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Terminal Weather Message Demonstration at Orlando, FL, Summer 1993

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4 March 1994

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16. Abstract

A successful demonstration of providing a text-based message via VHF data link (ACARS) was carried out at Orlando, FL during the summer of 1993. Five airlines participated in the three-month demonstration, which included an average of 145 Terminal Weather message requests per day. During a heavily impacted weather day, a total of 220 Terminal Weather requests were made. The format of the Terminal Weather message was developed by an ad hoc committee of pilots, dispatchers, controllers, and researchers. The format required a balance between the need for including important information and the need to fit the information into a limited number of characters. The approach was to divide the message into several blocks and to prioritize the potential meseage elements by importance and immediacy. The most important and timely elements are listed first, and the others appear only if more important elements are not present or were deleted altogether.

Pilot reaction to the demonstration was assessed from questionnaire responses. Overall, pilots thought that the system ahould be deployed operationally and found that it increased situational awareness. They felt that it provided some help in decision making and did not adversely affect cockpit workload. They also strongly endorsed the need for a graphical version of the Terminal Weather service. Controllers were initially concerned that the data link demonstration would result in increased radio traffic and concomitant controller workload. Prior to the demonstration, changes were made in the Terminal Weather meesage format to help allay these concerns. Consequently, controllers-were surprised to find that requests for weather information actually decreased over what they normally would expect during a period of heavy weather impact. Thus, evidence was obtained that delivery of Terminal Weather information by data link could decrease controller workload.

Dispatchers took a strong and unanticipated interest in the Terminal Weather message. The dispatchers for one airline used the Terminal Weather message to monitor weather conditions at Orlando during a period of heavy weather impact. Special meeeagee also were sent to &patchers to alert them when wind shear or microburst hazards initially impacted the Orlando airport.

Additional demonstrations of the Terminal Weather message service are planned for the summer of 1994 at Memphis, TN and Orlando, FL. Results of the summer 1993 demonstration are being used to make improvements to the message content. A demonstration of a graphical version of the Terminal Weather message is also planned.

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The author also wishes to thank his Lincoln collegues for their invaluable assistance. Michael Matthews was tireless in analyzing the message performance from the meteorological point of view and provided nearly all of the performance data shown in this paper. Martin Rooney wrote most of the software used to generate the Terminal Weather message (including all seven formats!). Also, thanks to the crew at the ITWS testbed facility at Orlando for all their efforts.

Finally, the author would like to thank the personnel at the Orlando FAA facility. In particular, he would like to dedicate this paper to the memory of Wendell Owens, who was tragically killed in an automobile accident shortly after the review meeting in September. Although I did not know him for very long, I came to appreciate him as a person and was grateful for his help in organizing the meeting. We all shall miss him.

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1. TEXT-BASED TERMINAL WEATHER DATA LINK

1.1 Introduction

The Federal Aviation Administration (FAA) is supporting a number of programs to upgrade the quantity and quality of terminal weather information. Lincoln Laboratory has been active in developing the Terminal Doppler Weather Radar (TDWR) and the Airport Surveillance Radar-9 (ASR-9) Wind Shear Processor (WSP) systems, both of which detect wind shear hazards in the terminal area. The Laboratory is currently developing the Integrated Terminal Weather System (ITWS) which combines input from multiple sensors (TDWR, ASR-9, etc.) to generate terminal area weather products. To facilitate dissemination of the weather information providing these systems, Lincoln Laboratory also has been active in developing a data link to provide both text and graphical terminal weather information to the cockpit.

The problem in providing these products to pilots is that the graphical capability does not yet exist for commercial aircraft. Moreover, even when graphical data link capabilities are being installed in new aircraft, older aircraft without this capability will remain in service for years. But are there current data link capabilities that could be used to inform pilots of terminal weather conditions?

The answer to this question is “yes.” The Aircraft Communications, Addressing and Reporting System (ACARS) is a text-based data link capability that is currently available in most, commercial aircraft. ACARS provides a two-way, alphanumeric data link capability via VHF radio channels. The airlines use ACARS to transmit gate assignments and aircraft fueling information to their aircraft and to receive take-off and landing information and engine maintenance data. The FAA uses ACARS to transmit flight plan clearances and to receive data on aircraft winds and temperatures aloft.

Since this system is available in most commercial aircraft, the challenge is whether ACARS can be used to demonstrate transmittal of text-based terminal weather information to pilots. Converting a weather graphic into a few lines of text that can be readily assimilated by a busy pilot is a formidable challenge. To develop the proposed Terminal Weather (TW) message format, an ad hoc committee was formed consisting of pilots, researchers, and service providers.

1.2 Message Format

For the existing ACARS displays, the message had to be limited to about 10 lines of text with no more than 21 characters per line. Figure 1 shows the number of elements competing for this limited text space. Initially, the messages were much too long because they included all weather elements. The committee finally agreed on the format shown in Table 1, which provides the necessary information in the allotted amount of space.

