.1-1, the total mean rating for the utility of all products was 1.76. Ratings for each individual product were significantly lower than the maximum mean (2.75) for product suitability.

TABLE 5.2.1-1. MEAN PRODUCT UTILITY RATINGS

PRODUCTS	ORLANDO			MEMPHIS		
	TOWER		ARTCC	TOWER		ARTCC
	SUP/TMC (8)	CIC (32)	TMC/SUP (8)	SUP (5)	CIC (14)	SUP/TMC (8)
STORM MOTION	1.25	1.54	1.00	1.40	1.28	1.25
GUST FRONT	1.25	1.43	1.38	1.40	1.28	1.75
MICROBURST DETECTION	1.38	1.57	1.13	1.20	1.07	2.14
PRECIP W/ AP REMOVED	1.12	1.73	1.13	1.80	1.21	1.86
STORM EXTRAPOLATED POSITION	1.75	1.71	1.25	1.40	1.28	1.88
LONG RANGE PRECIP	1.75	1.89	1.38	1.80	1.50	1.88
TERMINAL WINDS	+	+	+	1.80	1.38	2.50
ASR-9 PRECIP W/ AP FLAGGED	2.00	2.28	1.50	2.00	1.33	2.50
ATIS COUNTDOWN TIMERS	1.74	2.14	++	2.00	2.00	++
STORM CELL INFO	2.00	2.35	1.50	1.60	1.71	2.12
TORNADO	+++	+++	+++	1.80	1.71	2.38
LIGHTINING	2.25	2.27	2.50	2.20	1.92	2.25

+ = No Terminal Winds Product in Orlando

++ = No ATIS Countdown Timers at ARTCC

+++ = Never used product

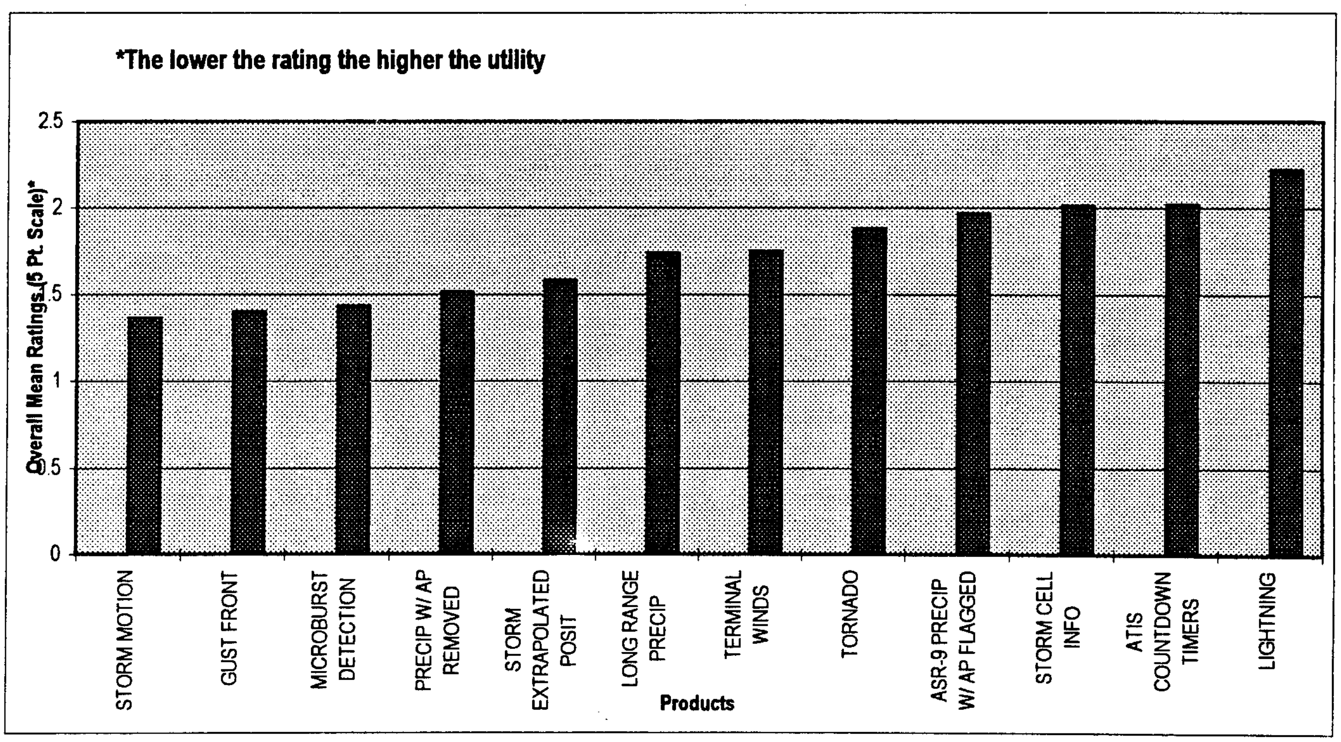


FIGURE 5.2.1-1. PRODUCT UTILITY

During the interviews, comments were received concerning the unavailability of certain products like windshear, microburst, and gust front when either TDWR or LLWAS was down. The lack of an operational TDWR at the start and finish of the MEM DEMVAL contributed to this problem. Also, there were several occasions at MCO when lightning temporarily disabled the LLWAS system. These problems are directly associated with the individual interfacing sensors; they are not problems that are inherent to the ITWS.

Table 5.2.1-2 presents the mean responses to questionnaire responses on timeliness (product update and display rate) and ease of use. The means are separated by position and location. Product update rate refers to the speed that the products are updated with the most recent sensor data (e.g., ASR-9 precipitation update rate is approximately 30 seconds). Display rate refers to the response speed of user requested display changes, as presented in table 5.2.1-2. The total mean rating for product update, display rate, and ease of use clearly meet the maximum rating of 2.75.

Sixty-nine percent (45) of 65 interview participants rated product availability of the ITWS as good. Contrary comments referred to unavailability of TDWR products when the TDWR was inoperable in MEM, and the lack of LLWAS data when the MCO LLWAS was struck by lightning.

TABLE 5.2.1-2. QUESTIONNAIRE RESPONSES TO PRODUCT SPEED AND EASE OF USE

	ORLANDO			MEMPHIS			TOTAL
	TOWER	ARTCC		TOWER	ARTCC		
FUNCTION	SUP/TMC	CIC	SUP/TMC	SUP	CIC	SUP/TMC	
UPDATE RATE	1.59	2.04	1.38	1.80	1.79	2.38	1.89
DISPLAY RATE	1.83	2.07	1.25	2.00	1.86	2.38	1.93
EASE OF USE	1.34	1.97	1.13	1.60	1.64	2.38	1.78

5.2.2 Interpretation/Understandability COI.

Are the ITWS products displayed without the need for further meteorological interpretation? Is the displayed information easily understandable for the end-user?

Responses to the questionnaire regarding interpretation/ understandability are as follows:

Do daylight conditions affect the readability of the display? If yes, please explain.

There were 33 responses to this question from the MEM and MCO Tower/TRACON. The responses were based on the ITWS SD not the TDWR SD. (See section 3.2.2.) No responses were solicited from the ARTCCs, since the operating environment is not affected by lighting conditions. Seventy-six percent (25) of the responses stated that daylight conditions did not effect the readability of the display. Eight respondents stated that glare and brightness in the tower affected the readability of the display, especially at a distance.

Do nighttime conditions affect the readability of the display? If yes, please explain.

There were 33 responses to this question from the MEM and MCO Tower/TRACON; all of the responses to this question stated that readability of the display is not affected by nighttime conditions.

Were there any colors that you had difficulty differentiating between? If yes, what color changes do you suggest?

There were 41 responses to this question. Eighty-three percent (34) of the respondents reported that there were no colors that were difficult to differentiate between. Color deficient respondents indicated minimal color differentiation problems.

Those who responded "yes" stated there was some confusion among the Microburst and level five and six Precipitation product colors (which are various shades of red), as well as the Gust Front and Storm Extrapolated Position product colors (purple and light blue, respectively).

Related questions asked during the structured interviews included:

How interpretable or understandable was the meteorological information you received?

There were 66 responses to this question. Ninety-five percent (63) of the responses to this question indicated that the meteorological information was very easy to understand and interpret, especially after training.

Did you require assistance in interpreting the meteorological information?

There were 66 responses to this question. Seventy-four percent (49) of the respondents indicated that they required no assistance in interpreting the meteorological information. Those who did state they required some assistance, added that the assistance was minimal or unnecessary after some familiarity with the system. Two of the respondents stated that they required continued assistance in interpreting the meteorological information, even after training and familiarity.

How would you rate the time it took to interpret meteorological information?

There were 66 responses to this question. Ninety-one percent (60) of the respondents stated that the time it took to interpret the meteorological information was minimal. Other responses (6) included "average" or "acceptable" in terms of rating interpretation time.

How distinguishable were the weather products from each other?

There were 66 responses to this question. Seventy percent (46) of the respondents stated that the weather products were distinguishable from each other.

The remaining 30 percent (20) related to confusion between the Windshear and Storm Motion products, the Gust Front and SEP products, and the Precipitation and Microburst products. There were also problems noted in distinguishing between level five and six precipitation and distinguishing products at selected ranges over 30 nm.

Rate the effectiveness of weather information overlays on runways and corridor locations.

There were 46 responses to this question from the MEM and MCO Tower/TRACON. Responses were not solicited from the ARTCCs since they do not deal directly with runways and terminal corridors. Eighty-three percent (38) of the respondents indicated that weather information overlays on runways and corridor locations were effective, especially for planning air traffic flow, transitions, arrival/departure changes, etc. Seeing the weather relative to the airport and other landmarks as well as user control of some of the overlays was also deemed positive.

Comments (8) were received to improve the effectiveness of the weather information overlays. These included: keeping overlays over the runways but not over corridors; and using overlays similar to maps that are already used. Other comments suggested the inclusion of more defined range markings and detailed airspace maps. (The overlays are a site adaptable parameter; the overlays used during the DEMVAL were designed based on input received from ITWS User Group members from Orlando and Memphis.)

Informal discussions with ARTCC personnel indicated that for the first time they had a system that showed them exactly where storm cells were relative to airport landmarks and runways. This aided them in anticipating storm arrival and departure at the airport.

5.2.3 Workload COI.

Does the ITWS reduce perceived controller workload during adverse weather conditions in the terminal area?

Mean workload ratings (figure 4.6.1.2-1 ten-point scale, 10 = highest workload, 1 = lowest workload) are given in table 5.2.3-1. Figure 5.2.3-1 depicts the overall workload rating of all tasks for ITWS and non-ITWS conditions. Figure 5.2.3-2 shows the workload ratings by task. Figures 5.2.3-3 and 5.2.3-4 show the workload rating by task for each DEMVAL site.

Results of the MCH Workload Scale indicate that perceived user workload is significantly decreased when using the ITWS, as seen in figures 5.2.3-1 through 5.2.3-4 and table 5.2.3-1.

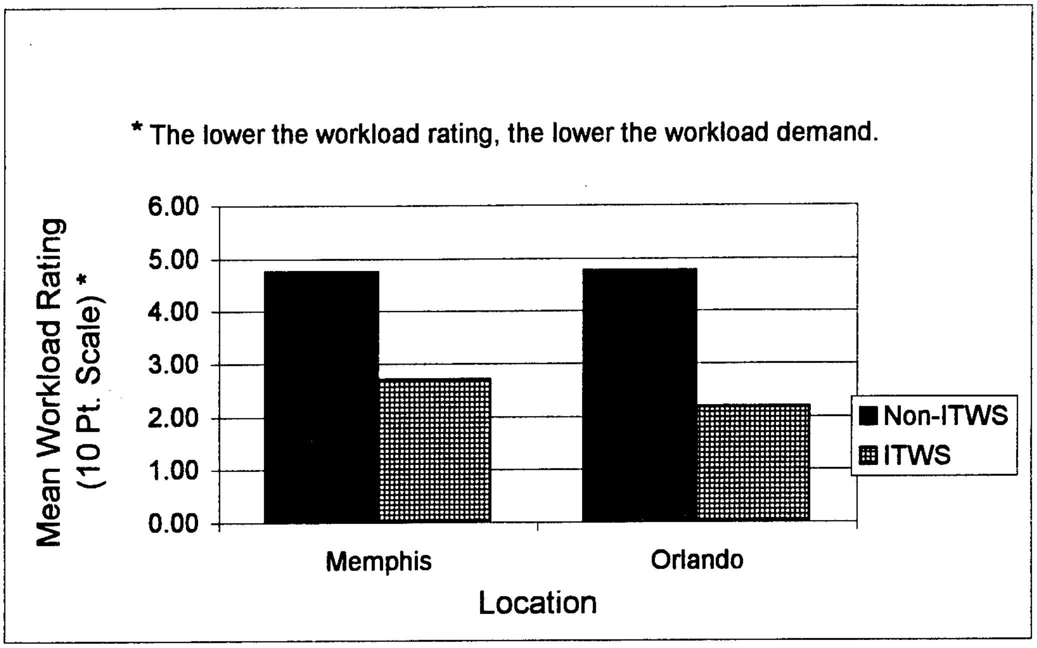
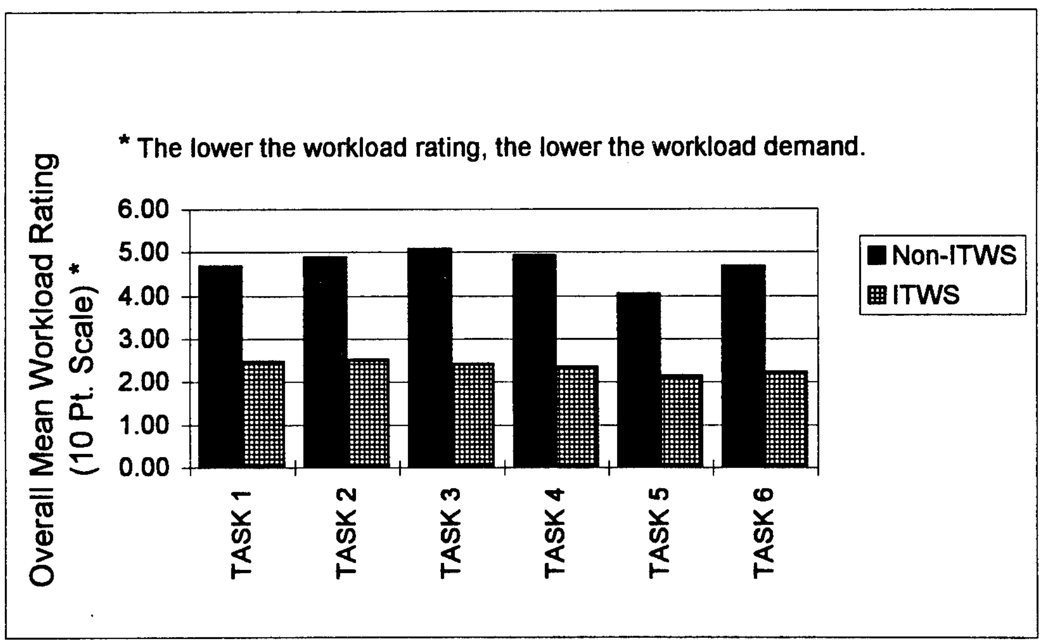


FIGURE 5.2.3-1. WORKLOAD RATINGS FOR NON-ITWS AND ITWS CONDITIONS AS A FUNCTION OF LOCATION



Task 1 - Planning air traffic flow
Task 2 - Planning airspace use
Task 3 - Decisions on rerouting aircraft
Task 4 - Avoidance of adverse weather
Task 5 - Choosing runways (Tower only)
Task 6 - Changing runways (Tower only)

FIGURE 5.2.3-2. OVERALL WORKLOAD RATINGS FOR NON-ITWS AND ITWS CONDITIONS AS A FUNCTION OF TASK

TABLE 5.2.3-1. MEAN WORKLOAD RATINGS

	MCO/ZJX		MEM/ZME		TOTAL	
NON-ITWS		ITWS	NON-ITWS	ITWS	NON-ITWS	ITWS
TASK 1	4.51	2.27	4.86	2.72	4.67	2.47
TASK 2	4.73	2.19	5.03	2.93	4.87	2.52
TASK 3	5.05	2.24	5.10	2.63	5.07	2.41
TASK 4	4.78	2.11	5.07	2.63	4.91	2.34
TASK 5	3.96	1.92	4.14	2.36	4.04	2.13
TASK 6	4.92	2.00	4.27	2.50	4.63	2.23
OVERALL	4.77	2.18	4.76	2.70	4.77	2.41

Task 1 - Planning air traffic flow
Task 2 - Planning airspace use
Task 3 - Decisions on rerouting aircraft
Task 4 - Avoidance of adverse weather
Task 5 - Choosing runways (tower only)
Task 6 - Changing runways (tower only)

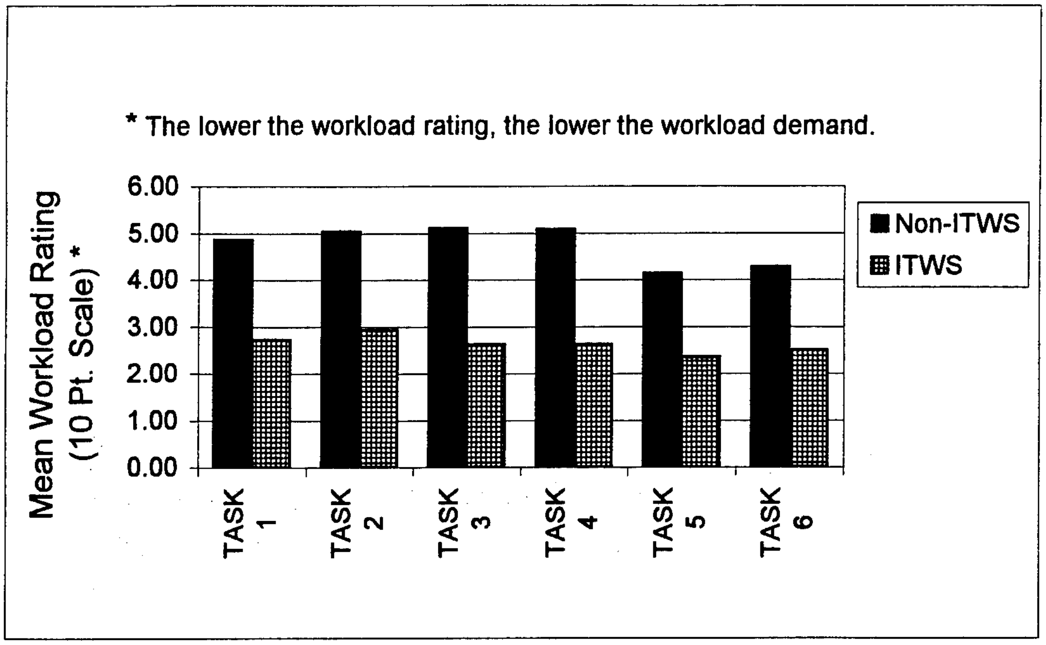
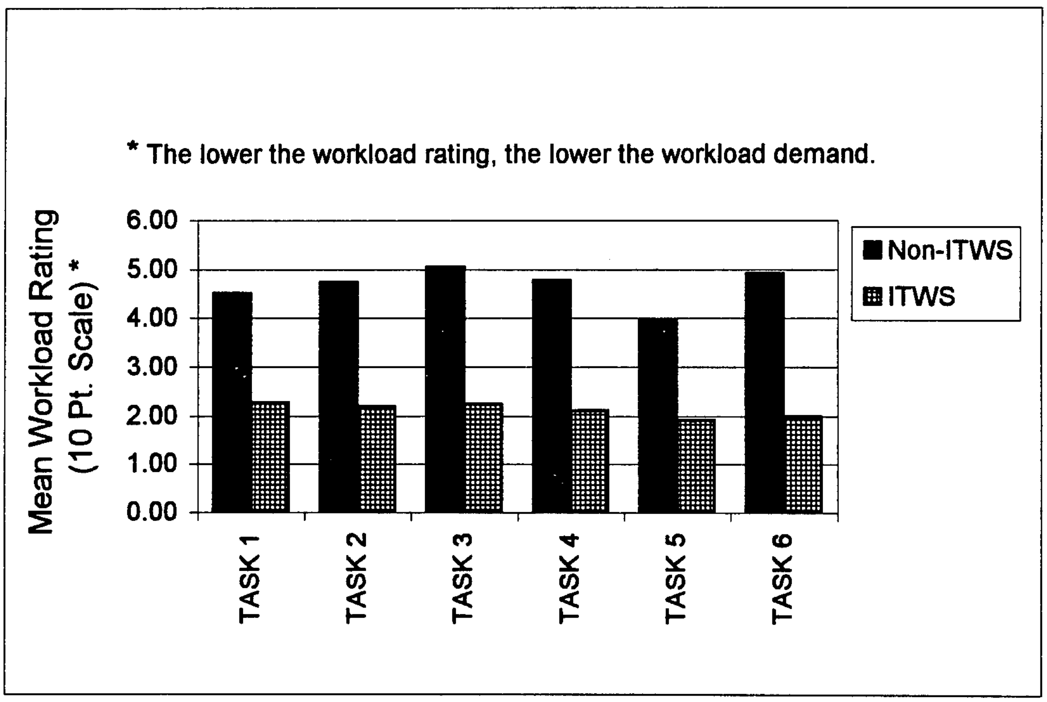


FIGURE 5.2.3-3. WORKLOAD RATINGS FOR NON-ITWS AND ITWS CONDITIONS AS A FUNCTION OF TASK FOR MEMPHIS TOWER AND ARTCC



Task 1 - Planning air traffic flow
Task 2 - Planning airspace use
Task 3 - Decisions on rerouting aircraft
Task 4 - Avoidance of adverse weather
Task 5 - Choosing runways (Tower only)
Task 6 - Changing runways (Tower only)

FIGURE 5.2.3-4. WORKLOAD RATINGS FOR NON-ITWS AND ITWS CONDITIONS AS A FUNCTION OF TASK FOR ORLANDO TOWER AND JACKSONVILLE CENTER

5.2.4 Management/Planning COI.

Do the ITWS products enhance supervisor effectiveness in traffic planning/management during adverse weather conditions in the terminal area (i.e., traffic flow)? Is terminal airspace planned and runways utilized more efficiently?

