Project Report
ATC-227

Terminal Weather Information for Pilots (TWIP) Test Report for 1994 Memphis and Orlando Demonstrations

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28 April 1995

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6. Abstract

Demonstrations of delivering the Terminal Weather Information for Pilots (TWIP) products to air carrier pilots via the Aircraft Communications Addressing and Reporting System (ACARS) data link were carried out at Memphis and Orlando during the summer of 1994. Six airlines participated in the demonstrations at both airports. The Terminal Weather Text Message and the Terminal Weather Character Graphics Depiction were evaluated using request/reply and forced update approaches. In the first case, the pilot needed to make a request in order to obtain tbe TWIP products. In the second case, the TWIP message was sent to the aircraft automatically when certain criteria were met (e.g., the aircraft was within 20 minutes of landing and wind shear alerts began at the airport). Five of tbe airlines used the request/reply approach, and one airline used the forced update approach.

Pilot and controller response to the TWIP products *were* evaluated using questibnnaires. Statistics on message traffic and content were analyzed, and some cases were analyzed in detail to compare the TWIP products with the existing Surface Aviation Observation (SAO) reports. Recorded radio traffic also was analyzed to determine if there was any effect on tbe number of requests for terminal weather information.

Pilots rated tbe TWIP products favorably, with most indicating that the messages provided improved situational awareness of terminal weather hazards without substantially increased cockpit workload. Controller reaction to the TWIP demonstration was generally neutral, indicating that providing these messages to pilots caused no substantial increase in controller workload. Further results of the demonstration are discussed in the report, along with recommendations for subsequent TWIP demonstrations.

7. Key Words

Terminal Weather — TWIP
Text Message — ACARS
Character Graphics

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EXECUTIVE SUMMARY

Demonstrations of delivering the Terminal Weather Information for Pilots (TWIP) products to air carrier pilots via the Aircraft Communications Addressing and Reporting System (ACARS) data link were carried out at Memphis and Orlando during the summer of 1994. Six airlines participated in the demonstrations at both airports. Two types of TWIP messages were evaluated: the Terminal Weather Text Message and the Terminal Weather Character Graphics Depiction.

Two operational approaches to providing the TWIP messages were evaluated: Request/Reply and Forced Update. In the first case, the pilot needed to make a request in order to obtain the TWIP products, In the second case, the TWIP message was automatically sent to the aircraft when certain criteria were met (e.g., the aircraft was within 20 minutes of landing and wind shear alerts began at the airport). Five of the airlines used the Request/Reply approach, and one airline used the Forced Update approach.

Pilot response to the TWIP products was evaluated using questionnaires distributed and collected by the participating airlines. Controller response was also evaluated using questionnaires administered by the FAA Technical Center. Statistics were gathered and analyzed concerning message traffic and content, and cases were analyzed in detail to compare the TWIP products with the existing Surface Aviation Observation (SAO) reports. Finally, recorded radio traffic was analyzed to determine if there was any effect on the number of requests from pilots to controllers for terminal weather information.

The TWIP products were rated favorably by pilots, with most indicating that the messages provided improved situational awareness of terminal weather hazards and did not substantially increase cockpit workload. Controller reaction to the TWIP demonstration was generally neutral, indicating that there was no substantial increase in controller workload caused by providing these messages to pilots. The message traffic showed that the number of TWIP requests increased when weather impacted the terminal area. The case analysis showed that the TWIP messages provided better situational awareness of terminal weather hazards than the SAO. The radio message traffic analysis suggested that pilot requests for terminal weather information may have been reduced when the TWIP messages were available.

The demonstration was somewhat hampered by limited hours of operation and the limited number of days. It is therefore strongly recommended that a demonstration be conducted next summer that provides 24 hour per day, seven day per week service. Consideration should also be given to revising the criteria for generating forced updates.

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1. INTRODUCTION

1.1. Purpose of Report

This test report provides results from demonstrations of the Terminal Weather Information for Pilots (TWIP) products at Memphis and Orlando during the summer of 1994.

1.2. Scope of Report

The suitability of the TWIP products was evaluated as part of the demonstration process. The functional performance and operational acceptability of the TWIP text-based products needed to be verified in order to include these products in the Integrated Terminal Weather System (ITWS) Initial Operating Capability (IOC).

2. SYSTEM DESCRIPTION

2.1. Mission Review

A TWIP block diagram is shown in Figure 1. This diagram represents the envisioned system architecture for providing TWIP products after ITWS becomes operational. The TWIP products will be provided by the Integrated Terminal Weather System (ITWS) to the Data Link Processor (DLP) for storage in a database. The DLP will provide these products to pilots via ATN (Aeronautical Telecommunications Network) compatible data link (e.g., VHF, Mode-S, etc.).