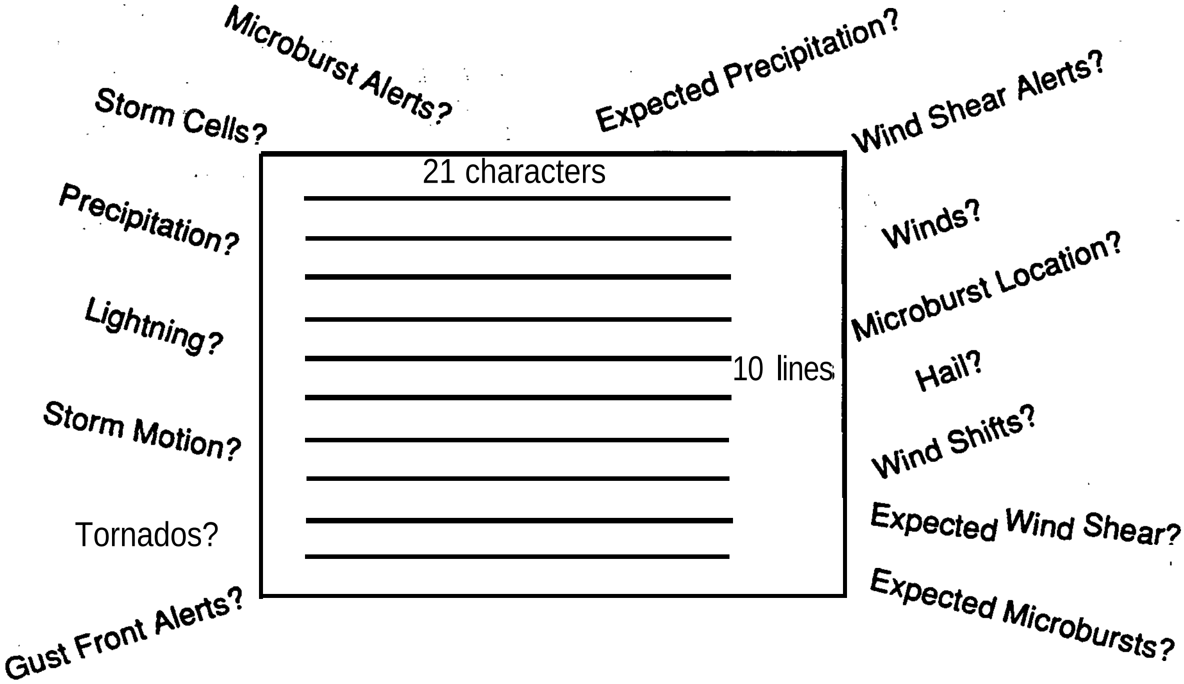


Figure 1. What weather elements should be included in the text message?

Table 1.
Terminal Weather Message Format

Header Section:

```
MCO ARR 1814
TERMINAL WEATHER DEMO
```

Runway Alert Section:

```
*MICROBURST ALERT
35KT LOSS - 1MF
BEGAN 1811 END 1830+
```

or if no microburst alerts

```
*WIND SHEAR ALERT
25KT LOSS - RWY
BEGAN 1811 END 1830+
```

or if no microburst or wind shear alerts

```
• HEAvYPR.EcIP
BEGAN 1811 END 1830+
```

or if no heavy precipitation

```
*MODERATE PRECIP
BEGAN 1811 END 1830+
```

Terminal Weather Section:

```
-STORM (8)
1NM NE HVY PRECIP
1NM N-E MOD PRECIP
3NM NW HVY PRECIP
MOVING SE AT 15KT
```

3 storms maximum

motion for all storms

Expected/Previous Runway Weather Section:

*If no **microburst** runway alerts*

```
. EXPECTED MICROBURST
35KT LOSS -1NME
BEGIN 1815 END 1825
```

*If no expected **microbursts***

```
. EXPECTED WIND SHEAR
25KT LOSS - 1NM E
BEGIN 1815 END 1825
```