Data used to answer this COI are in the form of responses to questions regarding use of the ITWS to perform specific management tasks. Graphical presentation of these data was not meaningful.

How has the ITWS affected your situational awareness of Terminal weather?

There were 65 responses to this question. Eighty percent (52) of the respondents indicated that the ITWS had positively affected situational awareness of Terminal weather. Many respondents stated that in enhancing awareness, preplanning was improved as well as coordination between the Tower/TRACON and ARTCCs. The remaining respondents indicated that awareness was not improved since they were already aware of terminal weather via the ASR-9 radar and reports from pilots.

What effect did the ITWS have on reducing/increasing in-trail separation?

There were 60 responses to this question. Forty-two percent (25) of the respondents indicated that the ITWS had a positive effect on reducing/increasing in-trail separation, that it was particularly useful in preplanning, decision-making, and predicting airspace openings and closings. Fifty-eight percent (35) of the users commented that the ITWS had no effect on in-trail separation.

What products did you use (for in-trail separation)?

For those who stated that the ITWS had an effect on reducing/increasing in-trail separation, 36 responded to this question. Products they reported using most often for in-trail separation included: Gust Front, Precipitation, Storm Motion, Storm Extrapolated Position, Microburst, and Windshear.

What effect did the SEP Product have on estimating impact times of fast or slow moving storms?

There were 64 responses to this question. Eighty-four percent (54) responded that the SEP product had a positive effect on estimating impact times of fast or slow moving storms. It was reported to enhance preplanning and provide accurate estimations of weather effecting air traffic control operations.

Ten percent (6) reported that the SEP had no effect on estimating impact times of fast or slow moving storms; that it was unnecessary since storm vectors are sufficient; that traffic would be rerouted around significant weather anyway; and that it only adds clutter to the display. Four respondents indicated that they had never used it or would not use it for estimating impact times of storms.

What effect did the storm motion product have in planning runway and airspace configuration changes?

There were 66 responses to this question. Seventy-nine percent (52) of the responses indicated that the storm motion product was very effective in planning runway and airspace configuration changes. Generally, respondents felt that this was a valuable tool for planning operations and making timely decisions.

The remaining 21 percent responded that this product afforded little or no effect in planning runway and airspace configurations or had never used the product for planning.

How did the gust front and wind shift products affect runway management?

There were 46 responses to this question from the MEM and MCO Tower/TRACON. No responses were solicited from the ARTCCs, since they do not directly deal with runway management. Seventy-eight percent (36) of the respondents indicated that the Gust Front and Wind Shift products were very effective for runway management. Many indicated that this was the best product.

The remaining twenty-two percent (10) of the respondents stated that the Gust Front and Wind Shift products had little or no effect on runway management. They also noted that LLWAS information was sufficient.

If you observed a tornado icon or alert, then what effect did the Tornado product have in routing aircraft away from tornado activity?

There were 30 responses to this question. Only one respondent stated that they would use the tornado product to reroute aircraft away from tornado activity.

The overall response to this question indicated that for the most part, air traffic would be rerouted around intense weather activity regardless of the presence of a tornado. Thus, they felt there was little use for the product. Additionally, it was noted that the information was not timely enough. (Tornadoes are capable of traveling significant distances during the 5 minutes required to update NEXRAD tornado data.)

<u>How did the ITWS precipitation products effect your planning of traffic flow patterns</u>?

There were 44 responses to this question from the MEM and MCO Tower/TRACON. No responses were solicited from the ARTCCs, but informal discussions indicated that they felt these products to be useful for traffic flow planning.

Eighty-four percent (37) of the respondents indicated that using the ITWS Precipitation products increased effectiveness while planning traffic flow patterns. It was cited as an important product in terms of ease of discriminating levels of precipitation and use for planning air traffic flow since aircraft will generally not fly through precipitation level three and above.

The remaining seven respondents felt that this product was redundant and not effective in planning air traffic flow since this was already accomplished with the ASR-9.

<u>How did the terminal weather text message product affect your situational awareness</u>?

There were 31 responses to this question from the MEM and MCO Tower/TRACON. Only two respondents stated that the text message product positively effected their situational awareness.

The overall response to this question indicated little or no use for the terminal weather text message product relative to its effectiveness for situational awareness. Those who did use the product found that looking at the display itself did more for their situational awareness than reading the Text Message.

<u>What effect did the terminal winds product have on traffic management (i.e., at the arrival and departure gates and at turn-on to final approach)</u>?

There were 17 responses to this question from the MEM Tower/TRACON. No responses were solicited from the ARTCCs or MCO Tower/TRACON.

Fifty-nine percent (10) of the respondents referred to the usefulness of the terminal winds products to anticipate tailwinds, allow them to use speed control more effectively, and to plan final turn-ons for arrivals. Remaining responses indicated that the product had little impact on operations and was rarely used.

What effect did the storm cell information have in planning traffic flow?

Forty-seven percent (20) of the 43 respondents indicated that using the Storm Cell Information product increased their effectiveness while planning by providing controllers information to determine pilot-preferred routes (around adverse weather) and aided them in vectoring aircraft accordingly.

Twelve of the remaining respondents indicated that the storm cell information was nice to know but not of any real use for air traffic operations. The remaining respondents experienced no effect from using the product or they did not use it.

How did the storm cell information product affect your situational awareness?

Seventy-one percent (29) of the 41 respondents to this question indicated that the storm cell information product positively affected situational awareness and that this awareness enhanced air traffic flow operations. Other responses indicated that although the information was nice to know, it had minimal impact on situational awareness.

5.2.5 Interfacing Sensor Availability COI.

Does the unavailability of interfacing systems/sensors adversely affect the ITWS operations?

As stated in section 5 and in appendices C and D, there was a high rate of availability of TDWR, ASR-9, and NEXRAD data to the ITWS during the DEMVAL. The Memphis DEMVAL was started without the TDWR available, and was completed with the TDWR inoperable. While windshear, microburst, and gust front products were not available at these times, other ITWS products remained available. AT personnel continued to have the ability to use the precipitation products, storm motion and extrapolated position, AP, lightning, and degraded terminal winds and storm cell information.

There were several times during the Orlando DEMVAL that the LLWAS was struck by lightning, rendering it inoperable. At these times, Runway Winds (on the RBDT) were unavailable. However, microburst and windshear alerts, which are TDWR products, continued to be available.

5.2.6 Meteorological Performance.

Are detections and false alarm rates acceptable to air traffic users?

The ITWS Operational Requirements Document specifies meteorological performance requirements in terms of probabilities of detection and false alarm for the microburst detection, microburst prediction, and gust front detection products. Measures of acceptable performance for the other products are described in the appropriate subsections below. These performance levels were the goal for ITWS meteorological product performance during the DEMVAL.

Results from individual product performance evaluations are provided in the following sections. Details of the analyses and analysis methods along with examples are presented in appendix B. Data descriptions as well as the times, dates, and sites used in each analysis are also provided in appendix B.

All analyses were based on limited quantities of data. Caution is advised when interpreting the results presented. The intent of the ACT-320 analysis was to "spot check" the performance of each of the products. A more comprehensive analysis of the DEMVAL product performance will be reported by MIT/LL.

5.2.6.1 Short-Range Precipitation.

The ITWS short-range precipitation product is based on the ASR-9 weather channel. Two problems exist with the ASR-9 weather channel. It is susceptible to anomalous propagation (AP), and it can be insensitive to precipitation very close to the radar site. These problems were evident in the ASR-9 data when the data were compared with NEXRAD and/or TDWR data (see section 5.2.6.2 and appendix B, section B.1). In spite of these problems, the performance of this product was acceptable.

5.2.6.2 Anomalous Propagation (AP) Edition Precipitation.

A qualitative analysis in which the AP edited precipitation product was compared with unedited ASR-9 reflectivity and NEXRAD composite reflectivity was employed in the evaluation of this product. Results of the analysis indicate that AP was appropriately reduced or eliminated. Additional information is provided in appendix B.

The evaluated data set provided an example of a limitation of the current system. This limitation affects the availability of NEXRAD data for AP editing close to the NEXRAD site. The NEXRAD is affected by ground clutter to a range of approximately 20 kilometers. There is also a small area within 10 kilometers of the NEXRAD called the cone of silence. Within this area the NEXRAD can detect precipitation only in the lowest part of the atmosphere. AP editing is not possible in these areas. This limitation is not a problem if the affected NEXRAD area is outside the ASR-9 coverage area. The affected NEXRAD area is within the ASR-9 coverage area in both Memphis and Orlando.

5.2.6.3 Long-Range Precipitation.

The long-range precipitation product was observed and found to be comparable to the short-range precipitation product where the two products coincide. The ITWS long-range product was compared visually with the NEXRAD base reflectivity data display, and was determined to be consistent with the base data. The performance of this product was acceptable.

5.2.6.4 Storm Motion.

Results from the data analysis of the storm motion product indicate that it was capable of providing an estimation of cell motion. This motion was consistent with the leading edges projected by the SEP product. The performance of this product was acceptable.

5.2.6.5 Storm Extrapolated Position (SEP).

The effectiveness of the SEP product in extrapolating storm leading edge positions 10 and 20 minutes in the future is dependent upon the degree of storm evolution (i.e., growth and decay). The current SEP algorithm was not designed to account for storm evolution; it projects the motion of a storm cell of a particular size and shape, and expects the cell to retain the same size and shape for as many as 20 minutes. In 20 minutes an evolving storm could grow such that its leading edge is in a location quite different from the location projected by the SEP product. A decaying storm for which leading edges were projected may not exist 20 minutes in the future.

The data used in the analysis were found to contain evolving storms. (Examples of evolving storms are provided in appendix B, section B.4.) This determination led to the definition and use of three performance statistics:

a. The probability of making a correct extrapolation using all extrapolations, including those for evolving cells (P_{CEI});

b. The probability of making a correct extrapolation, excluding extrapolations for evolving cells (P_{CEE});

c. The probability that a cell would be affected by growth and decay (P_{EA}).

For the SEP product performance analysis, a total of 204 10- and 20-minute extrapolation were examined. Computed statistics are shown in table 5.2.6.5-1.

TABLE 5.2.6.5-1. STORM EXTRAPOLATED POSITION PRODUCT EVALUATION STATISTICS.

	10 min	20 min
Number of extrapolations	204	204
Number affected by cell evolution (growth/decay/merging)	67	97
Number of hits	100	70
Number of misses	37	37
P_{CEI}	.49	.34
P_{CEE}	.73	.65
P_{EA}	.33	.47

The P_{EA}s indicate that after 10 minutes nearly one-third of the extrapolations were affected by growing or decaying storms. This increased to almost one-half after 20 minutes.

There was also a problem which caused erroneous leading edges and extrapolations under certain circumstances. These erroneous extrapolations are included in table 5.2.6.5-1 as "misses." More information about these problems is presented in appendix B, section B.4.

5.2.6.6 Microburst/Windshear Detection.

In order to evaluate microburst and windshear detection performance, the following statistics were computed: Probability of Detection (P_D) and Probability of False Alarm (P_{FA}) for microbursts, and P_D and P_{FA} for windshears. These statistics were computed for each site separately and in combination for a subset of the total microburst/windshear detections.

Microbursts and windshears as detected by the ITWS, were examined and compared with the a truth set of base TDWR velocity (raw sensor) data as described in appendix B, section B.5. ITWS detections corresponded favorably with the truth set; there were no missed detections, and only one false detection. This false detection was in a region of noisy velocity data.

Table 5.2.6.6-1 presents the statistics for microburst (MB) detection and includes the P_D and P_{FA}. Similar statistics for windshear (WS) detection are given in table 5.2.6.6-2. Separate and combined statistics are given for both Memphis and Orlando. For the data set examined, the microburst/windshear product scored perfectly in terms of detection (P_D = 1.00 for Memphis and Orlando); i. e., all microbursts in Memphis and Orlando were detected, as were all windshears. P_{FA}s were well below the requirement of 0.10.

TABLE 5.2.6.6-1. MICROBURST DETECTION STATISTICS (≥30 KT).

	#MB (Truth)	#MB Detections	#Correct MB Detections	P_D	P_{FA}
Memphis					
6/3	2	2	2		
6/22	7	7	7		
7/4	1	1	1		
Total	10	10	10	1.00	0.00
Orlando					
7/28	4	4	4		
8/9	1	1	1		
8/15	7	7	7		
Total	12	12	12	1.00	0.00
Total (MEM+MCO)	22	22	22	1.00	0.00

TABLE 5.2.6.6-2. WINDSHEAR DETECTION STATISTICS (≥15 KT, <30 KT).

	#WS (Truth)	#WS Detections	#Correct WS Detections	P_D	P_{FA}
Memphis					
6/3	18	18	18		
6/22	16	16	16		
7/4	6	6	6		
Total	40	40	40	1.00	0.00
Orlando					
7/28	23	23	23		
8/9	10	10	10		
8/15	16	17	16		
Total	49	50	49	1.00	0.02
Total (MEM+MCO)	89	90	89	1.00	0.01

Results indicate that the microburst detection product performed very well. However, these results should be taken with some caution, as a relatively small portion (about 6 hours) of the demonstration data were analyzed.

5.2.6.7 Microburst Prediction.

Two probabilities were computed for microburst prediction. One was the probability of prediction (P_P). The second statistic was the probability of false alarm (P_{FA}) for windshear events with strength greater than 15 kt.

Table 5.2.6.7-1 presents the microburst prediction statistics for the data set examined. The P_{FA}s related to this analysis were computed from the numbers contained in table 5.2.6.7-2. Cumulative statistics for all days at each site are given as well as combined statistics for all days and both sites.

The analysis indicated that the microburst prediction product performed well when it attempted to predict an event. In all instances of missed microbursts, the product did not attempt to predict the event.

The ORD states that the P_P shall be greater than 0.50. The P_P for Memphis (0.69) exceeded the requirement, but the Orlando P_P (0.23) was much lower (less than half) of the required P_P. The combined Memphis and Orlando P_P (0.48) was only slightly below the requirement. MIT/LL has performed a more comprehensive analysis that may indicate better prediction performance.

TABLE 5.2.6.7-1. MICROBURST PREDICTION PRODUCT STATISTICS, PROBABILITY OF PREDICTION (>25 KT).

	Number of Events		
	Truth	Predicted	P_p
Memphis (MEM)			
6/3	5	5	
6/22	8	3	
7/4	3	3	
Total	16	11	0.69
Orlando(MCO)			
7/28	10	2	
8/9	0	0	
8/15	3	1	
Total	13	3	0.23
Total (MEM+MCO)	29	14	0.48

TABLE 5.2.6.7-2. MICROBURST PREDICTION PROBABILITY OF FALSE ALARM (>15 KT).

	Number of Predictions	Number of Correct Predictions	P_{FA}
Memphis (MEM)			
6/3	26	26	
6/22	5	5	
7/4	27	27	
Total	58	58	0.00
Orlando(MCO)			
7/28	4	4	
8/9	0	-	
8/15	17	17	
Total	21	21	0.00
Total (MEM+MCO)	79	79	0.00

The statistics shown in table 5.2.6.7-2 indicate P_{FA}s of 0.00. There were no false alarms generated by the microburst prediction product during the analysis periods. This perfect score satisfies the ORD requirement for P_{FA} (< 0.1).

5.2.6.8 Gust Front Detection.

Probabilities of detection (P_{DL}) and false alarm (P_{FAL}), based on length, were used to determine the performance of the gust front detection product. Additional information is contained in appendix B, section B.7.

The resultant P_{DL} and P_{FAL} from the gust front detection product were 0.79 and 0.04, respectively. These meet the ORD accuracy requirements for P_{DL} (> 0.7) and P_{FAL} (<0.1).

5.2.6.9 Terminal Winds.

Results of the qualitative analysis indicated that the gridded winds of the terminal winds product were consistent with the velocity fields of the NEXRAD and TDWR in the areas where radar data were provided. Additional details are found in appendix B.

5.2.6.10 Storm Cell Information.

The storm cell information product reports echo tops and the presence of hail, lightning, and mesocyclones within selected storm cells. Each component, when assigned to a particular cell, is referred to as an "attribute." Assessments of the capability of the product to associate echo tops, hail, lightning, and mesocyclones with a storm cell follow in section 5.2.6.10.1. Assessments of the performance of the hail detection, echo tops, and mesocyclone detection algorithms appear in the remaining sections.

5.2.6.10.1 Attribute to Cell Association.

Hail. Results from the analysis indicate that hail algorithm detections were, for the most part, properly associated with storm cells. There were, however, missed associations (i.e., hail algorithm detections that the product failed to associate with a storm cell). Appendix B, section B.9, contains a discussion on these missed hail associations.

Lightning. Lightning flashes appeared to be scattered adequately over the map so that each cell containing lightning received the lightning attribute. There were, however, many flashes that were not associated with storm cells (see appendix B, figures B8-B13).

Mesocyclone. Three missed mesocyclone associations are discussed in appendix B, section B.9. In these cases, there were no cells with which to associate the mesocyclones.

Echo tops. Analysis results indicate that, for most cases examined, maximum echo tops were found and associated with the appropriate cell. There were, however, cases for which maximum echo tops were outside the cell boundary. These situations are discussed in appendix B, section B.9.1.