If no expected wind shears

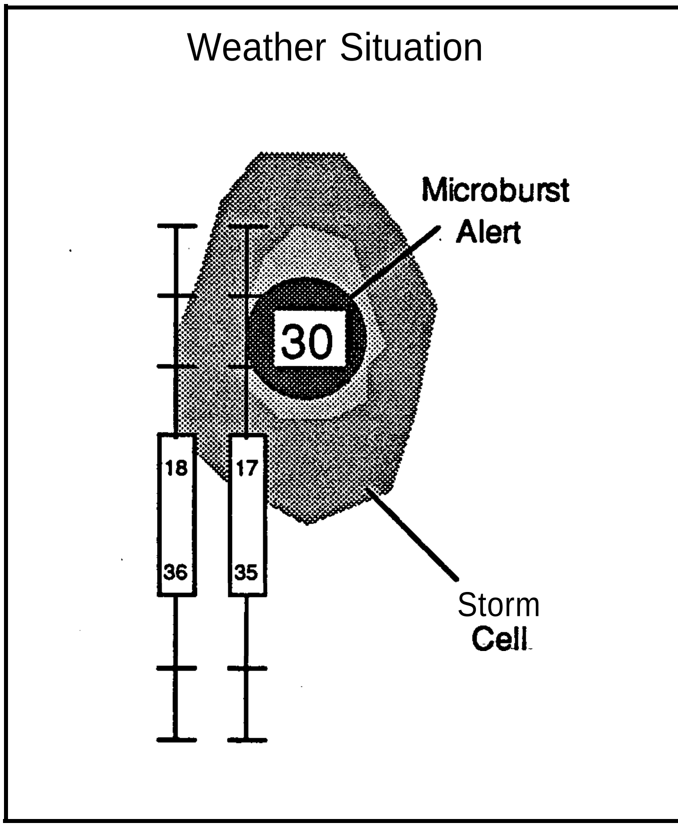
```
. EXPECTED HVY PRECIP
{or . EXPECTED MOD PRECIP}
BEGIN 1815 END 1835+
```

***If** no **expected** weather*

```
. PREVIOUS MICROBURST
{or . PREVIOUS WIND SHEAR}
BEGAN 1803 END 1811
```

The message is divided into four sections to highlight the different kinds of information: HEADER INFORMATION, RUNWAY ALERTS, TERMINAL AREA STORMS and EXPECTED RUNWAY IMPACTS. The elements within each section are presented in order of importance and timeliness. The most important appear **first** and other elements appear only in the absence of higher priority elements. The HEADER INFORMATION indicates the airport selected, whether approach or departure was requested, and the Universal Time. The RUNWAY ALERTS section provides the highest priority and most timely weather information, including the current microburst, gust front, or precipitation impacts (in order of priority). To save space, only the highest priority runway alert is shown. The TERMINAL AREA STORMS section provides information about storm cells in the terminal area. The cells are sorted by proximity to the airport and by severity. Only the first three storm cells on the list are included. Finally, EXPECTED RUNWAY IMPACTS shows the expected microburst, gust front or precipitation impacts for the runway (in order of priority). Again, only the highest priority expected impact is shown. If there are no expected impacts, then the previous microburst or wind shear impact (if any) is displayed for five minutes after the impact ceases. This format is summarized in Table 1.

An example of the Terminal Weather text message is contained in Figure 2. The left-hand window shows the weather situation in graphical form. A **30-knot** microburst is impacting runway 17 approach, causing a **15-knot** loss. The upper right window shows the alert as it appears to the tower controller. It is assumed in this example that **arrivals** are from the north.



TDWR Message

17A MBA 15K- 2MF 140 08

Data Link Message

```
MCO ARR 1848
TERMINAL WEATHER DEMO
*WIND SHEAR ALERT
 15KT LOSS - 2MF
 BEGAN 1846 END 1855
-STORM(S)
 3NM N HVY PRECIP
 3NM N-NE MOD PRECIP
 MOVG W AT 8KT
.EXPECTED MICROBURST
 30KT LOSS - 3NM NE
 BEGIN 1850 END 1855
```

Figure 2. Example of Terminal Weather text message.

The lower right window shows the Terminal Weather text message. The first line of the message identifies the airport, Orlando International Airport (MCO), arrivals (ARR) at 1848 Universal Time. The second line indicates that this is a Terminal Weather message. The next three lines indicate that there is a 15-knot loss wind shear impacting an arrival runway (note: because the message is intended as a strategic message and not a tactical warning, the runway was not specified). The respective beginning and expected ending times of the wind shear impact are 1846 and 1855 Universal Time.

The next four lines indicate that there are storms near the airport. A heavy precipitation storm is north of the airport, and a larger, moderate precipitation storm extends from the north through northeast. The storms are moving west at 8 knots. The last three lines indicate that a microburst alert is expected to begin at 1850 and last until 1855, with an intensity of 30 knots and a location 3 nm northeast of the airport.

2. SUMMER '93 DEMONSTRATION AT ORLANDO, FL

The summer 1993 demonstration was sponsored by the Federal Aviation Administration (FAA), with cooperation from major airlines and Aeronatical Radio, Inc. (ARINC). Five commercial airlines operating at Orlando International Airport (MCO) participated in the demonstration, involving nearly one hundred aircraft per day for a three-month period. As shown in Figure 3, the Terminal Weather text message was generated at Lincoln Laboratory's Integrated Terminal Weather System (ITWS) testbed in Orlando. The message was sent via the ARINC Data Network Service (ADNS) to a database in Annapolis, MD. When a pilot made an Automatic Terminal Information Service (ATIS) request from the cockpit via ACARS, the current Terminal Weather message was retrieved from the database and sent back to the aircraft via ACARS. The Terminal Weather message also could be sent directly to an airline's host computer for direct relay to aircraft, if desired.

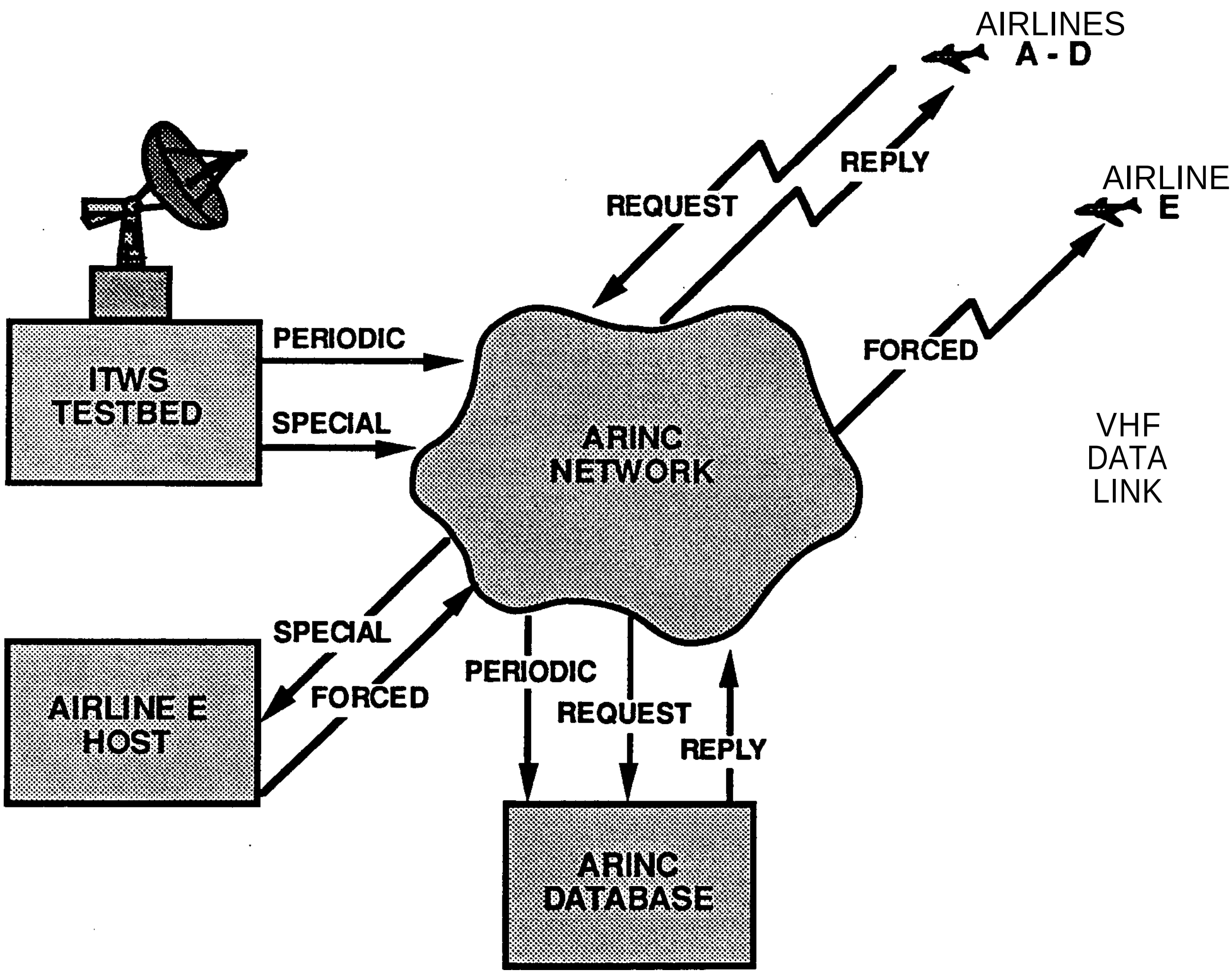


Figure 3. ACARS terminal weather demonstration architecture.

The demonstration was carried out from July 14th through September 30th. As shown in Figure 4, there were an average of 145 requests per day for the Terminal Weather message and an average of 1.7 requests per aircraft. Over 11,000 requests were made over the three-month period. There were 220 requests on July **31st,** which was a day with very heavy weather impact.

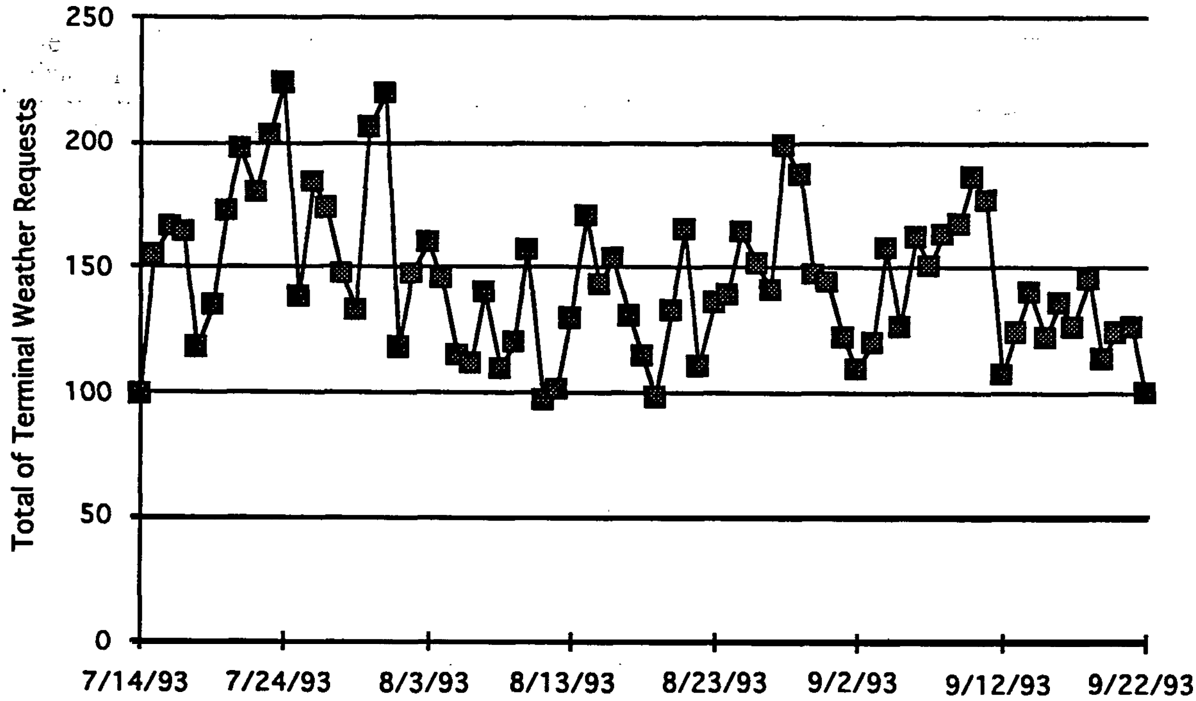


Figure 4. Terminal Weather requests by day.

Figure 5 shows the Terminal Weather requests by airline. Airline D had the highest number of requests, apparently because it had the highest number of operations with aircraft that had the correct ACARS equipment. Also, the ATIS request on this airline was tied to a surface weather report request that was already familiar to the pilots. For airlines A and B, the percentage of requests per operation was lower because the pilots had to make a special request that worked only for Orlando. The procedure for requesting the Terminal Weather message for airline A involved entering a numeric code whereas airline B simply made a menu choice from a touchscreen.