5.2.6.10.2 Hail.

The NWS compiles reports of hail sightings. There were 22 sightings of hail in excess of 0.75 inches in the Memphis ITWS coverage area during June 1994. For 17 of these sightings, there were corresponding hail product detections. For two of these sightings, the ITWS hail product did not detect the NWS hail event. For the remaining three NWS sightings, the ITWS was not operational at the time of occurrence. See appendix B, section B.9.2 for details of the analysis.

5.2.6.10.3 Echo Tops.

Early in the demonstration at Memphis DEMVAL it was found that the echo tops provided by the ITWS echo tops product were lower than those of the NEXRAD by as much as 5000 feet. MIT/LL found an error in their software and corrected it. Thereafter, the echo tops product appeared to be consistent with the echo tops reported by the NEXRAD.

5.2.6.10.4 Mesocyclone.

Data adequate for evaluating the mesocyclone product were unavailable at the time of this report. The NWS does not compile reports of public sightings of mesocyclones; so an analysis similar to the hail product analysis was not possible. MIT/LL or NSSL will issue a report on the performance of this product.

5.2.6.11 Lightning Warning.

The lightning warning box product was evaluated in real-time by comparing it with the Storm Cell Information product. Whenever the lightning alert box changed to yellow, the SCI boxes for storm cells within 20 nm of the airport center were checked for the lightning attribute. Likewise, when the lightning attribute appeared in an SCI box for a storm cell within 20 nm of the airport center, the lightning box was checked to ensure it had changed to yellow. Observations indicated that the warning box product registered lightning strikes as expected.

5.2.6.12 Tornado.

A total of 79 tornadoes were determined to have occurred in the Memphis ITWS coverage area in June 1994. These 79 tornadoes constitute the truth set for this analysis of the tornado product and were determined from examination of base TDWR and NEXRAD velocity data. Of these 79 tornadoes, only 42 were detected by the ITWS tornado product. This resulted in a P_D of 0.53. There were eight false detections, with a P_{FA} of 0.16. These statistics are presented in table 5.2.6.12-1.

The ORD does not specify performance requirements for the tornado product. However, the P_{FA} of 0.16 is close to the value of 0.10, the maximum allowable P_{FA} specified for the ITWS microburst and gust front products in the ORD.

TABLE 5.2.6.12-1. TORNADO DETECTION STATISTICS (JUNE 1994, MEMPHIS)

Hits	Misses	False Detections	P_D	P_{FA}
42	37	8	0.53	0.16

NSSL is conducting an evaluation of the tornado product using DEMVAL data and results from experiments they are conducting in other areas of the United States. Their studies are expected to result in refinement of the tornado algorithm and improvement of performance, and in particular, the P_D.

5.2.6.13 Terminal Weather Text Message.

The terminal text message was compared with the SD. The product appeared to be consistent with the SD. Locations were within roughly ± 1.0 nm.

6. CONCLUSIONS.

The conclusions that were reached are based on the results of the questionnaires, interviews, workload scales, and meteorological analysis as they relate to the Critical Operational Issues (COI). The results were analyzed from an air traffic (AT) perspective.

The responses received from the questionnaires, interviews and informal discussions were not always consistent. Similarly, they did not always correlate with the product performance analysis. Products AT personnel consider marginally useful may prove to be much more useful to other users (e.g., flight standards, systems capacity, the airlines, etc.).

6.1 COMPLETION CRITERIA.

Sufficient adverse weather was experienced during the Memphis and Orlando Demonstration/Validation Phase (DEMVAL) Operational Test and Evaluation (OT&E) from which to properly evaluate meteorological performance and Integrated Terminal Weather System (ITWS) product suitability. A sufficient number of AT personnel utilized the ITWS during adverse weather conditions.

6.2 CRITICAL OPERATIONAL ISSUES.

Each of the COIs that were evaluated for DEMVAL are listed below in boldface type. The conclusions are contained in the following paragraphs.

1. Are the ITWS products useful during operationally significant weather in terms of their availability, timeliness, and suitability for air traffic use? Are detection and false alarm rates acceptable to users?

The results presented in sections 5.2.1 and 5.2.6 support the conclusion that for the Demonstration Phase, the ITWS products were useful in terms of availability, timeliness, and suitability for air traffic use. Some products were rated higher than others, but all were rated as enhancing user job performance. No products were rated as hindering job performance, although the utility of some products (lightning, terminal weather text message, and tornado) was rated as marginal. The lightning and tornado products may be more useful to systems capacity, airlines dispatch, and ramp personnel, while the terminal weather text message product may be useful to pilots, in the form of the terminal weather information for pilots (TWIP).

There were some users that responded that product availability was not acceptable. In these instances, unavailability was due to the interfacing sensor availability, not a function of ITWS product unavailability. Terminal Doppler Weather Radar (TDWR) unavailability in Memphis prohibited the generation of windshear and gust front products; Low Level Windshear Alert System (LLWAS) lightning damage caused product unavailability in Orlando on several occasions. Otherwise ITWS products were available at all times. Interfacing sensor availability remains a risk.

The timeliness aspect of this COI was based on user responses on display rates and update rates of selectable products and display options. Respondents rated the update speed of the products and the speed at which the selected products were displayed as frequently enhancing their performance. A number of respondents did state that the update rate for the range and anomalous propagation (AP) editor products was slow. Additionally, half of the respondents wanted a faster update speed for the products overall.

The ITWS products were rated as useful and suitable for AT personnel use. Availability and timeliness of the products were satisfactory, but require improvement. The ITWS DEMVAL operating software was written in four different computer languages (e.g. C, C++, LISP, FORTRAN); processing speed was not optimized. Production software using a single higher order programming language should minimize/eliminate processor induced delays in product display. In some cases, users confused ITWS product update rates with the update rates of the input sensors.

Based on analysis of meteorological data collected during the DEMVAL, it was determined that the ITWS products performed to an acceptable level relative to probability of detection and false alarm rates and other performance levels. Some of the products require further work in order to meet the performance standards of the Operational Requirements Document (ORD), prior to formal OT&E testing. Conclusions specific to certain products are listed below:

a. The Airport Surveillance Radar Model 9 (ASR-9) had difficulty detecting precipitation in the area near the radar due to radar insensitivity. This is an ASR-9 radar problem, and not within the scope of the ITWS DEMVAL.

b. There is a high probability that the ITWS storm extrapolated position product can be affected by the growth and decay of storm cells. This product was not designed to account for growth and decay.

c. The microburst detection product performed very well. The P_D for the product was 1.00 for the combined Memphis and Orlando cases, and the P_{FA} was 0.02 for Orlando and 0.00 for Memphis. The P_{FA} for the combined Memphis and Orlando cases was 0.01.

d. The microburst prediction product performance was acceptable when it attempted to predict microbursts. However, it did not always attempt to predict all microbursts that did occur.

e. The gust front product scored a P_{DL} of 0.79 and a P_{FAL} of 0.04. These numbers met the Operational Requirements Document (ORD) requirements of 0.7 and 0.1.

f. Not all hail and mesocyclone events were associated with storm cells, and were not listed as storm cell attributes by the storm cell information product

g. Initially, ITWS echo tops were being reported as lower than those being reported by the Next Generation Weather Radar (NEXRAD); this was also found to be due to association problems. The highest echo tops were found to be outside the storm cell contour. This problem was corrected during the DEMVAL; subsequent analysis indicated acceptable performance.

h. There is a 20-km radius circle centered on the NEXRAD wherein data are sparse or unusable due to the NEXRAD's cone of silence and ground clutter. There is no AP editing capability in this area. If this area is coincident with the ASR-9 coverage area, no AP editing will take place. This is a known problem with the NEXRAD, and was outside the scope of the ITWS DEMVAL.

i. The tornado product is a replacement for the current NEXRAD tornado vortex signature product. Based on analyses by Massachusetts Institute of Technology/Lincoln Labs (MIT/LL) and ACT-320, the product scored a P_D of 0.53 and a P_{FA} of 0.16. Given what is available in terms of the tornado product, this performance is satisfactory; improvements are still required.

j. Slight discrepancies in the terminal weather text message (TWTM) product can be explained by realizing that the text message may have been based on a radar scan taken just prior to the scan which the meteorologist used for comparison.

2. Are the ITWS products displayed without the need for further meteorological interpretation? Is the displayed information easily understandable for the end-user?

Overall, the ITWS products satisfied this COI for this stage of testing, in terms of interpretability and understandability. Results derived from data collected in relation to this COI support this conclusion. AT personnel found the meteorological information easy to understand and interpret. After training and familiarity with the system, AT personnel considered the time required to interpret the meteorological information as minimal. Proper training will continue to assure a high degree of understanding of ITWS products as they are displayed on the Geographic Situation Display (SD).

One-third of the respondents found some difficulties in retrieving information from the display during daylight conditions. There was some difficulty in distinguishing information on the display due in part to the similarity of some colors used for different products. Noted examples are storm extrapolated position versus gust front and the similarity in color between levels five and six precipitation and their similarity of the microburst icon.

3. Does the ITWS reduce (perceived) controller workload during adverse weather conditions in the terminal area?

Results from the workload scale data analysis indicate that the ITWS significantly reduced perceived controller workload during the DEMVAL, in the presence of adverse weather conditions. This was demonstrated in the Tower/Terminal Area Approach Control (TRACON) and Air Route Traffic Control Center (ARTCC) environments for both Orlando and Memphis. Across all job tasks evaluated, workload was rated significantly lower when utilizing ITWS than when not utilizing the ITWS.

4. Do the ITWS products enhance supervisor effectiveness in traffic planning/management during adverse weather conditions in the terminal area (i.e., traffic flow)? Is terminal airspace planned and runways utilized more efficiently?

Traffic management, planning, and flow, as well as terminal airspace and runway management were enhanced by the ITWS products as indicated by the structured interviews. Situational awareness and the degree of coordination between the Tower/TRACON and the ARTCC was increased, creating a smoother transition of aircraft from the ARTCC to the Tower/TRACON. Both long- and short-range precipitation products were found to be effective for planning air traffic flow of arriving and departing aircraft.

Use of the storm motion product increased the effectiveness of planning runway and airspace configuration changes and valuable for planning operations and timely decision making. The gust front and windshear products were also found to be increase the effectiveness of runway management.

The terminal winds product was assessed in terms of its effectiveness for traffic management. No conclusion can be drawn on the effect the terminal winds product had on traffic management due to the disparity of the responses, and the limited data set (Memphis only).

Several products neither enhanced air traffic planning and situational awareness nor hindered job performance. In particular, storm cell information and terminal weather text message were felt to have insignificant impact in enhancing situational awareness and traffic planning. The tornado product was not effective for rerouting air traffic away from a tornado, since pilots automatically avoid areas of severe weather.

5. Does the unavailability of interfacing systems/sensors adversely affect the ITWS operations?

All input sensors were available for the vast majority of the DEMVAL period in Orlando; The TDWR was the only sensor with measurable unavailability in Memphis. Lightning strikes rendered the LLWAS unavailable on several occasions in Orlando.

Sensor unavailability did not adversely affect ITWS operations during the DEMVAL. During times of individual sensor unavailability, AT personnel were able to continue to use the ITWS, given the high availability rate of the input sensors during the DEMVAL. Some of the input sensor data were received via MIT/LL, not the operational interface, compounding the assessment. Since input sensor availability was high, a quantitative assessment of ITWS system performance with reduced capability cannot be given.

The ITWS contained usable products even without the availability of some of the interfaces. This is due to the redundancy that exists with the major interfaces (e.g., TDWR or NEXRAD used to display 0-50 nm range precipitation upon loss of ASR-9 Weather Channel, LLWAS III used to generate microburst detections and RBDT runway alerts, TDWR used to edit ASR-9 AP in case of NEXRAD failure). Therefore, it can be concluded that the ITWS is less susceptible than other systems to interface induced outages. Table 3.2-1 of the ITWS ORD illustrates product availability in relation to sensor availability.

6.3 PRODUCT IMPROVEMENTS.

Current RBDT configurations do not display all runway alerts; they only display alerts for their respective runways. Controllers unaware of alerts present on adjacent runways may inadvertently vector aircraft into these alerts.

A countdown timer indicating gust front airport impact time would be useful. AT personnel would not have to estimate time to impact based on the gust front lines on the SD.

Suggestions for improvements of ITWS products were minimal; they are presented in appendix A. These suggestions are pertinent to the ultimate design of the ITWS products; many of them have been discussed at the ITWS Users meetings and will be implemented in future ITWS prototypes.

6.4 USER INTERFACE.

Many of the conclusions listed in the following paragraphs are based on results reported in appendix A. Overall confidence in the displayed products was very high, but responses received from AT users indicate that some of them question the accuracy of the microburst and windshear products. This is contrary to the results of the microburst and windshear detection product evaluation presented in sections 5.2.6.5 and 5.2.6.6, which indicate excellent detection and false alarm performance.

There were some users that suggested larger SDs. At this time, the ITWS is a strategic (supervisory) tool, not for use by controllers. Consideration should be given to making the ITWS a tactical tool for use by air traffic controllers since they use the ITWS when they are acting as controllers in charge (CIC). The ITWS would be beneficial to controllers as well as Supervisors and Traffic Management Coordinators (TMC).

The effect the Lightning product has on influencing a supervisor's decision to turn on backup generators was assessed. Overall responses indicated that the Lightning product was not needed for this task, due to the existence of the uninterruptible power supply (UPS); however, not all Airport Traffic Control Towers (ATCT) and ARTCCs may have a UPS. In addition, the Lightning product is a useful product with respect to ramp operations and airline dispatch. The benefits to these groups were not assessed by ACT-320 since Flights Standards and Systems Capacity were not official sponsors at the time of the DEMVAL. Benefits to these groups were assessed by the Benefits Assessment Team.

The terminal weather text message product had minimal impact on the number of requests from pilots for details about convective weather in the terminal area or on radio traffic during the DEMVAL. Most respondents were unaware of its existence.

The effect of switching from the long- to short-ranges of the precipitation products was inconclusive, due to the disparity of the responses. Half of the respondents related that movement was easy, whereas the other half noted that the movement was slow and cumbersome.

The selection process for some of the product can be cumbersome; too many steps are involved. The speed at which some selected products and options are updated is too slow (e.g., changing the short-range precipitation range, changing from short- to long-range precipitation).

7. RECOMMENDATIONS.

Based on the results of the Integrated Terminal Weather System (ITWS) 1994 Demonstration Validation (DEMVAL) and the conclusions that were reached, ACT-320 recommends that the ITWS program proceed to Key Decision Point 3 (KDP-3). Some of the recommendations that are made correspond to results and comments that fall within more than one category (e.g., Critical Operational Issues (COIs), product improvement, user interface); these recommendations are listed one time.

7.1 COMPLETION CRITERIA.

No recommendations are given.

7.2 CRITICAL OPERATIONAL ISSUES.

a. Continue to monitor the ITWS input sensor interfaces and their development. This can be accomplished by continuing to collect data during subsequent DEMVALs and monitoring Interface Requirement Document (IRD) development via Interface Control Working Group (ICWG) meetings, both with the program offices that direct the interfacing sensors and the prime contractor. Reliable input sensor interfaces should provide the ITWS with a high rate of availability.

b. To assure continued user satisfaction with ITWS product availability, usefulness, timeliness, and suitability, continue data collection and evaluation at future DEMVALs and continue the ITWS AT User Group meetings. Minimize product update rate and quantify the number of required steps to change product options.

c. Ensure that at future DEMVALs: (1) input sensor interfaces are hardened as much as possible prior to the start of DEMVAL; (2) sites have commissioned input sensors in order to ensure higher reliability/availability of input data; and (3) system software should be optimized as much as possible to give the user a realistic system to operate.

d. Use the Terminal Doppler Weather Radar (TDWR) reflectivity to generate the ITWS precipitation product for the 5-nm range in order to negate the effects of Airport Surveillance Radar Model 9 (ASR-9) insensitivity in this region. Investigate the possibility of including this radar data into the ASR-9 mosaic for selected ranges greater than 5 nm.

e. Modify the storm extrapolated position (SEP) algorithm to account for the effects of growth and decay of storm cells.

f. Continue to evaluate the microburst and windshear algorithms, particularly the microburst prediction algorithm. The accuracy of the prediction algorithm was acceptable but the probability of prediction performance needs improvement. Document pilot reports and compare to the ITWS information.

g. Collect TDWR data as the radars are installed. The data collected at these sites should be used to improve the accuracy of microburst and windshear detection and prediction algorithms.

h. Improve storm cell information product association techniques for echo tops, hail, and mesocyclone products. Storm cells may need to be redefined with extended association areas.

i. Investigate the feasibility of using the TDWR to perform anomalous propagation (AP) editing wherever the ASR-9 coverage falls within the Next Generation Weather Radar (NEXRAD) cone of silence and ground clutter affected areas.

j. Continue analysis of the improved tornado algorithm and include in future ITWS product suites.

k. Develop a comprehensive training program in order to maintain a high level of user understanding of the ITWS products and display.

l. A situation display (SD) with maximum contrast and brightness control is required in order to ensure maximum visibility of displayed products. Tests should be conducted to evaluate SD visibility under all anticipated lighting conditions. Ensure that the SD is optimally located in order to maximize product and display visibility under all conditions.

m. Further investigation of color discernability is required to minimize confusion between products.

n. Further evaluation is required in regards to the effects of the terminal winds, terminal weather text message, and tornado products on traffic planning and management, as well as non-AT users. A terminal winds evaluation will take place in Orlando during February 1995.

o. Keep the SDs in the Air Route Traffic Control Centers (ARTCCs) to maintain situational awareness and smooth coordination between the ARTCC and Tower.

p. Conduct a controlled test of the effects of sensor unavailability on the ITWS.

q. Controller tasks in the ARTCC and terminal environments need to be assessed to ensure ITWS products provide all the necessary information to complete weather related job tasks.

r. Evaluate the effects of ITWS on AT personnel performance in an environment that has never had ITWS or TDWR.

s. Monitor current product development activities for inclusion as future ITWS products.

7.3 PRODUCT IMPROVEMENTS.

Recommendations for product improvements, based on feedback from interviews and questionnaires include the following.

a. Modify the ribbon display terminal to present current windshear and microburst warnings for all runway configurations at all controller positions.

b. Place centerfield wind information on the top of the Ribbon Display.

c. Investigate the feasibility of including a gust front impact timer within the gust front warning box.

d. Investigate the feasibility of allowing multiple windows on the SD to display either different precipitation ranges (e.g., 200 nm and 50 nm) or different airports within the same Terminal Radar Approach Control (TRACON) area. This would be particularly useful for multiple airport TRACONs and ARTCCs controlling multiple ITWS airports.

e. Investigate the inclusion of storm trend (growth and decay) within the storm cell information.

f. Investigate the inclusion of graphical lightning data on the SD.

g. Evaluate additional product improvement. Some products require low level detail areas to be evaluated and refined, whereas other products require high level utility issues to be addressed (e.g., the text on the terminal winds product, the tornado product and the effectiveness of the display to alert controllers, and the density of information displayed).

7.4 USER INTERFACE.

User interface recommendations include:

a. Streamline the product selection process; too many steps are required for some processes.

b. A quantitative requirement is needed for the number of steps required to access products and select options.