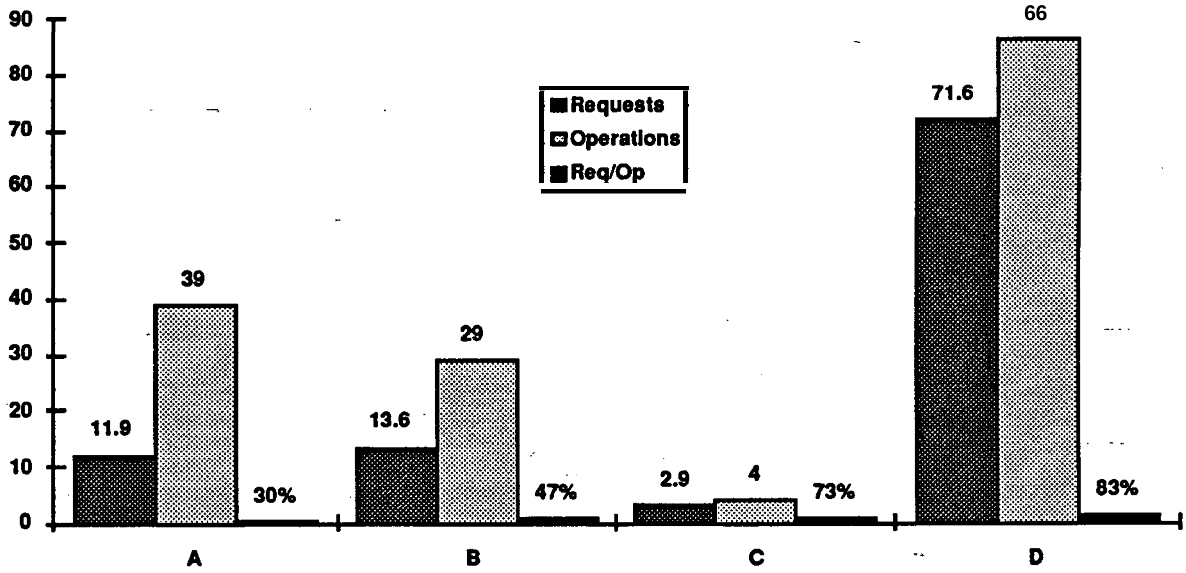


Figure 5. Terminal Weather requests by airline.

Figure 6 summarizes the responses to pilot requests for Terminal Weather information. For the three-month demonstration, the hours of the ITWS testbed operation were limited to the period between noon and 7 p.m. Early in the demonstration period pilots frequently requested the Terminal Weather message (seven percent of the requests) for airports where the message was not available. These messages were primarily concentrated in the first two weeks of the demonstration. Forty-one percent of the requests were made in the morning hours when the system was not operating, primarily during the departure rush between 8 and 11 a.m. Another 34 percent of the requests received responses of “no weather near the airport.” Therefore, for most of the demonstration there were no storms within 5 nm of the airport. However, late in the demonstration the message was changed to report storms within 20 nm of the airport. The system was unavailable because of technical problems for three percent of the requests.

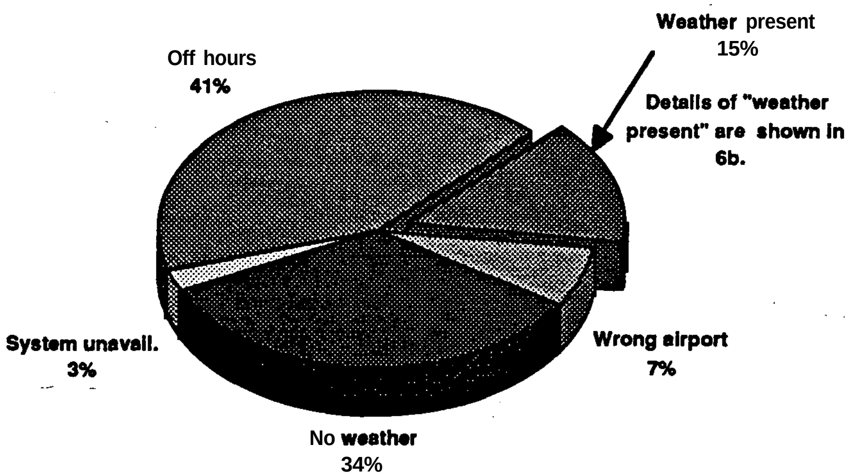


Figure 6a. Terminal Weather text message responses.

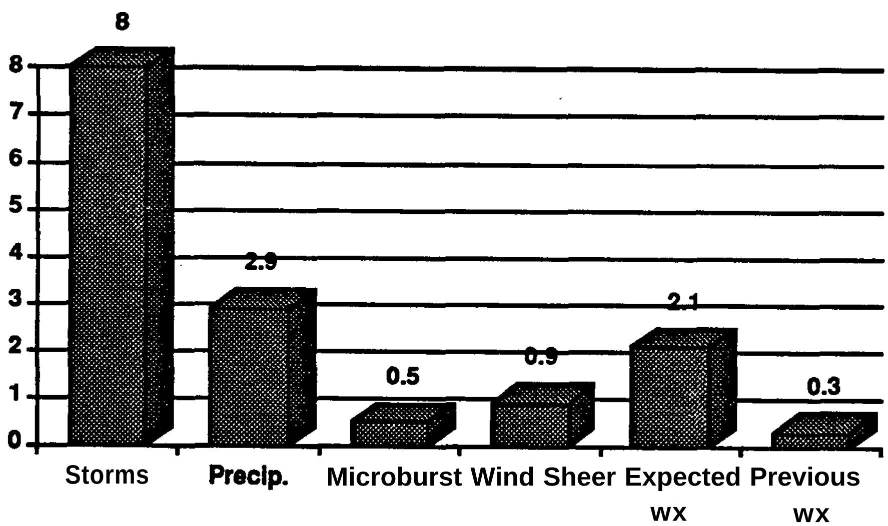


Figure 6b. Details of "weather present" section of chart in figure 6a.

There was weather reported for the remaining 15 percent of the requests. Storms were reported in eight percent of the replies, and precipitation impacted the runway in three percent of. the replies. Expected precipitation was seen in two percent of the replies, and wind shear alerts were reported in one percent of the replies. There were microburst alerts in 53, or 0.5 percent, of the replies.

3. PERFORMANCE ASSESSMENT

3.1. Pilots

To assess how valuable the product is to pilots, ARINC developed a questionnaire for the pilots at the Orlando and other flight operations stations. The airlines returned 142 questionnaires [A (89), B (49), C (1) and D (3)]. Airline E distributed a shorter version of the questionnaire to its pilots and returned 19. Figure 7 shows how the pilots rated the Terminal Weather service on a scale of 1 (low) to 5 (high). Overall, pilots found the system operationally acceptable (4.4) and that it provided improved situational awareness (4.3). They found it provided some assistance in making operational decisions (3.9) and that it slightly decreased workload (3.2).

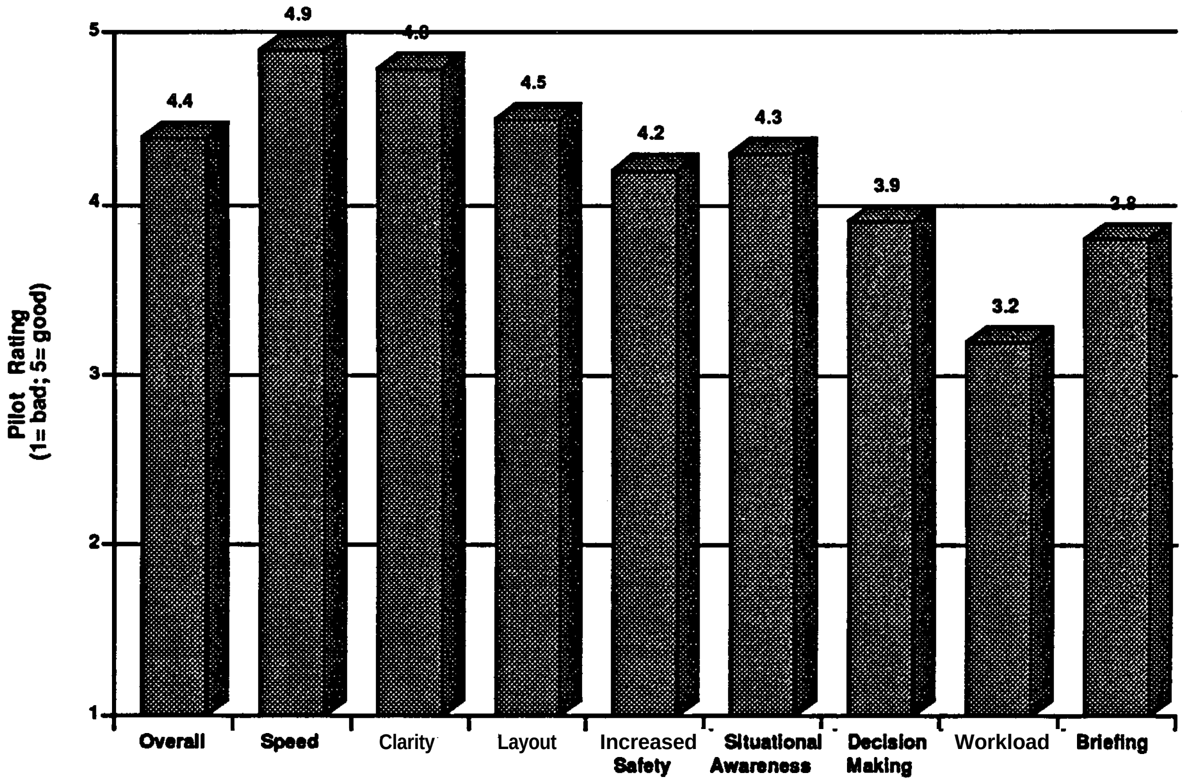


Figure 7. Pilot rating of Terminal Weather message service.

Figure 8 summarizes how the pilots rated the products provided in the Terminal Weather message. It is interesting to note that the pilots rated the Expected Microburst and Expected Gust Front as the highest value products.