8. ACRONYMS.

ACT-320	Weather Branch
AFSFO	Airways Facilities Sector Field Office
AP	Anomalous Propagation
APMT	Associate Program Manager For Test
AND-420	TDWR Program Office
AND-460	Aviation Weather Development Program
ARTCC	Air Route Traffic Control Center
ASOS	Automated Surface Observing System
ASR-9	Airport Surveillance Radar, Model 9
AT	Air Traffic
ATC	Air Traffic Control
ATCT	Airport Traffic Control Tower
ATIS	Automated Terminal Information System
ATR-400	Air Traffic Requirements Service, Program Sponsor
AWOS	Automated Weather Observing System
CIC	Controller In Charge
COI	Critical Operational Issue
CWSU	Center Weather Service Unit
DEMVAL	Demonstration/Validation
FAA	Federal Aviation Administration
FSL	Forecast Systems Laboratory
GFE	Government Furnished Equipment
GFI	Government Furnished Information
ICWG	Interface Control Working Group
IOC	Initial Operational Capability
IRD	Interface Requirements Document
ITWS	Integrated Terminal Weather System
LLWAS	Low Level Windshear Alert System
MAPS	Mesoscale Area Prediction System
MB	Microburst
MBA	Microburst Alert
MCH	Modified Cooper-Harper Workload Scale
MCO	Orlando International Airport
MDCRS	Meteorological Data Collection And Reporting System
MEM	Memphis International Airport
MIGFA	Machine Intelligent Gust Front Algorithm
MIT/LL	Massachusetts Institute Of Technology/Lincoln Laboratories
NAS	National Airspace System
NATCA	National Air Traffic Controllers Association

NCP	NAS Change Proposal
NEXRAD	Next Generation Weather Radar, WSR-88D
NLDN	National Lightning Data Network
NSSL	National Severe Storms Laboratory
NWS	National Weather Service
ORD	Operational Requirements Document
OT&E	Operational Test And Evaluation
OTS	Out Of Service
P_{FA}	Probability Of False Alarm
P_D	Probability Of Detection
PD	Program Directive
POSH	Probability Of Severe Hail
P_P	Probability of Prediction
RBDT	Ribbon Display Terminal
SCI	Storm Cell Information
SD	Situation Display
SEP	Storm Extrapolated Position
T&E	Test And Evaluation
TDWR	Terminal Doppler Weather Radar
TEMP	Test And Evaluation Master Plan
TMC	Traffic Management Coordinator
TMU	Traffic Management Unit
TRACON	Terminal Radar Approach Control
TWTM	Terminal Weather Text Message
TWIP	Terminal Weather Information For Pilots
UPS	Uninterruptible Power Supply
VCP	Volume Coverage Pattern
VIL	Vertically Integrated Liquid
WS	Windshear
WSA	Windshear Alert
WSFO	Weather Service Forecast Office
ZJX	Jacksonville ARTCC
ZME	Memphis ARTCC

APPENDIX A

QUESTIONNAIRE AND INTERVIEW RESULTS

APPENDIX A - QUESTIONNAIRE AND INTERVIEW RESULTS

This appendix contains additional results from data collected from the questionnaires and interviews, but not directly related to the COIs.

Some of the questionnaire rating scale questions asked users to rate aspects of the ITWS other than the utility of the products. The results of these questions are as follows:

<u>Identify and explain any product that was difficult to use</u>.

There were nine responses to this question. Six of the respondents indicated that there were no products that were difficult to use.

Other users indicated that it would be easier to change the selection steps from three to one; that user specific preference sets could be devised to enhance ease of use of the products; and that changing the cursor may help in finding it on the display. The selection process has been discussed at the ITWS User Group meetings and in all likelihood will be modified to reduce the number of steps required to perform a selection.

<u>Identify and explain any selected product in which the display speed was unacceptable</u>.

There were eight responses to this question. Four of the respondents stated that there were no selected products in which the display speed was unacceptable. Three stated that the update rate was a little slow for the range and AP editor selection products. One responded "not applicable."

<u>Identify and explain any product in which the update speed was unacceptable</u>.

There were 12 responses to this question. Seven respondents reported that the update speed was acceptable. The remaining comments indicated faster update speeds were desired overall, and one indicated a faster tornado product update speed. (In general, the update rates of the ITWS products are directly related to the update rates of the respective input sensors, and thus are not changeable within the ITWS software.)

<u>Was the 5-second time out of the AP editor product acceptable</u>?

Thirty-eight responses to this question were received. Thirty-five of the respondents stated that the AP editor product was acceptable. Of the remaining responses, only one stated that a 10-second timer would be more efficient; and two stated they had never used it.

Some questions requested controllers to rate the readability of various aspects of product timeliness. The following are the mean rating scale responses to these questions.

Rate the readability of the text information on the terminal winds product. The mean was 2.08, frequently enhances job performance.

Rate the density of information when using the storm extrapolated position product. The mean rating was 1.99, frequently enhances job performance.

Rate the readability of the textual information provided by the tornado product. The mean response was 2.28, consistent with the responses reported above; the readability of this product does enhance controller performance. It must be remembered that this product was only utilized on those rare occasions when a tornado occurred.

Other questions solicited specific information concerning suggested changes to existing products, as listed below.

Is there any product information in a textual format that you would prefer in a graphical format?

There were 34 responses to this question. Overall, the respondents stated that there were no products in a textual format that they would prefer in a graphical format. Three of the respondents would prefer to see lightning strikes in a graphical format.

Is there any product information in a graphical format that you would prefer in a textual format?

There were 36 responses to this question. With only two exceptions, each respondent stated that there were no products in a graphical format that they would prefer in a textual format. One of the respondents would prefer to see the microburst product in text with distance and radial to aid in identifying it immediately.

Additional comments were solicited per product.

ITWS Precipitation Product.

There were 12 responses to this question. Seven of the respondents stated that they had no suggestions for improving the ITWS precipitation product.

Those who had suggestions for improvement suggested: a window to show a variable range while watching a larger picture on the main screen, and a feature to predict areas of building precipitation.

AP Editor Product.

There were 21 responses to this question. All respondents stated that they had no suggestions for improving the AP editor product.

Long-Range Precipitation Product.

Twenty-one controllers responded to this question. Fourteen respondents stated that they had no suggestions for improvement of the long-range precipitation product.

There were several suggestions for improvement which included: the incorporation of more range choices; speeding the product up; addition of more fixes (NAVAIDS); reduction of steps for product selection (from three to one); and splitting the GSD screen out into separate windows, allowing views of the long- and short-ranges simultaneously.

Storm Motion Product.

Of the 19 responses to this question, fourteen had no suggestions for improving the storm motion product. The remaining suggestions for improvement included: display of the back side of the storm to predict changes; and display of the storm motion product at ranges greater than 5 knots past the 50 nm range.

Storm cell information product - Are there additional products that you would like to be added?

There were 28 responses to this question. Sixteen had no suggestions for improving the storm cell information product. Nor did they identify any additional products that they would like to be added.

Suggestions for additions included: displaying the bottom level of a storm cell; showing a trend in storm intensity (increase, decay, etc.); and eliminating the storm top information. (Storm tops frequently occur above the terminal airspace ceiling of 16,000 feet.)

Storm Extrapolated Position Product.

There were 22 responses to this question. Sixteen had no suggestions for improving the storm extrapolated position product.

Respondents who had suggestions stated that the color contrast between gust front and the storm extrapolated position should be improved. It was also suggested that the product wasn't necessary and that storm motion vectors were sufficient. Typically, storms move at much slower speeds in Orlando than they do in Memphis, hence storm cells are easier to track without this product. The usefulness of this product will depend on the prevailing characteristics of local storm movement.

Lightning Product.

There were 26 responses to this question. Fourteen respondents had no suggestions for improving the lightning product.

Those who had suggestions wanted to see lightning strikes displayed per location (much like the 3M Scope). Another suggested that the lightning product not be a part of the final package since it was unnecessary.

Microburst Detection Product.

There were 25 respondents to this question. Fourteen had no suggestions for improving the microburst detection product.

There were several suggestions for improvement of the microburst detection product. Many respondents stated that the microburst color should be changed to avoid confusion with levels of weather (similarity to level 5 and 6 precipitation).

Several suggestions also centered around the concern that microburst alerts should be displayed on all RDTs regardless of runway configuration. This has subsequently been discussed by the ITWS User Group; possible solutions will be evaluated during future prototype evaluations.

This information may have an impact on those departures that do not fly-out on a straight line and may be impacted by weather affecting the other runway. Other suggestions included having the product more accessible to the flight data position for the ATIS, and feedback from pilots when the microburst alert is issued.

Terminal Winds Product.

There were eight responses to this question. This question was not applicable to Orlando Tower/TRACON and Jacksonville ARTCC, since the product was not available to them.

Four of the respondents had no suggestions for improving the terminal winds product. The only suggestion for improvement of the terminal winds product was to make winds aloft information easier to understand.

Do you have any suggestions for improving the gust front product?

There were 21 responses to this question. Fifteen of the respondents had no suggestions for improving the gust front product. Suggestions for improvement centered on the inclusion of a count-down mode on the warning panel to indicate gust front impact time. This also has been discussed by the User Group and will be implemented and evaluated during future prototype operations.

ATIS Countdown Timer Product.

There were 17 responses to this question. Fourteen of the respondents had no suggestions for improving the ATIS countdown timer product.

Suggestions for improving the ATIS countdown timer product included: a turn-off command in the event it is accidentally turned on; an automatic tie to the ATIS; and better placement in the tower for easier accessibility.

Tornado Product.

There were 25 responses to this question. Eleven of the respondents had no suggestions for improving the tornado product. Eight of the respondents stated that they had never seen the product operationally.

Those who had suggestions for improving the tornado product generally stated that the update rate was too slow; tornado information was too infrequent; and that the range for tornado warnings on the Ribbon Display should be farther than 10 miles. The tornado update rate is dictated by the scan rate of the NEXRAD radar; the maximum range of the tornado alert on the RDT is a site adaptable parameter.

Additional comments and suggestions were solicited from the questionnaire respondents, as shown below.

Please provide any other comments or suggestions you may have regarding the products, display, and/or system.

There were 37 responses to this request for comments and suggestions. Twenty-five of the respondents provided comments to this general question regarding the ITWS products, display, and/or system. The respondents stated that the system was excellent; beneficial; useful; enhanced safety; a valuable tool for the TMU; the best tool in traffic management; invaluable; enhances traffic management; the best product; etc.

Others stated that the reliability must be improved; the ribbon display information was incorrect; and that overall the information was only occasionally useful. Since ITWS reliability was nearly 100 percent, increased input sensor reliability should improve perceived ITWS reliability.

Eleven of the respondents provided suggestions for improving the ITWS. These include: splitting the display screen into windows to view both the long and close range; making the displays accessible to everyone (controllers, flight data, etc.); eliminating the "Done" box after a user selection; and placing the center field wind information on the top line of the ribbon display.

How would you rate movement through the different display screens?

There were 65 responses to this question. Approximately half (33) of those who responded stated that movement through the different display screens was easy or good.

Thirty-two of the respondents, however, did not rate movement through the different displays positively. Overall, the comments were similar in expressing that the movement was too slow, cumbersome, and difficult.

If you used lightning products to turn on back-up generators, what effect did the lightning product have on your decision to switch to back-up generator power?

There were 17 responses to this question. Comments were not solicited from the ARTCCs. Only three respondents actually stated that they would use the lightning product to turn on backup power. Others responded that they were aware of lightning and didn't need help in deciding when to turn on the generators. The overall response to this question was negative due to the existence of the Universal Power Supply (UPS). "The UPS would go on automatically as soon as lightning was within 20 nm. Therefore, the product is unnecessary for this task. Also, it's easy enough to tell if lightning is nearby - just look out the window."

How confident were you in the accuracy of the displayed products, i.e., warnings, storm movements, etc.?

There were 65 responses to this question. Seventy-eight percent of the responses (51) were positive. Confidence in the displayed products was high for the majority of respondents.

Although expressing confidence in most of the products, some respondents (14) did have some reservations about a few specific products. Those products identified most often were windshear and microburst. It was noted that the products would sometimes become activated despite reports from pilots or other indicators that there was no significant wind activity. It was suggested that the algorithms for these products may be too sensitive. This is contrary to the results of the microburst and windshear product performance evaluation presented in sections 5.2.6.5 and 5.2.6.6, which indicate excellent detection and false alarm probabilities.

How did the microburst products affect your degree of confidence during landing and take-off operations?

There were 44 responses to this question. Comments were not solicited from the ARTCCs. Fifty-four percent of the respondents (25) stated that the microburst products had a positive effect on their degree of confidence during landing and take-off operations. This was especially true in terms of warning pilots of microburst activity.

Thirteen indicated that confidence was not high; that the product did not accurately portray what was actually happening; that the algorithm was too sensitive; and that bad weather conditions would deter landing and take-off operations anyway - whether or not a microburst was detected. Three reported not using the product; and three indicated that the microburst product did not effect their degree of confidence.

<u>Rate the impact of the terminal weather text message product on the number of requests from pilots for details about convective weather in the terminal area.</u>

The mean overall score to this question was 3.07. This suggests that there was no significant impact of this product on the number of requests from pilots for details about convective weather in the terminal area.

<u>Rate the impact of the terminal weather text message product on radio traffic in general.</u>

The mean overall score to this question was 3.05. This also suggests that there was no significant impact of the product on radio traffic in general.

<u>Provide any comments on the terminal weather text message demonstration that you consider to be relevant:</u>

There were 36 responses to this question. Twenty respondents (56 percent) were unfamiliar with the product or were unaware of any impact it had to air traffic control operations.

There were seven responses (19 percent) from those who had experienced some impact from pilots using the terminal text product. Most of this interaction was minimal. Some of the more positive respondents stated that: a pilot delayed approach based on terminal text information; there was more agreement between the pilots and the controllers; and that it assisted in preplanning for holding aircraft. Less positive comments stated that: the product precipitated questions from pilots about lack of information to the aircraft; some outside telephone communications increased with Northwest carrier operations; there were more questions on microburst; and a pilot reported no depiction of character graphics in the cockpit.

Seven respondents (19 percent) made hypothetical statements about the potential positive or negative impact of the product on air traffic control operations. Two of the responses were not relevant to the question.

APPENDIX B

METEOROLOGICAL PERFORMANCE

APPENDIX B

METEOROLOGICAL PERFORMANCE

This appendix contains details of the analyses and analysis methods used to obtain the results presented in the meteorological performance evaluation section, section 5.2.6.

B.1 Short Range Precipitation

The ITWS Short Range Precipitation Product was observed to have problems providing accurate measurement of cell precipitation and coverage near the radar. An example of this problem was a well-defined windshear producing storm cell that could readily be seen in TDWR data, but was barely noticeable in ASR-9 data. The TDWR, located 11 nm south of the airport, appeared much more sensitive to the cells than the ASR-9 located in the terminal area. At 1830 UTC on July 4, storm cells developed over and near the Memphis terminal area. These cells remained in the terminal area for about one hour, generating windshear features and then dissipating.

Figure B-1 shows the ITWS GSD with the ASR-9 short-range precipitation product at 184403. The lower left panel of Figure B-2 shows TDWR reflectivity at 184348. The TDWR panel indicates reflectivity values of 40 dBZ close to and over the airport runways. (A measurement of 40 dBZ is at the upper end of the range for level two precipitation.) Note that in Figure B-1 there were only two squares of light green (level one) in the area where the TDWR indicated level two precipitation. The ASR-9 was detecting only a small portion of the cell. The problem persisted for about an hour, until the cells dissipated.

<u>B.2 Anomalous Propagation (AP) Edited Precipitation</u>

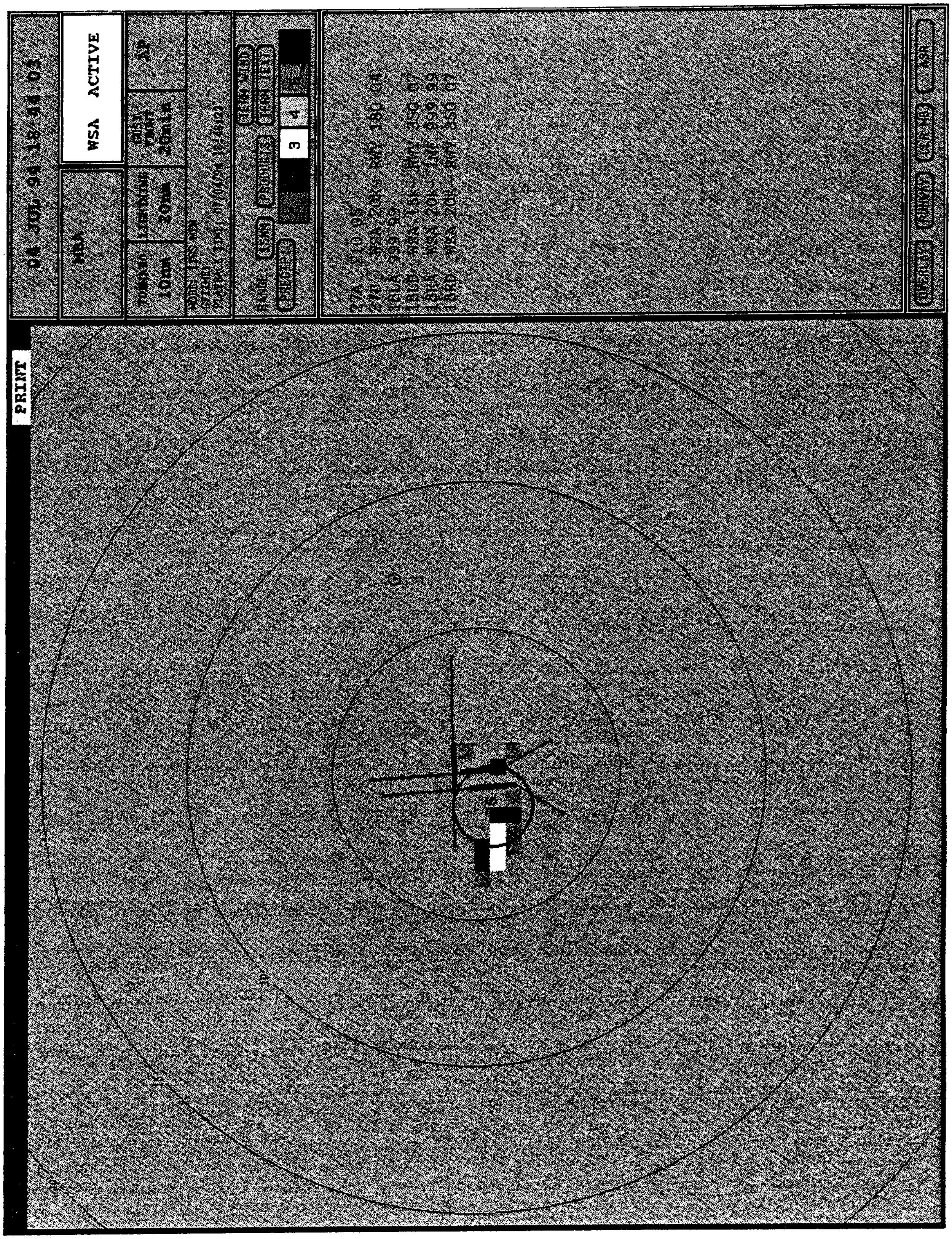
Color data plots (an example plot is shown in Figure B-3) used to evaluate this product contained four panels:

1) Map of the raw, unedited ASR-9 reflectivity (upper left panel);

2) Map of the NEXRAD composite reflectivity (upper right);

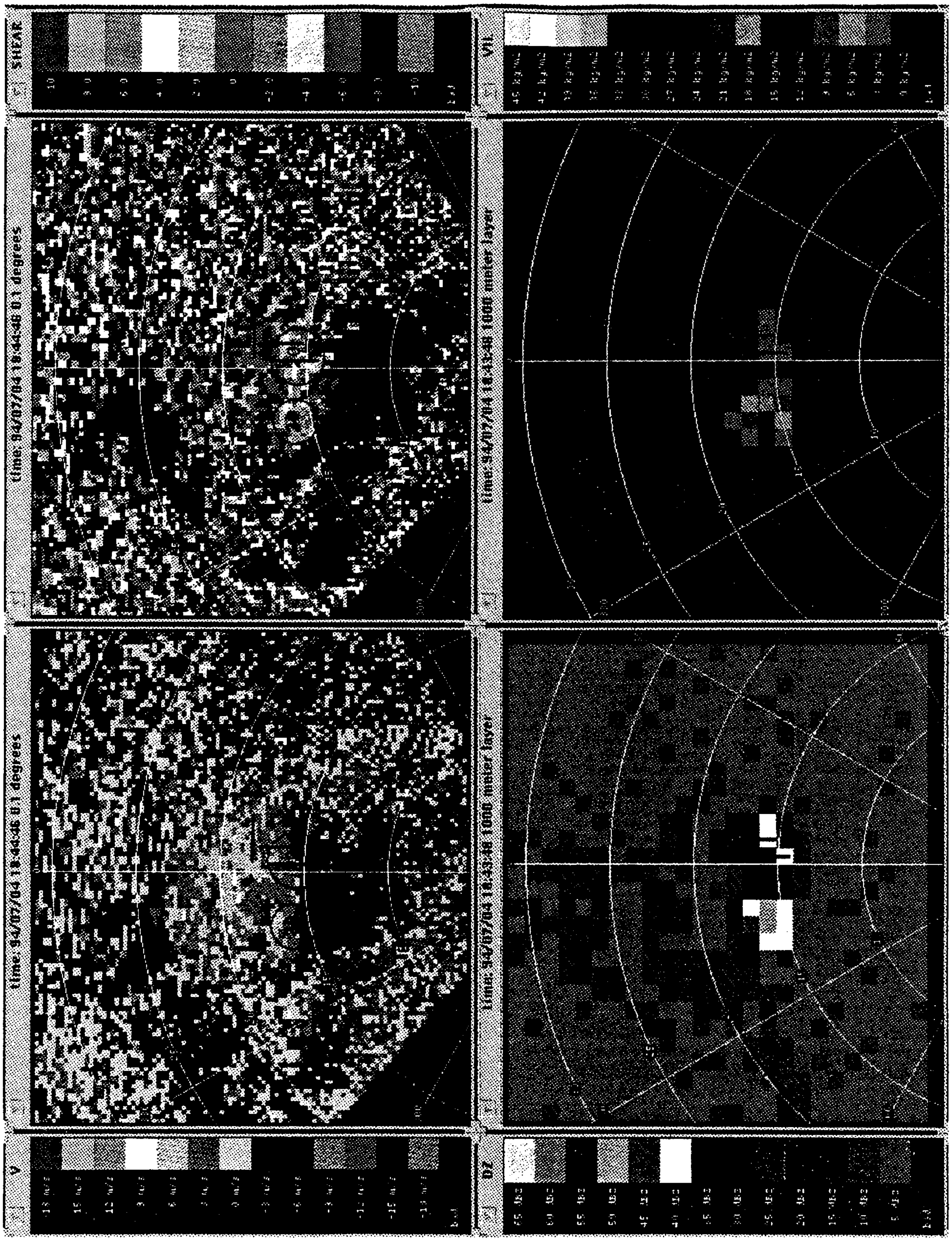
3) Map of the raw, unedited ASR-9 reflectivity, with echo regions determined to be affected by AP shown in black (lower left);
and

4) Map of the AP edited precipitation (lower right).



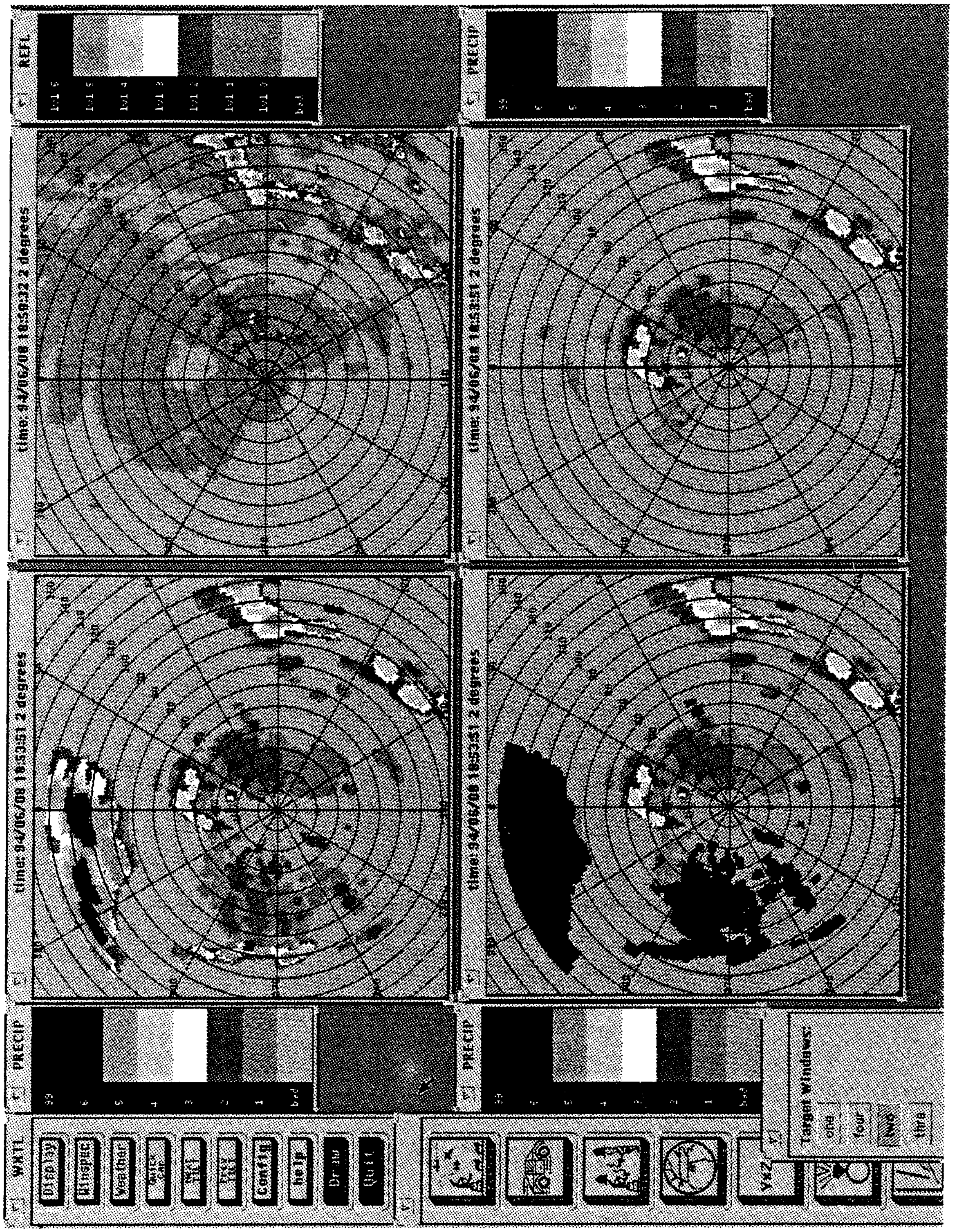
Real-time display at Memphis, TN. Note sparse precipitation intensity over airport (compare with Fig. B-2).

FIGURE B-1. ITWS GEOGRAPHIC SITUATION DISPLAY (GSD), JULY 4, 1994, 184403 UTC.



Lower left panel shows TDWR reflectivity over airport (compare with Fig. B-1).

FIGURE B-2. DATA PLOT, JULY 4, 1994, 184348 UTC, MEMPHIS, TN.



Shows evaluation data for AP edited precipitation product. Upper left panel depicts raw ASR-9 reflectivity. Upper right is a composite of NEXRAD reflectivity. Lower left is the ASR-9 precipitation with AP affected areas shown in black. The lower right panel is the AP edited precipitation product.

FIGURE B-3. DATA PLOT, JUNE 8, 1994, 184029 UTC, MEMPHIS, TN.

The NEXRAD composite reflectivity map contains, at each pixel on the map, the highest NEXRAD reflectivity sensed in the vertical column above that pixel. The NEXRAD provides the composite reflectivity by performing a set of successive scans while increasing elevation angles (this scan strategy is known as a Volume Coverage Pattern (VCP)). The NEXRAD completes a VCP approximately once every five to six minutes. The ASR-9 precipitation updates every 30 seconds.

The AP editing process was evaluated by comparing the raw ASR-9 scan closest in time to the middle of the VCP with the NEXRAD composite reflectivity map. This comparison provided a reference ASR-9 map with pixels flagged as being affected by AP. This reference was first used in conjunction with the next VCP. Each ASR-9 update map during the VCP was compared with the reference from the prior completed VCP. Each update map was eligible for AP editing only at pixels that were flagged on the reference ASR-9 map. AP editing rules prescribed that pixels on the update map be assigned lower precipitation levels, or remain the same, depending upon the maximum allowed reflectivity (from the NEXRAD composite reflectivity map) for the individual pixel.

For the AP edited precipitation product, the following data were analyzed:

Memphis	6/8/94	1840-1903 UTC

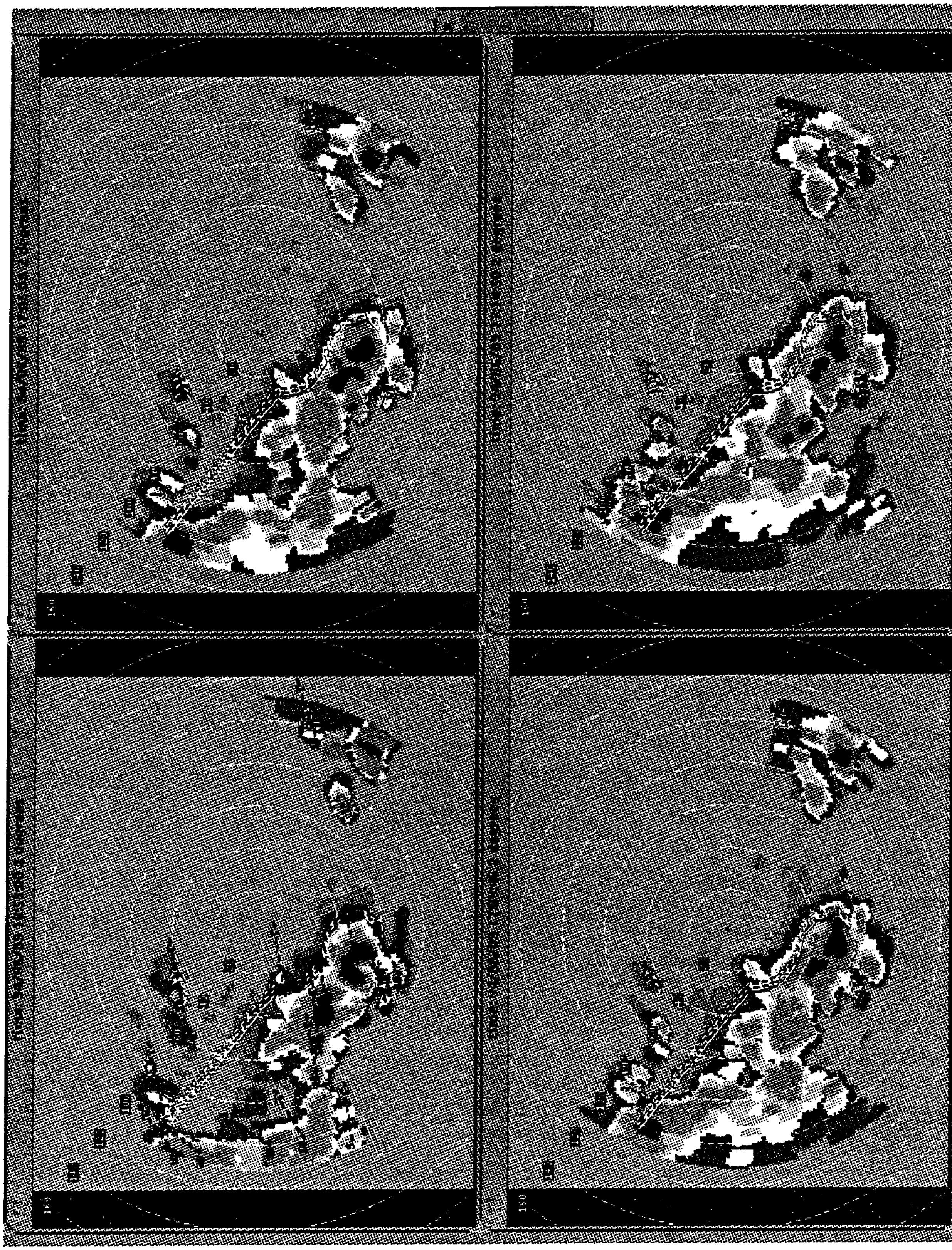
B.3 Storm Motion

In order to evaluate the data for the storm motion product four-panel plots were generated from a time history of storm cells. A sample data plot used in the evaluation of the Storm Motion product is shown in Figure B-4. The top left panel on the plot contains the current precipitation product along with the storm motion (arrow and numeric showing direction and speed) for each significant storm. The other panels contain data related to the Storm Extrapolated Position product (see section B.4), and are not relevant to the current discussion. The plots were updated approximately once every two minutes.

The location of each storm cell shown in the top left panel of each plot was compared visually with the location of the corresponding storm cell in successive plots. From these comparisons, determination of motion for each cell was made. A check for consistency of direction was made with the extrapolated leading edge positions, where possible.

Data for the evaluation of the storm motion product were taken from:

Memphis	6/9/94	1611-1741 UTC



Shows evaluation data for storm motion and extrapolated position products.

FIGURE B-4. DATA PLOT, JUNE 9, 1994, 165500 UTC, MEMPHIS, TN.

B.4 Storm Extrapolated Position

The plots used to evaluate the SEP product (an example plot is shown in Figure B-4) contained four panels:

1) A combination of the current precipitation product with SEP leading edges (depicted in blue) and the current storm motion product (arrows and numeric characters) (upper left panel);

2) The precipitation product for ten minutes later overlaid with the original projected leading edges (upper right);

3) The precipitation product for 15 minutes later overlaid with the original projected leading edges (this panel was not used in the analysis) (lower left);

4) The precipitation product for 20 minutes later overlaid with the original projected leading edges (lower right).

One plot was provided for each update, which occurred about once every two minutes.

For each plot, the first panel was examined to determine if the initial SEP leading edge for each precipitation cell corresponded with the actual leading edge of the cell. Then the projected edges were checked to determine consistency with the storm motion direction and speed. Next, the second panel was examined to determine how well the SEP ten-minute projected location for each cell corresponded with the actual location of the cell leading edge ten minutes later. The fourth panel was examined in like manner to determine how well the SEP 20-minute projected location for each cell corresponded with the actual location of the cell leading edge 20 minutes later.

Data for the evaluation of the storm extrapolated position product were taken from:

Memphis	6/9/94	1611-1741 UTC

The probabilities in Table 8 were computed as follows:

P_{CEI} = Number of hits / Number of extrapolations

P_{CEE} = Number of hits / (Number of extrapolations - Number affected by evolution)

P_{EA} = Number affected by evolution / Number of extrapolations

Figure B-4 shows the data plot for June 9 at 165500 (upper left panel). At this time, there was a straight solid blue line about 80 km long representing a "leading edge." This line was not following the level three edge of any storm on the plot. For this reason, any extrapolations based on this "leading edge" were considered to be erroneous. The SEP product continued from that time to generate erroneous extrapolations based on similar "leading edges." These erroneous extrapolations account for the number of misses shown in Table 8. An algorithm change, implemented after the demonstration in Memphis and for the demonstration in Orlando, prevented these erroneous edges from occurring. This will be evaluated during future prototype operations.

Figure B-4 also shows examples of storm cell growth, decay, and merging. The small level three cell located at coordinates (330 degrees, 47 km) at 165500 decayed to level two by 170508 (upper right panel in Figure B-4) and to level one by 171450 (lower right panel in Figure B-4).

Between 20 and 60 km south of the airport there was an example of cell growth. The solid blue line for this cell (with two level 5 cores) at 165500 (Figure B-4) followed the leading edge (level three) very closely. As time progressed, the edge of the level three contour expanded beyond the extrapolated positions. At 171450 (lower right panel), almost 20 minutes later, the actual leading edge was 2-15 km beyond the 20 minute extrapolation.

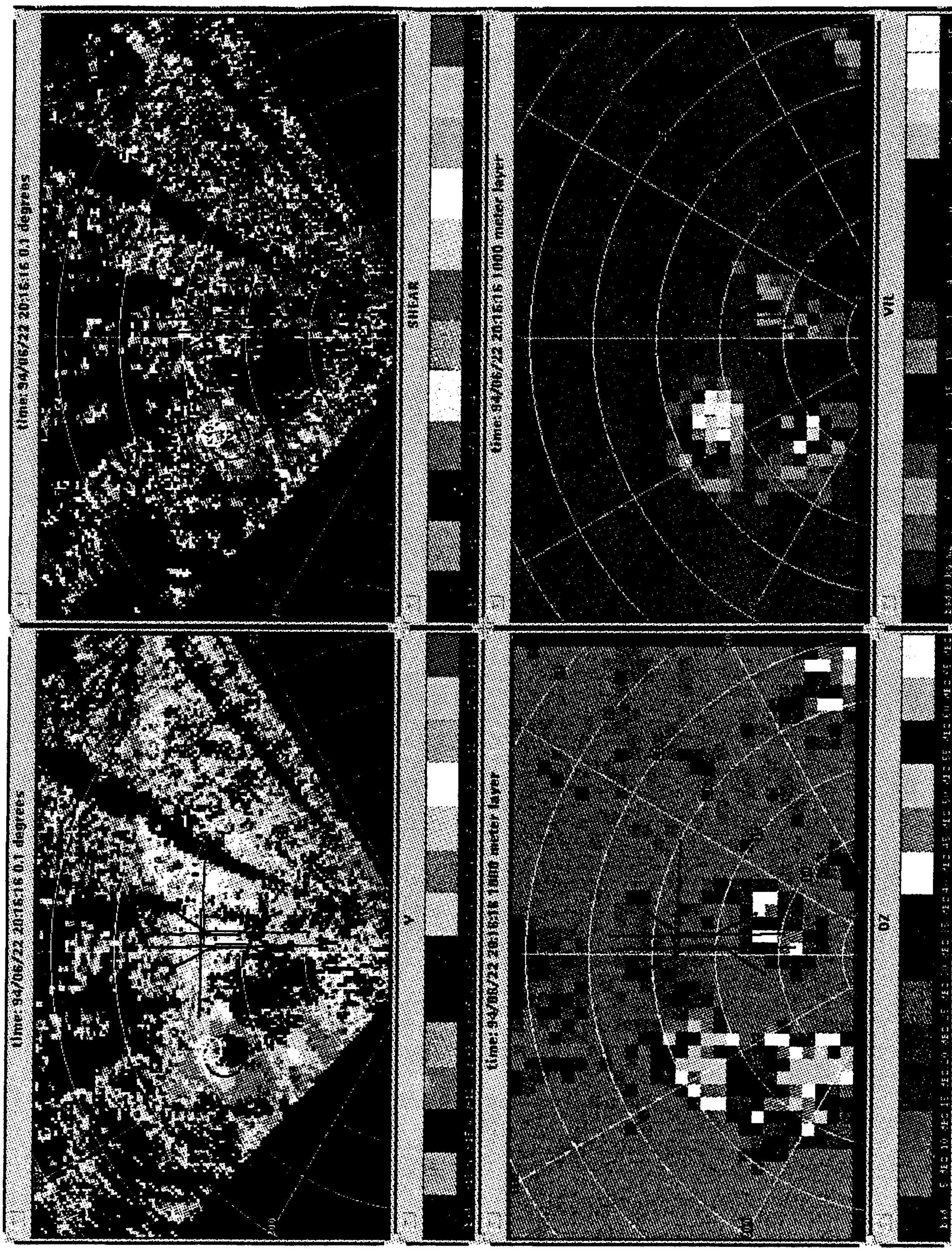
At 165500 (Figure B-4), there was an example of cell merging. Consider the storm cell at (200,52). By 171450 (lower right panel), this cell had merged with the large cell to its northeast.