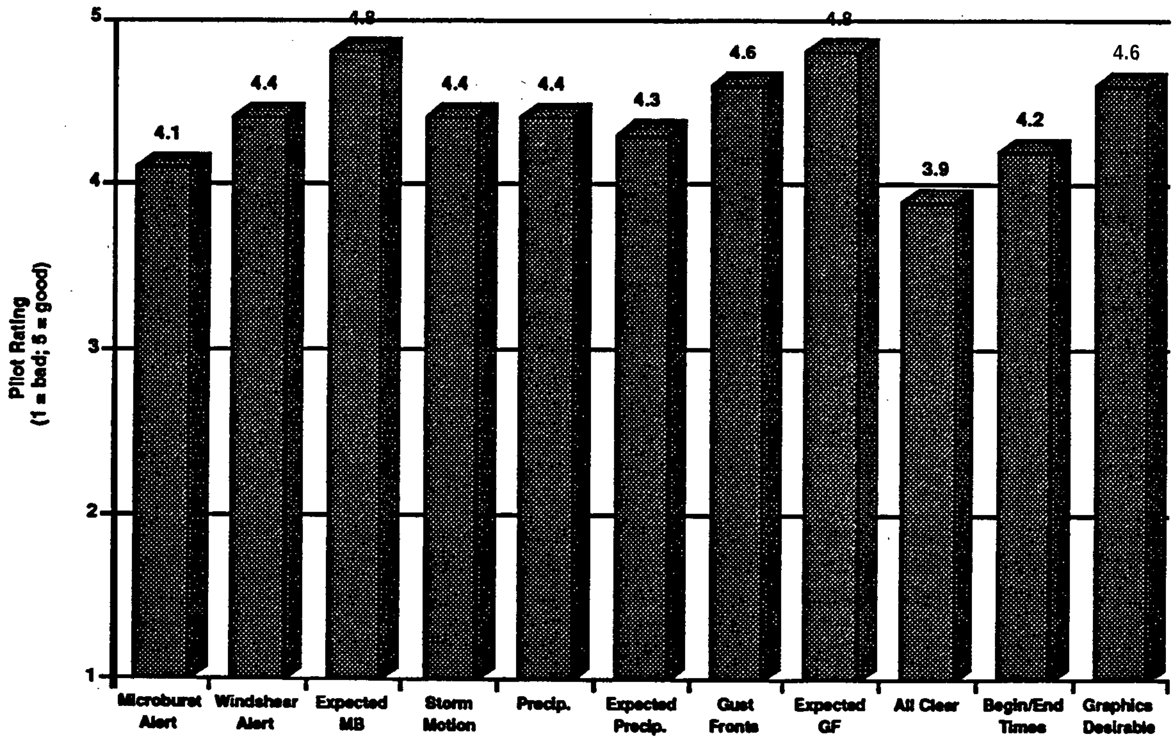


Figure 8. Pilot rating of Terminal Weather message elements.

This preference is probably explained by Figure 9 which shows the phase of flight when the message was requested. The message was most frequently requested during initial descent or about 20-30 minutes before landing. Thus, information about anticipated wind shear hazards would naturally be of great interest.

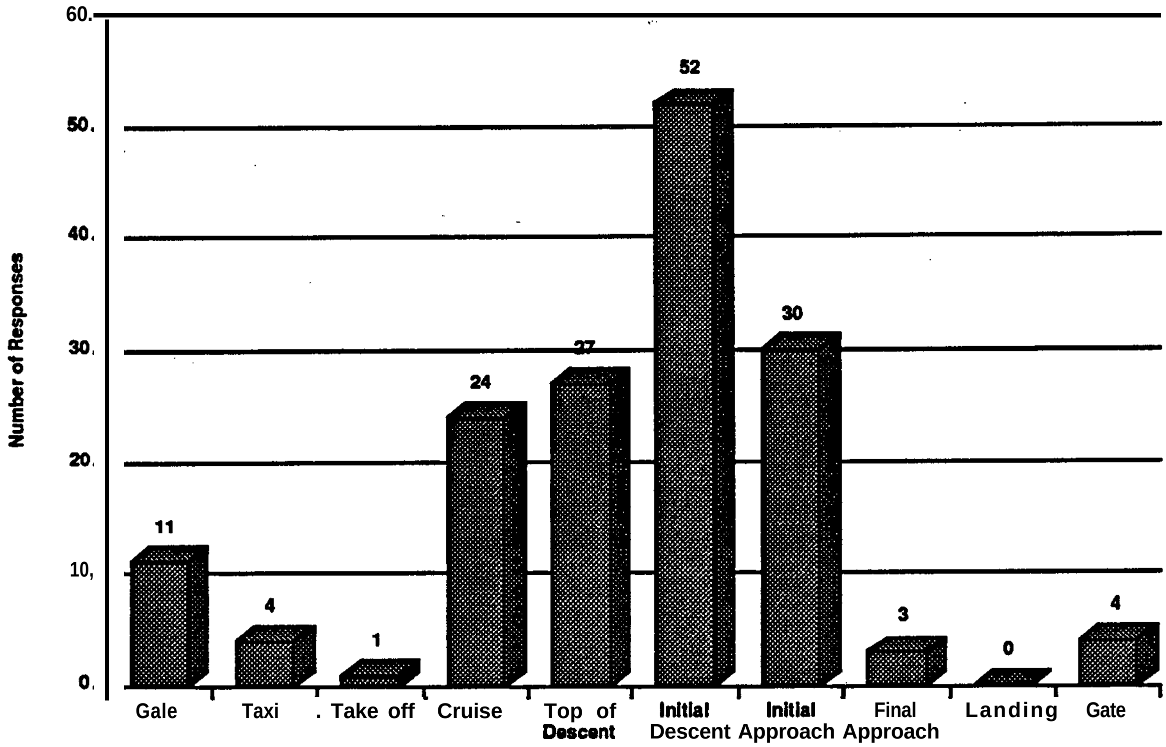


Figure 9. Phase of flight when the Terminal Weather message was requested.

A final interesting note from the questionnaires was that the pilots expressed a strong desire (4.6) for a graphical depiction of microburst, gust **fronts** and precipitation. This is an issue that will be mentioned in a later section. Overall, there was strong support for implementing the Terminal Weather message operationally and for developing a graphical version of the service.

3.2. Controllers

Orlando air traffic controllers were concerned about a possible increase in radio traffic because of the data link message, particularly that pilots might ask questions about the Terminal Weather message and increase the controller's workload. The controllers and pilots met early in June and agreed to make certain modifications to the Terminal Weather message. For example, they decided that all expected begin times also had to have expected end times. They also decided not to specify the exact runways being impacted (e.g., 18 Left) but indicate only Arrival or Departure because of the transient nature of the wind shear alerts.