B.5 Microburst/Windshear Detection

To aid in the evaluation of this product, MIT/LL provided color maps of TDWR base velocity at 0.1 degrees elevation; shear at 0.1 degrees elevation calculated from the TDWR base velocity; TDWR base reflectivity adjusted to the 1000 meter layer; and vertically integrated liquid (VIL) derived from TDWR and MCARS base data, also in the 1000 meter layer. An example plot is depicted in Figure B-5.

The TDWR performed sector scans that covered the airport (e.g., 315 to 45 degrees) at a typical elevation of 0.1 degrees. The microburst product was applied over this sector. The detection range for the product was set at 35 km. The maps provided by MIT/LL covered only this sector and range.

Detected and predicted windshear shapes were superimposed in red and white, respectively, on the base velocity and shear plots. These maps were updated approximately once each minute, the same update rate as the TDWR.



Shows evaluation data for microburst detection and microburst prediction products. Red shapes are detections and white shapes are predictions.

FIGURE B-6. DATA PLOT, JULY 26, 1994, 193334 UTC, ORLANDO, FL.

These data plots were analyzed as follows: The shear map was examined for areas of strong shear (>4 X 10^{-3} sec^{-1}). Then the velocity map was examined in and near the strong shear regions for radial velocity differences of 7.5 m/sec (15 kt) or greater (up to 15 m/sec (30 kt)) for minimal windshears, and 15 m/sec (30 kt) or greater for microbursts.

Qualified regions were subjected to a test for adequate VIL. The VIL map was examined for values in excess of three kg/m^2 for Memphis and five kg/m^2 for Orlando within 1.5 km of the region perimeter. Only those prospective velocity/shear features that could be associated with these VIL values were identified as truth. These features constituted the truth set used in evaluating the performance of the microburst detection and prediction products.

The following data were used in the evaluation of the microburst/windshear detection product:

Memphis	6/3/94	2110-2220 UTC
"	6/22/94	2000-2045
"	7/4/94	1840-1940
Orlando	7/28/94	1835-1915
"	8/9/94	1945-2120
"	8/15/94	2010-2040

B.6 Microburst Prediction

The plots used to evaluate the microburst/windshear detection product were also used in evaluating the microburst prediction product. Figure B-5 contains an example plot.

Events verified in the microburst detection product analysis were used as truth for verifying the prediction product. (There were no missed detections for the examined data set, see sections 5.2.6.7 and B.5).

MIT/LL product literature indicated that the prediction product does not predict events on the edges of data (within three degrees in azimuth or five kilometers in range). The range for predictable events was 5-30 km, whereas the range for detectable events was 0-35 km. Events outside the predictable event area were removed from the truth set.

For each microburst, plots as early as nine minutes prior to a microburst occurrence were checked for predictions. If one or more predictions were found, then the microburst was considered to have been predicted. The prediction must have overlapped or been within one kilometer of the microburst.

B.7 Gust Front Detection

Plots used in the evaluation depicted two panels:

1) TDWR base velocity at 0.3 degree tilts to a range of 60 km;

and

2) TDWR base reflectivity.

These plots were provided at five minute intervals. An example plot is shown in Figure B-6. On the plots, detected gust fronts are represented by white lines superimposed on the base data.

Data analysis for the gust front product proceeded as follows: Each plot was examined for gust fronts. This involved searching for "thin lines" in the reflectivity data and convergence lines in the velocity data. Each analyst determined truth gust front was outlined in red on both panels.

Probabilities of detection (P_{DL}) and false alarm (P_{FAL}), based on length, were computed as follows:

P_{DL} = sum [lengths of detected front segments determined to be hits] /
sum [lengths of truth fronts]

P_{FAL} = sum [lengths of detections determined to be false] /
(sum [lengths of detected front segments determined to be hits] +
sum [lengths of detections determined to be false])

Summations apply to the entire data set.

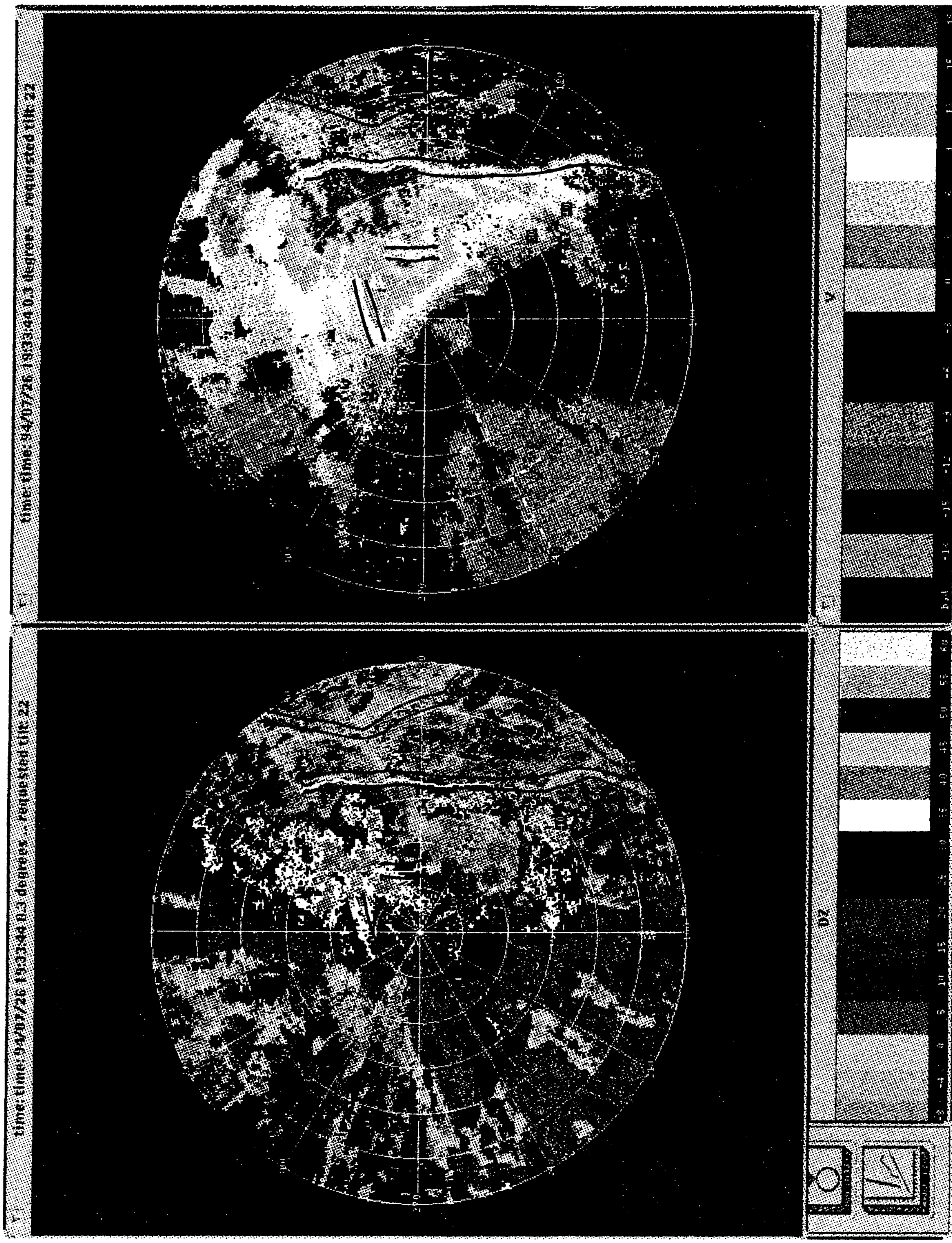
Data used in evaluating the gust front detection product were:

Orlando	7/26/94	1826-1933 UTC
"	7/27/94	1941-2035
"	8/9/94	1948-2101
"	8/11/94	1731-1810
"	8/13/94	1759-1931
"	8/14/94	2017-2051

B.8 Terminal Winds

For the evaluation, MIT/LL provided three different plots:

1) Gridded terminal winds arrows superimposed on a color coded NEXRAD base velocity map;



Shows evaluation data for gust front product. White lines are product detections. Red lines enclose truth gust fronts.

FIGURE B-6. DATA PLOT, JULY 26, 1994, 193334 UTC, ORLANDO, FL.

2) Arrows superimposed on a NEXRAD base reflectivity map;

and

3) Arrows superimposed on a TDWR base velocity map.

The grid was 120 X 120 km^2, with winds spaced 4 km apart horizontally. Three levels were provided: 1800, 6400, and 12000 feet. Updates were every 15 minutes. An example plot with NEXRAD data and superimposed gridded terminal winds arrows is shown in Figure B-7.

According to MIT/LL, aircraft winds and timely MAPS forecasts were not available. Also, the actual winds at each gate that appeared on the GSD were not provided.

The analysis for the terminal winds product involved visual examination of the two velocity plots to determine the degree of correlation between the gridded winds and the radar base velocities. Reflectivity was examined to determine the validity of the base velocity.

For the terminal winds product evaluation, the following data were analyzed:

Memphis	6/3/94	1700-1800 UTC
"	6/9/94	1815-2000
"	6/17/94	2100-2200

B.9 Storm Cell Information

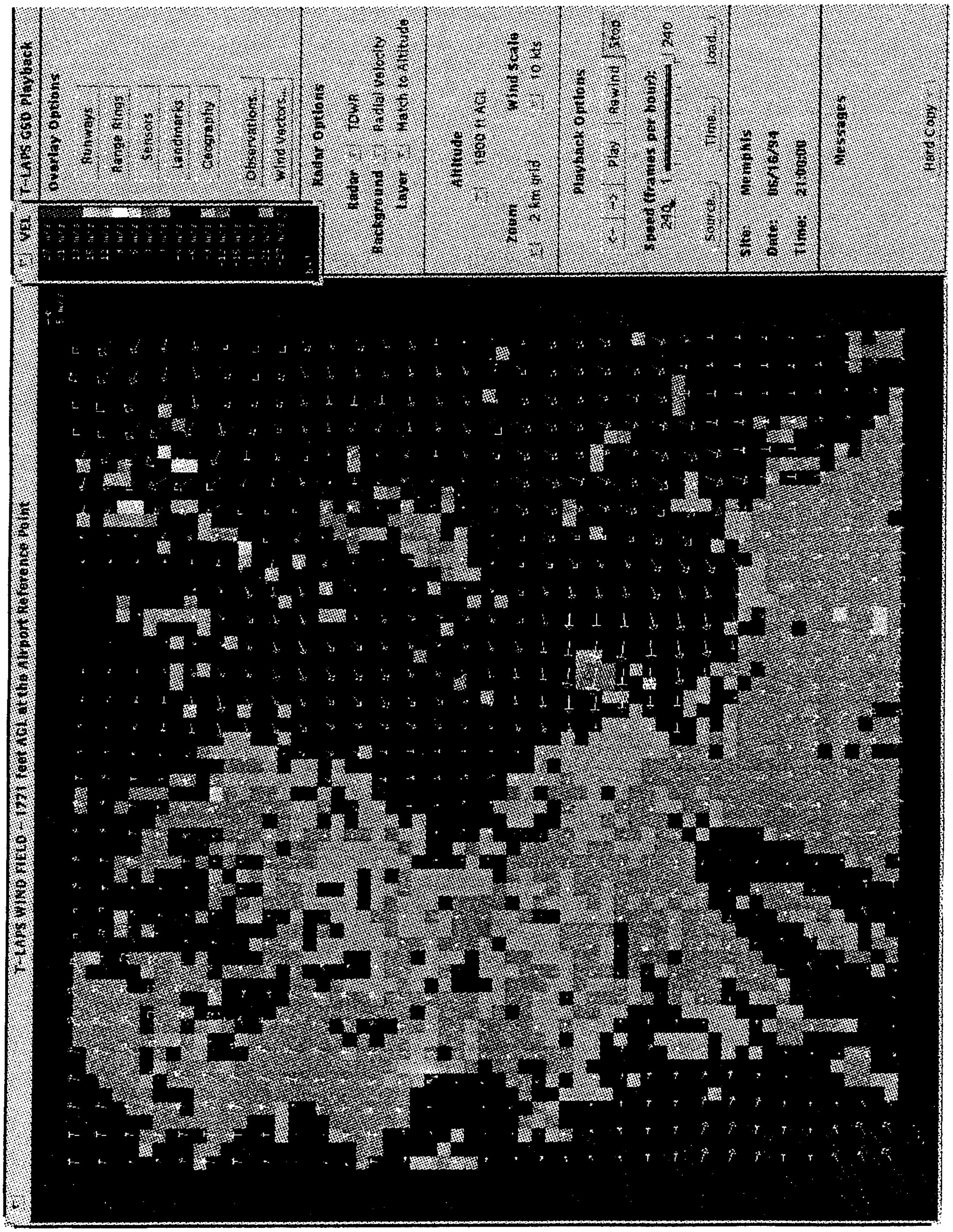
The Storm Cell Information (SCI) product associates attributes with individual storm cells. These attributes are hail, lightning, mesocyclone, and echo tops. Section B.9.1 contains discussion relative to product performance in associating cells and attributes. Section B.9.2 contain discussions related to hail detection performance analysis.

B.9.1 Attribute-to-Cell Association

MIT/LL provided a sequence of plots (an example plot is provided in Figure B-8), each containing four panels:

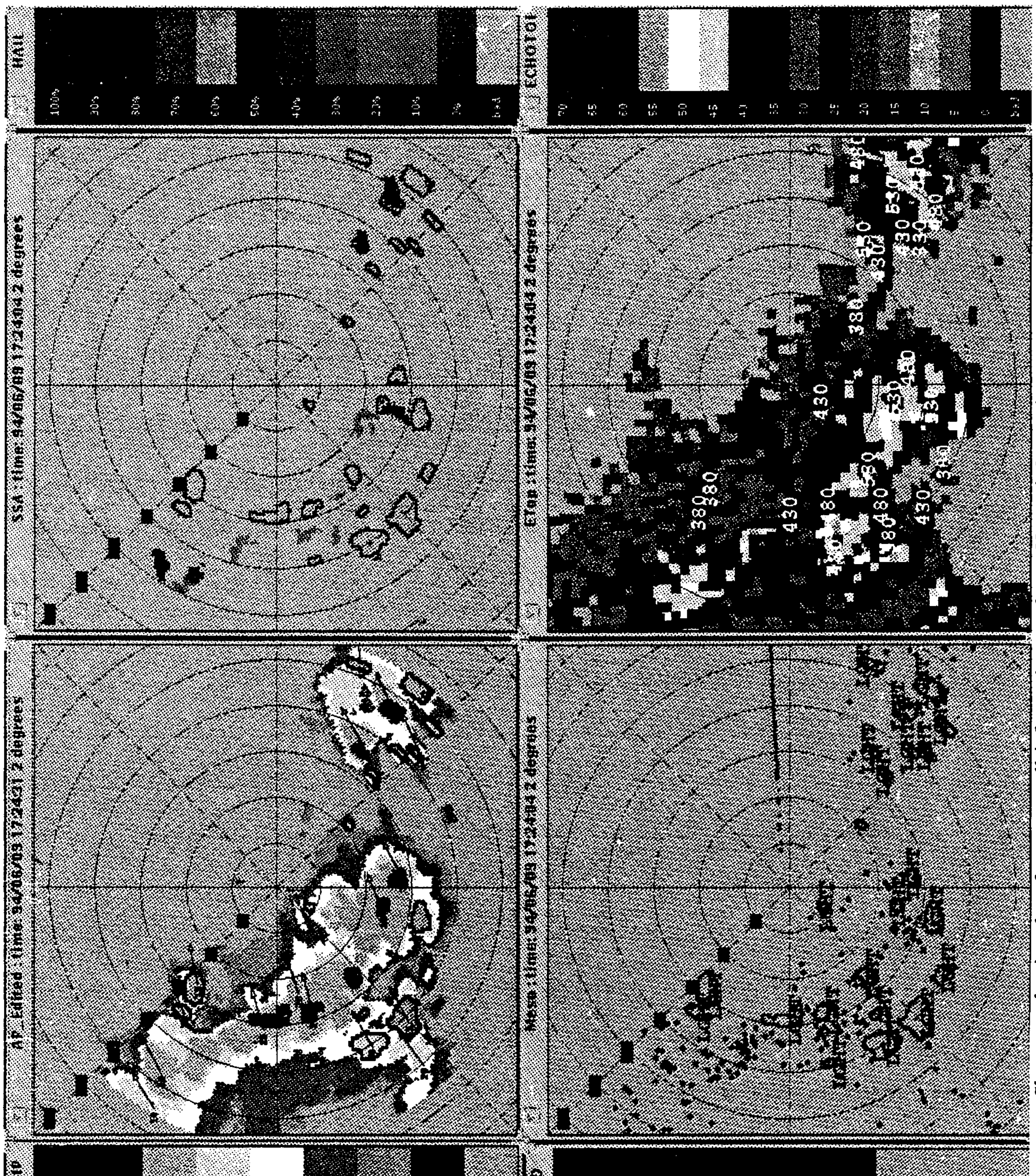
1) AP-edited precipitation map with cell contours (upper left panel);

2) Hail probability map with cell contours (upper right);



Shows evaluation data for terminal winds product. Plot depicts product wind field at 1800 feet AGL; NEXRAD base velocity map is in background.

FIGURE B-7. DATA PLOT, JUNE 16, 1994, 210000 UTC, MEMPHIS, TN.



Shows evaluation data for storm cell information product. Upper left panel contains contoured storm cells overlaid on AP edited precipitation. Upper right contains hail probability map overlaid with storm cell contours. Lower left shows the lightning flash map and lower right the echo top map, both overlaid with storm contours.

FIGURE B-8. DATA PLOT, JUNE 9, 1994, 172404 UTC, MEMPHIS, TN.

3) Lightning flashes and mesocyclone map with cell contours (lower left);

and

4) Echo tops map with cell contours (lower right).

Each map was overlaid with contours (outlines) of the highest level reflectivity in each significant storm cell. These plots were updated about once each minute.

The AP-edited precipitation map with overlaid cell contours was examined for correspondence between the contours and actual cell boundaries. The other maps were checked for correct associations between the contoured cells and attributes. A probability of severe hail (POSH) of 50 percent or higher (color coded to the right of the hail map) was necessary for hail detection and hail attribute-to-cell association. The association algorithm required that an ITWS detection be within the cell contour in order for the detection to be associated with the cell.

Hail. There were hail product detections, and these detections were associated with cells. However, some detections were outside the contours. An example of this is shown in Figure B-8, in the hail probability map in the upper right panel (time: 172404). An area of POSH between 50 and 60 percent is evident in the hail probability map, but there is no cell with which to associate it. This POSH area is at coordinates (305,92), where the first coordinate is the azimuth relative to the airport center in degrees, and the second coordinate is the range from the airport center in kilometers.

There was also no association in the next update, 172459, shown in Figure B-9. An association was not made until the following update, 172745, when a contoured cell appeared and encompassed the POSH area (see Figure B-10). There was no hail alert for this POSH area for almost three minutes.

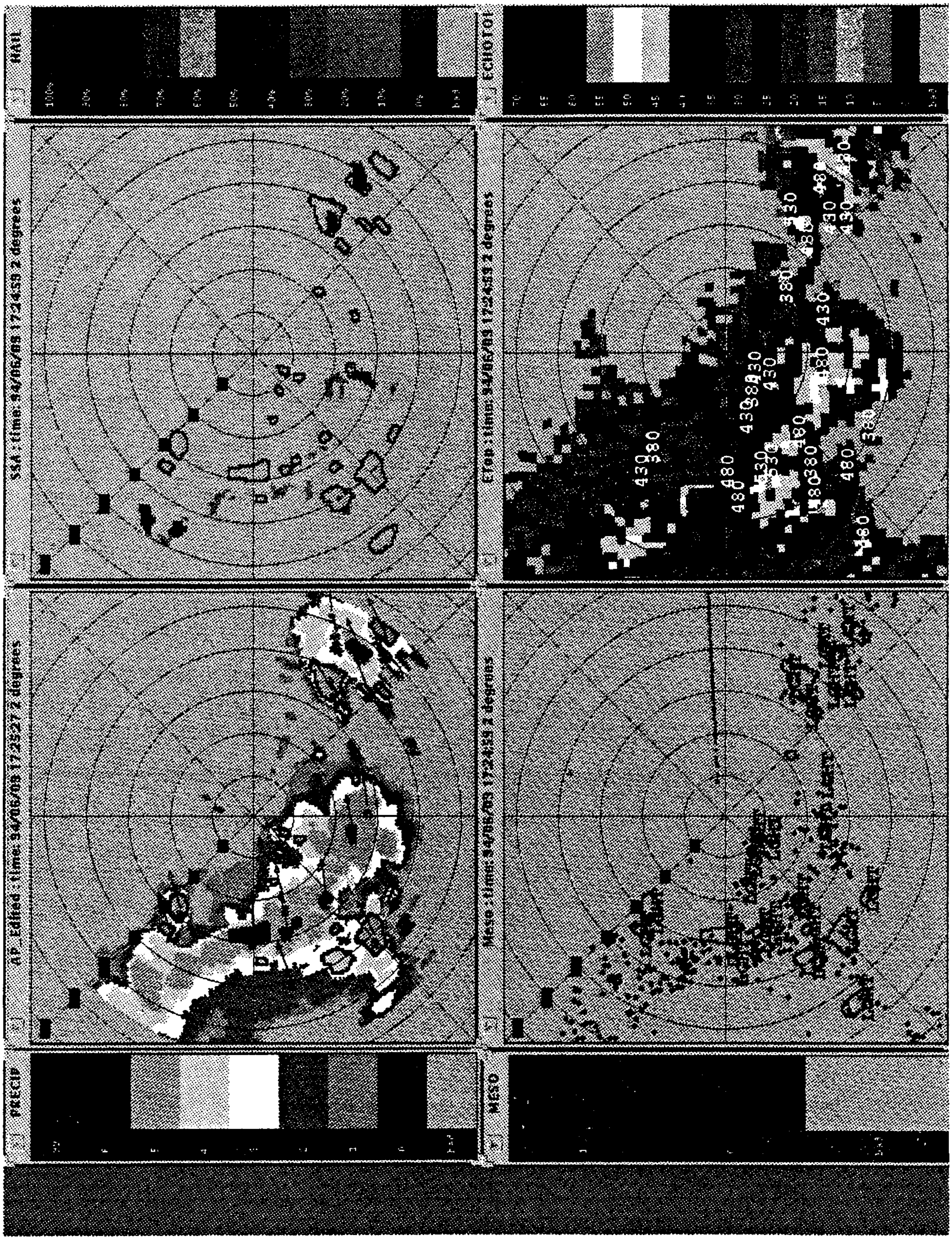


FIGURE B-9. SAME AS FIG. B-8, EXCEPT 172459 UTC

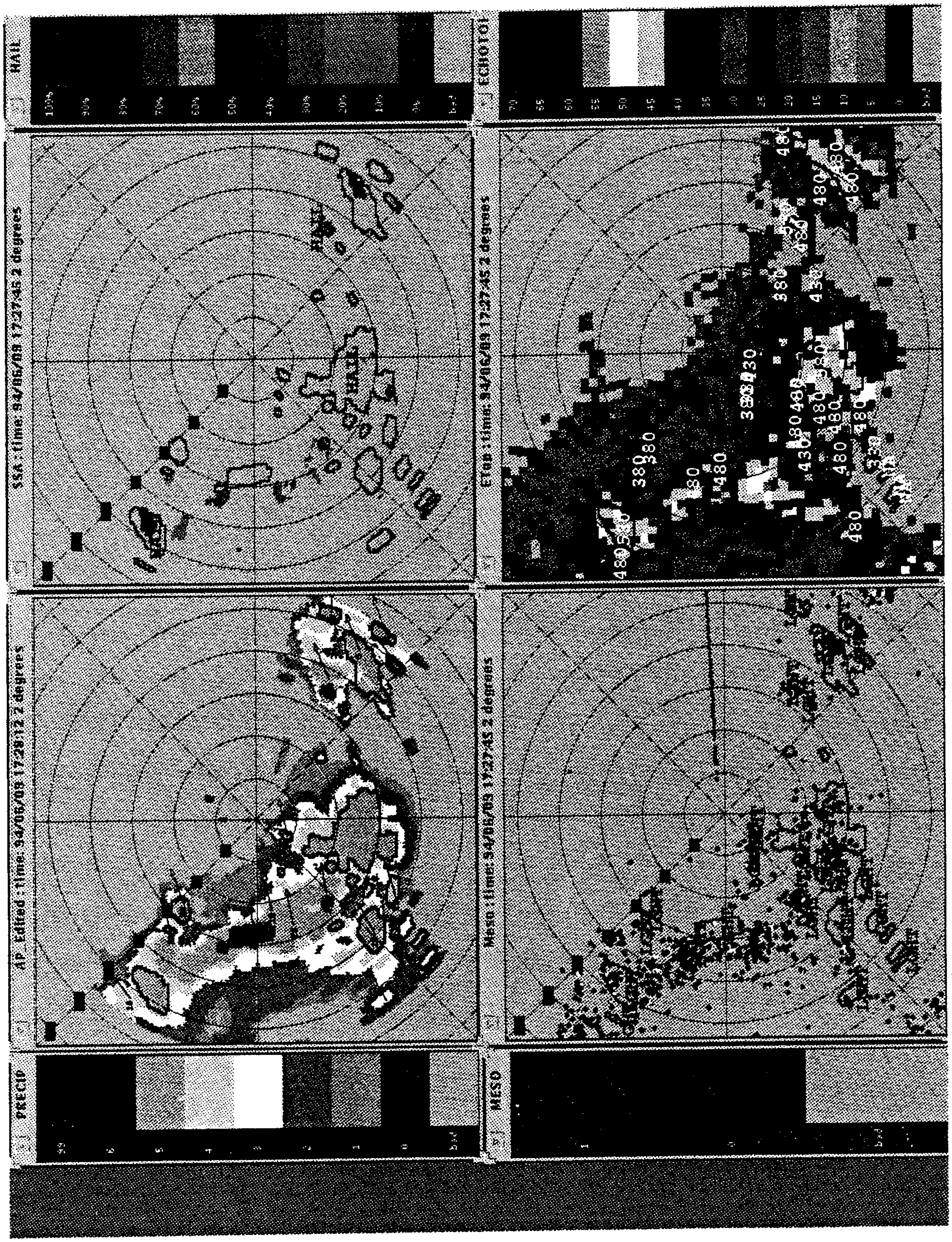


FIGURE B-10. SAME AS FIG. B-8, EXCEPT 172745 UTC

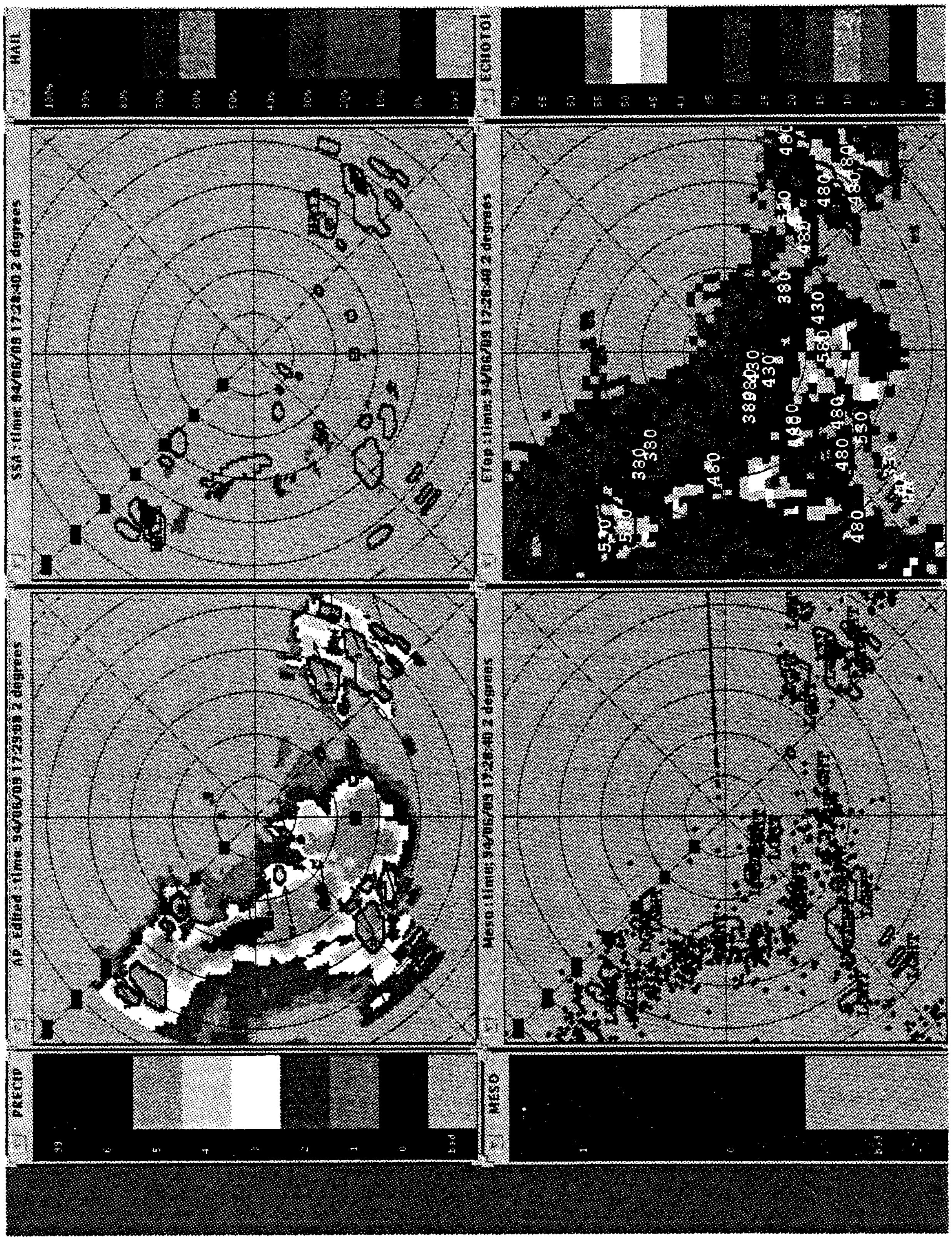


FIGURE B-11. SAME AS FIG. B-8, EXCEPT 172840 UTC.

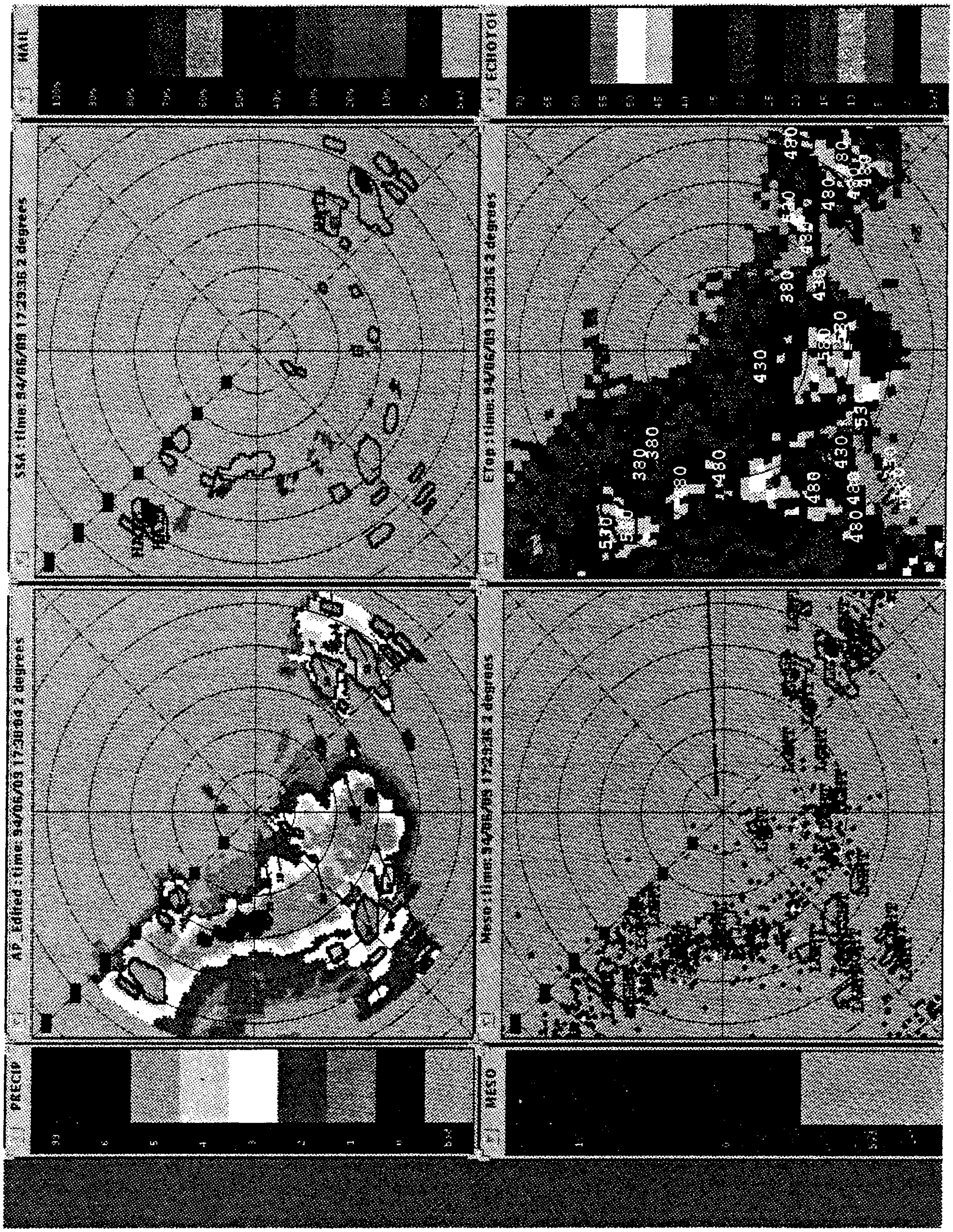


FIGURE B-12. SAME AS FIG. B-8, EXCEPT 172936 UTC

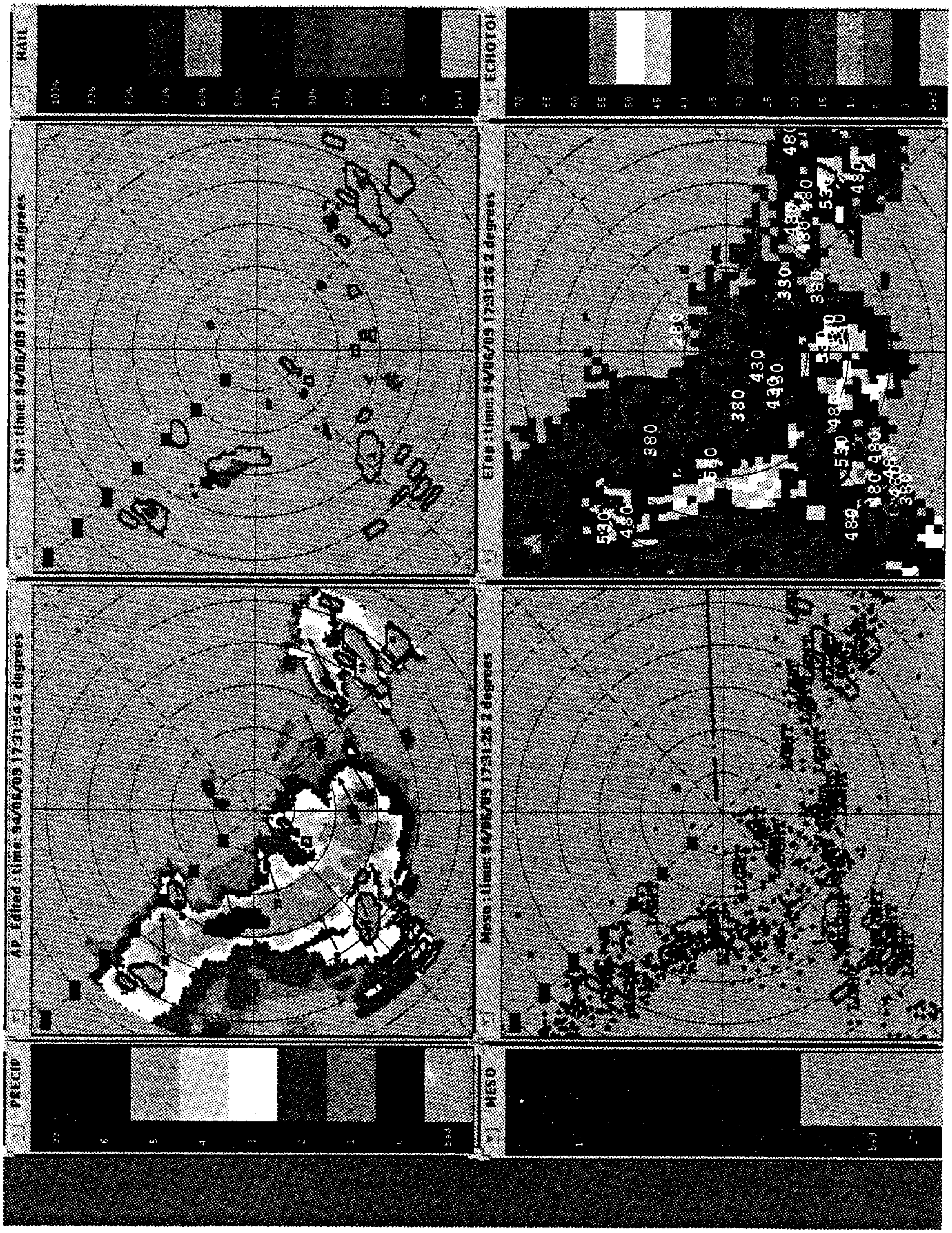


FIGURE B-13. SAME AS FIG. B-8, EXCEPT 173126 UTC

A second example may be seen at 172745 (see Figure B-10). An area of 50-60 percent POSH was located at (195,70), at the south end of a large level five cell with the hail attribute. In the next update, 172840 (Figure B-11), the level five cell developed a small core of level six. The contour around the level five cell was dropped in favor of a contour around the small level six core. Further examination of Figure B-11 indicated that the POSH area did not move or decrease, but yet was no longer associated with a cell. The next update at 172936 (Figure B-12), is similar, and also without an association. The following update (the NEXRAD also updated in the interim) at 173126 (Figure B-13), showed the POSH area with an increase in areal extent and POSH of 60-70 percent. However, there was still no association. An association was made at 173154, when another contoured cell appeared and overlapped the POSH area. Again, there was no hail alert for three minutes.

Mesocyclone. Mesocyclone detections at 175309 and 175404, location (280,35), were not associated with any cell. In fact, there were no contoured cells nearby. Other mesocyclone detections at 175309 and 175404, location (225,70); and at 175213, location (205,70) also were not associated with a contoured cell.

Echo Tops. An example of a 58000 ft echo top that was not associated with a contoured cell is shown in Figure B-10. The coordinates of the 58000 ft echo top are (252,65). The nearest contoured cells to the southeast and northeast were indicating echo tops of only 48000 ft. Comparing the ASR-9 precipitation with the echo top map indicates that the area of highest echo tops is offset to the west from the contoured area of highest precipitation level. Other examples of missed associations of 58000 ft echo top maxima occurred at 173126 at coordinates (220,88) and (195,55) (Figure B-13). The nearest contoured cells contained maximum echo tops of 53000 ft. Again, neither was associated with a cell.