The Terminal Weather message did not increase radio traffic. In fact, at a review meeting in September the controllers stated that, to their surprise, there actually was a ***&crease*** in the number of requests for weather information during a highly weather-impacted day (July 31st). An informal check of pilot-ATC radio conversations showed that six of seven requests for weather information came from aircraft that could not receive the Terminal Weather message. The one request from an equipped aircraft was from a departure aircraft that could request only the arrival message. This observation supported the idea that data link dissemination of weather products can decrease controller workload.

3.3. Dispatchers

An interesting and unanticipated observation was the interest that airline dispatchers took in the Terminal Weather message. When dispatchers from airline D found out that their pilots were receiving the Terminal Weather message, they began to access this information via the ADNS network as well. During the period of weather impact on July 31st, these dispatchers made 15 Terminal Weather message requests to monitor the weather situation at Orlando. To make the Terminal Weather message even more valuable to dispatchers, it was decided to route special messages indicating the onset of wind shear activity at Orlando to dispatchers at airline D and a sixth airline (F) which could not participate in the demonstration because of equipment limitations. These special messages were being generated for airline E, which did forced uplinks to aircraft within 20 minutes of landing or to aircraft ready for takeoff. These special messages have the advantage of alerting the dispatcher or pilot that wind shear activity had started at the airport without the pilots having to monitor the Terminal Weather message continuously. It seems likely that a deployed system should be able to respond to requests and also should be able to generate messages spontaneously when hazards begin.

4. FUTURE WORK

Additional demonstrations of the Terminal Weather message product are scheduled for the summer of 1994 as part of the ITWS Initial Operating Capability (IOC) product demonstration and validation (DemVal). These demonstrations will be carried out at Memphis, TN and Orlando, FL, for two months at each location.. One significant change will be that the 1994 product will be generated from ITWS products whereas the 1993 product was generated entirely from TDWR products. The improved ITWS products will include new microburst, gust front, storm cell, storm motion, and precipitation algorithms. Another substantial change is that the storm cells will be reported out to 15 nm instead of the 5 nm limit used during most of the 1993 demonstration. This limitation resulted from the TDWR storm cells being identified only in the immediate airport vicinity whereas ITWS identifies storm cells in the entire Terminal Control (TRACON) area. Both pilots and controllers identified the need to provide this storm cell information out to this increased distance. A scheme will be implemented which should greatly improve the accuracy of estimates of expected begin and end times for microbursts, gust fronts and precipitation. It is also planned to incorporate information from the ITWS Microburst Prediction algorithm to improve the expected microburst/wind shear begin and end times. Finally, an advanced gust front detection algorithm has been implemented which should greatly improve the expected gust front prediction times.

The current plan for providing graphical ITWS microburst, gust front, storm motion and precipitation products to airborne weather displays via ACARS for the summer 1994 demonstration is to modify an airborne weather radar display (and possibly ACARS Message Unit) to accept encoded and compressed graphical weather data. An auxiliary processor in the radar display would decode and decompress the graphical weather data and display it on the unit's color screen. The radar display (or ACARS Message Unit (MU)) also would be modified to generate requests for graphical products which would be routed via ACARS and the ARINC ground network to the ITWS testbed. An outboard processor on the ITWS testbed would service these requests and provide the products (in encoded and compressed form) over the ARINC network to the requesting aircraft.

The initial demonstration would be carried out on the ground and might be shown to line pilots at an airline flight operations center near an ITWS testbed. Lincoln would be responsible for generating the graphical products, transmitting them via the ARINC network, receiving the products via an ACARS interface emulation, and making the appropriate software changes in the flight hardware to decode, decompress and display the products. The participating airlines would have the responsibility for installing the software changes in their hardware, handling certification issues, and installing the equipment in their aircraft.

Lincoln Laboratory continues to be active in the development of data link standards. A Radio Technical Committee for Aeronautics (RTCA) is currently developing the standards for delivering Flight Information Services (FIS) via data link, including the delivery of text and graphical terminal weather products. A Terminal Weather Service (TWS) has been defined in the draft Minimum Operational Performance Specification (MOPS) which includes these products.

ACRONYMS AND ABBREVIATIONS

ACARS	Aircraft Communications Addressing and Reporting System
ADNS	ARINC Data Network Service
ALPA	Air Line Pilots' Association
ARINC	Aeronautical Radio, Inc.
ARR	Arrival
ASR-9	Airport Surveillance Radar-9
ATC	Air Traffic Control
ATIS	Automatic Terminal Information Service
DemVal	Demonstration and Validation
FAA	Federal Aviation Administration
FIS	Flight Information Services
FL	Florida
IOC	Initial Operational Capability
ITWS	Integrated Terminal Weather System
MCO	Orlando International Airport
MD	Maryland
MIT	Massachusetts Institute of Technology
MOPS	Minimum Operational Performance Specification
MU	Message Unit
NCAR	National Center for Atmospheric Research
RTCA	Radio Technical Committee for Aeronautics
STX	ST Systems, Inc.
TDWR	Terminal Doppler Weather Radar
TN	Tennessee
TRACON	Terminal Radar Approach Control
TW	Terminal Weather
VHF	Very High Frequency
WSP	Wind Shear Processor
WX	Weather

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Gertz, J.L., 1990: Weather Map Compression for Ground to Air Data Links, Preprints, ***Aeronautical Telecommunications Symposium on Data Link Integration,*** Annapolis, **131-**140.