B.9.2 Hail Detection

In order to evaluate the hail product, ACW-200 obtained lists of hail detections prepared by MIT/LL from demonstration data. These lists provided occurrence times and locations in rectangular coordinates (x,y) and kilometers relative to the NEXRAD. ACW-200 also obtained severe storm data from the NWS. These severe storm data are a compilation of public and official reports of severe weather sightings, including those of hail 0.75 inches or larger on the ground. It was these hail sizes that the NSSL hail product was, according to NSSL, designed to detect.

The NWS reports were the only truth available for verifying the detection capability of the hail product. There were, no doubt, cases for which severe hail was detected by ITWS and reached the ground, but was not observed or officially reported. Verifying these types of events would have required many human and automated observers strategically located in the ITWS coverage area, and is beyond the scope and resources of this study.

Analysis for the hail product evaluation proceeded as follows: Rectangular coordinates (x,y) in kilometers of each NWS hail event location relative to NEXRAD were determined from US Army Corps of Engineers 1:250,000 topographical maps. These coordinates were compared with those of the product hail detections. Searches of from one hour before to an hour after the NWS event time were made to find corresponding hail detections.

For the hail detection product, these data were analyzed:

Memphis	6/5/94
"	6/9/94
"	6/12/94
"	6/26/94
"	6/28/94

A list of all NWS compiled hail siting reports for the Memphis demonstration coverage area in June 1994 is contained in table B-1. Table B-2 shows detections by the hail product that correspond to the NWS hail siting reports. These hail product detections were taken from a list of all hail product detections compiled by MIT/LL for the hail product.

TABLE B-1. National Weather Service Hail Sightings in Memphis ITWS Coverage Area During the Demonstration (June 1994).

Event #	Date	Location	Time (UTC)	Hail Size
1	6/5	Horseshoe Lake, AR	1945	1.75
2	6/5	Walcott, AR	2300	0.75
3	6/9	Savage, MS	1658	1.00
4	6/9	Batesville, MS	1720	1.00
5	6/9	Covington, TN	1820	0.75
6	6/9	Memphis, TN	1840	1.00
7	6/9	Belen, MS	1815	0.75
8	6/9	Potts Camp, MS	1830	0.75
9	6/12	Caldwell, AR	2230	0.75
10	6/26	Cash, AR	1010	1.00
11	6/26	Harrisburg, AR	1100	0.88
12	6/26	Wynne, AR	1147	1.00
13	6/26	Parkin, AR	1153	1.75
14	6/26	Forrest City, AR	1201	0.75
15	6/26	Brighton, TN	1301	0.75
16	6/26	Bradford, TN	2230	1.75
17	6/26	Nutbush, TN	2303	0.75
18	6/26	Brownsville, TN	2355	1.75
19	6/28	Monette, AR	1305	0.75
20	6/28	Osceola, AR	1327	0.75
21	6/28	Wilson, AR	1358	0.88
22	6/28	Memphis, TN	1425	1.00

TABLE B-2. Product Detected Hail Events Corresponding to NWS Sightings in Memphis ITWS Coverage Area (June 1994)

NWS Event #	NWS Event Location (x,y) km from NEXRAD	Product Event Location (x,y) km from NEXRAD	Time (UTC)
1	(-42,-50)	(-46,-49)	1859
2	(-78,78)	(-76,82)	2303
3	(-33,-87)	(-31,-78)	1654
4	(-10,-118)	(-13,-114)	1812
5	(20,21)	No corresponding detection	
6	(Memphis)	No corresponding detection	
7	(-47,-123)	(-40,-117)	1753
8	(50,-85)	(46,-95)	1753
9	(-91,-35)	(-80,-33)	2214
10	(-102,48)	(-103,49)	1018
11	(-83,20)	(-88,18)	1108
12	(-90,-17)	(-87,-17)	1143
13	(-67,-12)	(-79,-14)	1138
14	(-88,-40)	(-76,-36)	1158
15	(12,13)	(6,25)	1238
16	(100,82)	(90,80)	2222
17	(43,38)	(37,31)	2252
18	(56,26)	(49,21)	2326
19	(-47,60)	ITWS not operational	
20	(-13,38)	ITWS not operational	
21	(-25,23)	ITWS not operational	
22	(Memphis)	(1,-29)	1424

B.10 Tornado

MIT/LL provided a list of product detected tornadoes along with event dates, times, and locations. They also provided another list with analyst determined truth events. These truth events were determined by examining base TDWR and NEXRAD velocity data for tornado signatures.

The tornado data were analyzed by reviewing MIT/LL's analysis, determining the number of hits, misses, and false detections, and computing the P_D and P_{FA} for the data set.

The tornado product was evaluated using these data:

Memphis	6/8/94
"	6/9/94
"	6/26/94
"	6/27/94

B.11 Terminal Weather Text Message

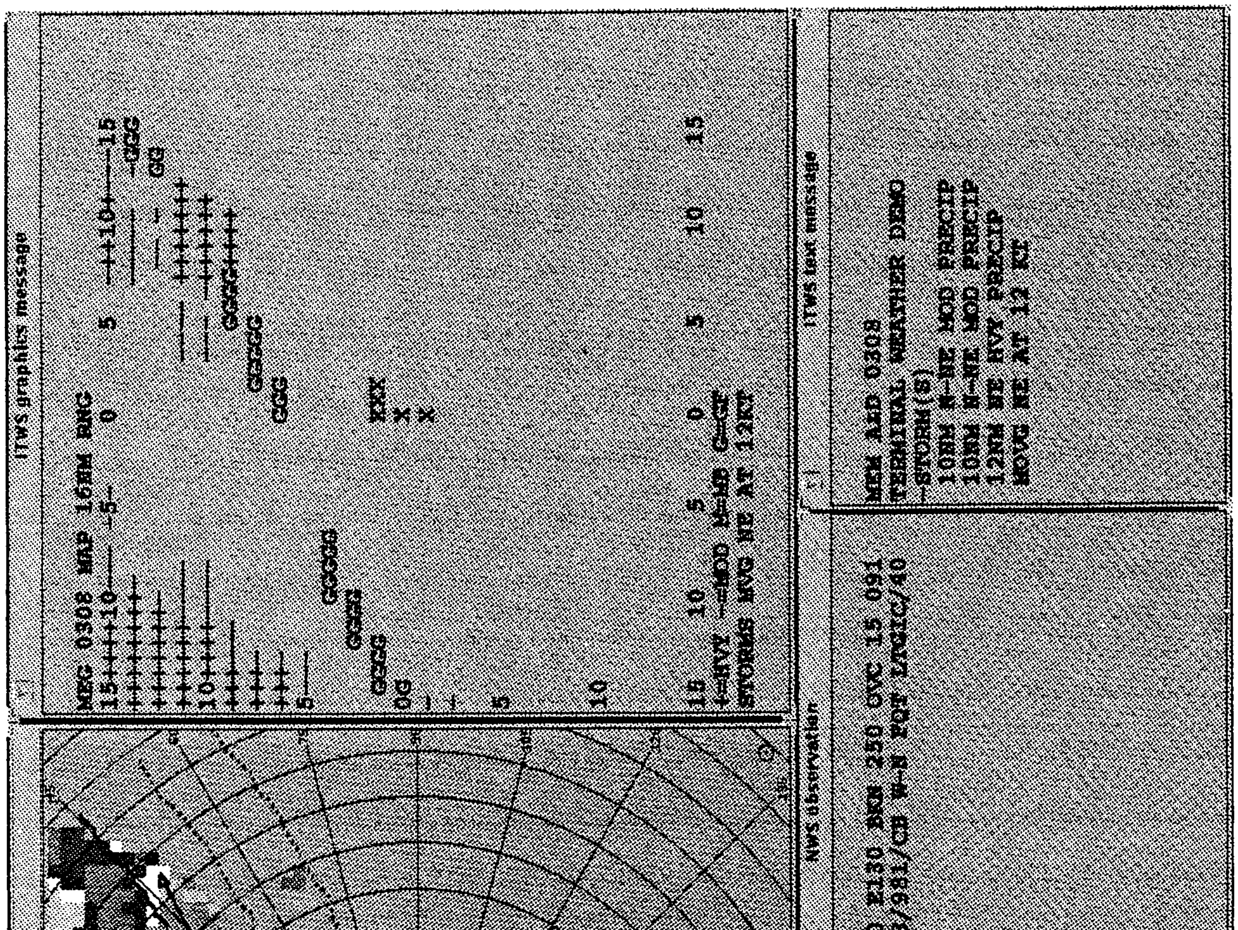
For the evaluation of this product, MIT/LL provided color plots showing the ITWS GSD display out to 16 nm in range, along with the ITWS graphics message, RDT display, terminal text message, and corresponding NWS observation. The plots were updated every five minutes. An example plot is depicted in Figure B-14.

For each plot, the information in the terminal text message was compared with the graphical information on the GSD for consistency.

The terminal weather text message product was evaluated using the following data:

Memphis	6/7/94	0308-0625 UTC

This appendix contains details of the analyses and analysis methods used to obtain the results presented in the meteorological performance evaluation section, section 5.2.6.



Shows evaluation data for terminal weather text message product.

FIGURE B-14. DATA PLOT, JUNE 7, 1994, 0308 UTC, MEMPHIS, TN.

APPENDIX C

INTEGRATED TERMINAL WEATHER SYSTEM OPERATION MEMPHIS DEMVAL 1994

Integrated Terminal Weather System Operation
Memphis DEMVAL 1994

DATE	ITWS OPERATION	TDWR OPERATION	NEXRAD OPERATION	ASR-9 OPERATION
5/23	1700 - 0000	DOWN	1700 - 0000	1700 - 0000
5/24	1710 - 0011	DOWN	1710 - 0011	1710 - 0011
5/25	1721 - 0132	1721 - 0132	1721 - 0132	1721 - 0132
5/26	0857 - 1400, 1700 - 0000	0857 - 1112, DOWN	0857 - 1044, 1700 - 0000	0857 - 1400, 1700 - 0000
5/27	1700 - 0000	1700 - 0000	1700 - 0000	1700 - 0000
5/30	1410 - 0338	DOWN	1410 - 0338	1410 - 0338
5/31	1701 - 0000	1701 - 0000	1701 - 2105, 2305 - 0000	1701 - 0000
6/1	1701 - 0000	1701 - 0000	1949 - 0000	1701 - 0000
6/2	1700 - 0408	1700 - 0408	1700 - 0408	1700 - 0408
6/3	1700 - 0014	1700 - 0014	1700 - 0014	1700 - 0014
6/4	1700 - 0003	1700 - 0003	1700 - 0003	1700 - 0003
6/5	1700 - 0115	1700 - 0115	1700 - 0115	1700 - 0115
6/6	1700 - 1300	1700 - 1300	1700 - 1036	1700 - 1300
6/7	1600 - 0003	1600 - 1953	1600 - 0003	1600 - 0003
6/8	1633 - 2330	1633 - 2330	1633 - 2330	1633 - 2330
6/9	1225 - 0000	1225 - 0000	1225 - 0000	1225 - 0000
6/10	1700 - 0000	1700 - 0000	1700 - 0000	1700 - 0000
6/12	2225 - 0200	2225 - 0200	2225 - 0200	2225 - 0200
6/13	1600 - 0002	1600 - 0002	1730 - 0002	1600 - 0002
6/14	1705 - 0005	1705 - 2300	1705 - 0005	1705 - 0005
6/15	1658 - 0001	1658 - 0001	1658 - 0001	1658 - 0001
6/16	1658 - 0142	1658 - 0142*	1658 - 0142	1658 - 0142
6/17	1700 - 0125	1700 - 0125	1700 - 0125	1700 - 0125
6/18	1823 - 0130	1823 - 0130	1823 - 0130	1823 - 0130
6/19	1615 - 0100	1615 - 0100	1615 - 0100	1615 - 0100
6/20	1700 - 0007	1700 - 0007	1700 - 2152, 2220 - 0007	1700 - 0007
6/21	1700 - 0102	1700 - 0102	1700 - 0102	1700 - 0102
6/22	1700 - 0001	1700 - 0001	1700 - 0001	1700 - 0001
6/23	1630 - 0003	1630 - 0003	1630 - 2110, 2137 - 0003	1630 - 0003
6/24	0654 - 1315, 1700 - 2300	0654 - 1315, 1700 - 2300	0654 - 1131, 1200 - 1315, 1700 - 2300	0654 - 1315, 1700 - 2300
6/26	1109 - 0705	1109 - 0705	1109 - 1642, 1800 - 0705	1109 - 0705
6/27	1708 - 0056	1708 - 0056	1708 - 0056	1708 - 0056
6/28	1335 - 0420	1335 - 0420	1335 - 0420	1335 - 0420
6/29	1058 - 0030	1058 - 1830, 1954 - 0030	1058 - 0030	1058 - 0030
6/30	1531 - 0326	1531 - 0326	1531 - 0326	1531 - 0326
7/1	1700 - 0004	1700 - 0004	1700 - 0004	1700 - 0004

7/2	0045 - 1630, 2330 - 0539	0045 - 1630, 2358 - 0539	0045 - 1630, 2330 - 0539	0045 - 1630, 2330 - 0539
7/3	1246 - 0346	1246 - 0346	1246 - 0346	1246 - 0346
7/4	1700 - 0000	1700 - 0000	1700 - 0000	1700 - 0000
7/5	1645 - 0253	1645 - 0253	1645 - 0253	1645 - 0253
7/6	1708 - 0034	1708 - 1942, 2026 - 0034	1708 - 0034	1708 - 0034
7/7	1700 - 0050	1700 - 0050	1700 - 0050	1700 - 0050
7/8	1225 - 0014	1225 - 0014	1225 - 2014, 2025 - 0014	1225 - 0014
7/9	1609 - 2250	1609 - 1735, 1808 - 2250	1609 - 2250	1609 - 2250
7/11	1638 - 0256	1638 - 0256	1638 - 0256	1638 - 0256
7/12	1454 - 0304	1454 - 1630	1454 - 0304	1454 - 0304
7/13	1150 - 0000	DOWN	1150 - 0000	1150 - 0000
7/14	1310 - 1429, 1700 - 0500	DOWN	1310 - 1429, 1700 - 0500	1310 - 1429, 1700 - 0500
7/15	1612 - 0310	DOWN	1612 - 0310	1612 - 0310
7/16	1225 - 0014	DOWN	1225 - 2014	1225 - 0014
7/17	2140 - 0240	DOWN	2140 - 0240	2140 - 0240
7/18	1700 - 0000	DOWN	1700 - 0000	1700 - 0000
7/19	1705 - 0000	DOWN	1836 - 0000	1705 - 0000
7/20	1648 - 0000	DOWN	1648 - 0000	1648 - 0000
7/21	1650 - 0558	DOWN	1650 - 0558	1650 - 0558
7/22	1601 - 0025	DOWN	1601 - 0025	1601 - 0025

* TDWR had intermittent failures throughout the operational period due to a problem in the SBC in the servo control unit.

- Number of hours ITWS operational :530hr., 53min.
- Number of hours TDWR available :378hr., 43min.(71%)
- Number of hours NEXRAD available :510hr., 31min.(96%)
- Number of hours ASR-9 available :530hr., 53min.(100%)

- Dates ITWS was not operational : 5/28, 5/29, 6/11, 6/25, 7/10.

The TDWR was not available for thirteen days of the DEMVAL period. No signifiacant weather was observed during six of the days. The dates no events occured are: 5/23, 5/24, 7/13, 7/14, 7/17, 7/18, 7/19.

APPENDIX D

INTEGRATED TERMINAL WEATHER SYSTEM
OPERATION ORLANDO DEMVAL 1994

Integrated Terminal Weather System Operation
Orlando DEMVAL 1994

DATE	ITWS OPERATION	TDWR OPERATION	NEXRAD OPERATION	ASR-9 OPERATION
7/11	1600 - 2301	1600 - 2301	1600 - 2301	1600 - 2301
7/12	1559 - 0157	1559 - 0157	1559 - 0157	1559 - 0157
7/13	1601 - 0218	1601 - 0218	1601 - 1840 1912 - 0218	1601 - 0218
7/14	1556 - 2351	1556 - 2351	1556 - 2351	1556 - 2351
7/15	1600 - 2353	DOWN	1600 - 2353	1600 - 2353
7/16	1723 - 2310	2014 - 2310	1723 - 2310	1723 - 2310
7/17	1741 - 2222	1741 - 2222	1741 - 2222	1741 - 2222
7/18	1557 - 2241	1557 - 2241	1557 - 2241	1557 - 2241
7/19	1506 - 2318	1506 - 2318	1506 - 2318	1506 - 2318
7/20	1553 - 0011	1553 - 0011	1553 - 0011	1553 - 0011
7/21	1538 - 2300	1538 - 2300	1538 - 2300	1538 - 2300
7/22	1557 - 2305	1557 - 2305	1557 - 2305	1557 - 2305
7/23	1733 - 2339	1733 - 2339	1733 - 2106 2128 - 2339	1733 - 2339
7/24	1645 - 2108	1645 - 2008	1645 - 2108	1645 - 2108
7/25	1559 - 2302	1559 - 2302	1559 - 1835	1559 - 2302
7/26	1552 - 2300	1552 - 2300	1552 -2028	1552 - 2300
7/27	1513 - 0001	1513 - 0001	1513 - 0001	1513 - 0001
7/28	1559 - 2307	1559 - 2307	1559 - 2004	1559 - 2307
7/29	1556 - 2300	1556 - 2300	1556 - 1929	1556 - 2300
7/30	1602 - 0122	1602 - 0122	1602 - 0100	1602 - 0122
7/31	1530 - 2324	1530 - 2324	1530 - 2324	1530 - 2324
8/1	1600 - 2300	1600 - 2300	1600 - 1900 1927 - 2300	1600 - 2300
8/2	1523 - 2305	1523 - 2305	1523 - 2305	1523 - 2305
8/3	1555 - 2340	1555 - 2340	1555 - 2340	1555 - 2340
8/4	1556 - 2354	1556 - 2354	1556 - 2354	1556 - 2354
8/5	1559 - 2300	1559 - 2300	1559 - 2300	1559 - 2300
8/6	1640 - 2145	1640 - 2145	1640 - 1818 1906 - 2145	1640 - 2145
8/7	1600 - 2342	1600 - 2342	1600 - 2222	1600 - 2342
8/8	1556 - 2300	1556 - 2300	1556 - 2300	1556 - 2300
8/9	1558 - 2300	1558 - 2217 2234 - 2300	1558 - 2300	1558 - 2300
8/10	1555 - 0031	1555 - 0031	1555 - 0031	1555 - 0031
8/11	1559 - 2232	1559 - 2232	1559 - 2232	1559 - 2232
8/12	1522 - 2301	1522 - 2301	1522 - 2301	1522 - 2301
8/13	1441 - 2119	1441 - 2119	1441 - 2119	1441 - 2119
8/14	1618 - 2218	1618 - 2218	1618 - 2218	1618 - 2218
8/15	1732 - 2303	1732 - 2303	1732 - 2303	1732 - 2303
8/16	1401 - 2305	1401 - 2305	1401 - 2305	1401 - 2305
8/17	1553 - 0009	1553 - 0009	1553 - 0009	1553 - 0009
8/18	1557 - 0021	1557 - 0021	1557 - 0021	1557 - 0021
8/19	1554 - 0152	1554 - 0152	1554 - 0152	1554 - 0152

- Number of hours ITWS operational : 297 hr., 07 min.
- Number of hours TDWR available : 285 hr., 11 min. (96 %)
- Number of hours NEXRAD available : 279 hr., 43 min. (94 %)
- Number of hours ASR-9 available : 297 hr., 07 min. (100 %)