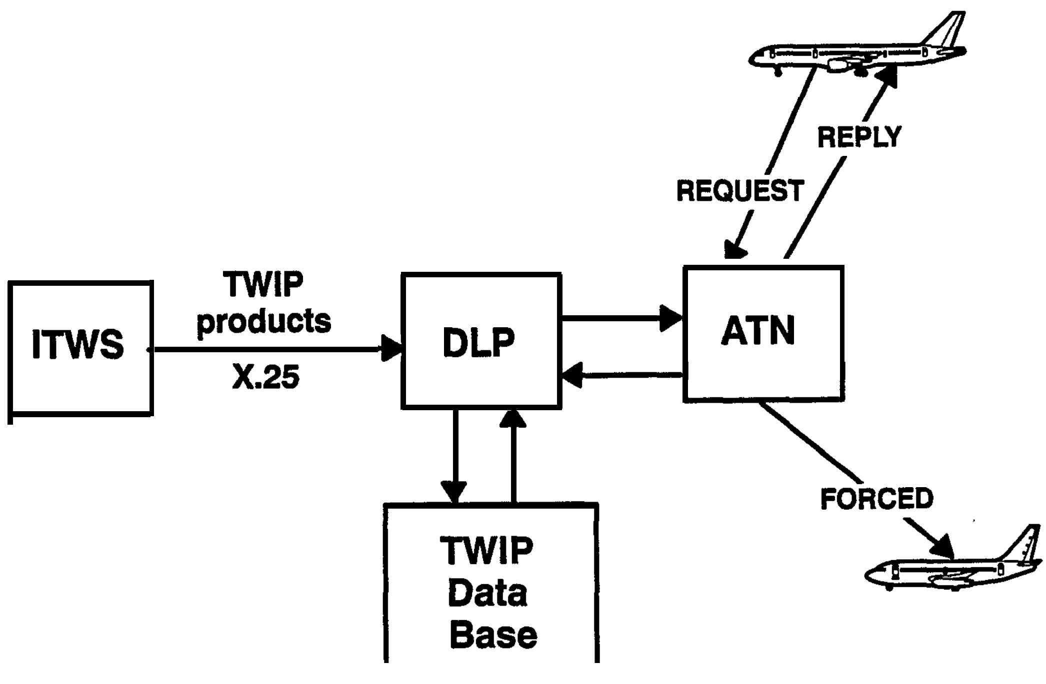


Figure I. Terminal Weather Information for Pilots (TWIP) block diagram and interfaces.

There are two methods for triggering a TWIP message to be sent to an aircraft: request/reply and forced update. The first method requires the aircraft to generate a request for TWIP product; the second method forces a message to the aircraft when a weather condition is met (e.g., wind shear activity begins or ends at an airport). [Note: The DLP functionality has not yet been fully defined and does not currently support forced updates.]

2.2. Test System Configuration

The TWIP demonstration configuration for summer 1994 is shown in Figure 2. As shown in the figure, the ITWS testbeds at Memphis and Orlando provide the TWIP text-based products over land-line connections to the ARINC Data Network Service (ADNS). The TWIP products are stored in a database at ARINC headquarters in Annapolis, MD. Aircraft from five airlines (American, Delta, Federal Express, UPS and USAir) are able to request these products by making Digital ATIS

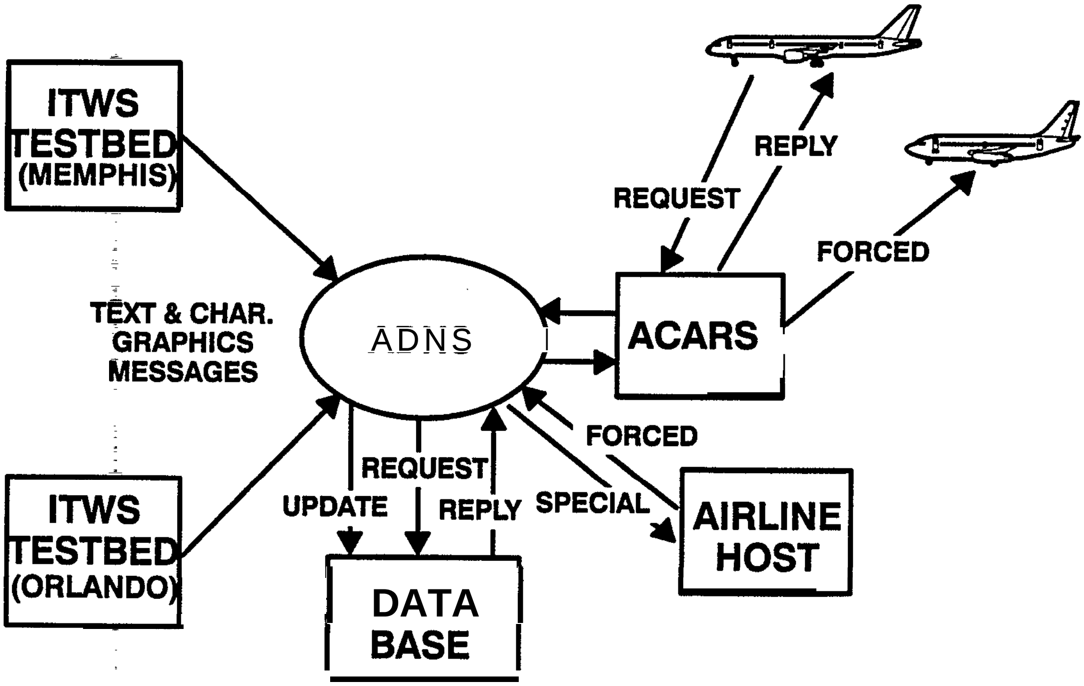


Figure 2. Terminal Weather Information for Pilots (TWIP), summer 1994 Demonstration at Memphis and Orlando.

requests via ACARS. Another airline (Northwest) is sent a special TWIP message whenever wind shear activity starts or stops at an airport; the airline host computer can then force the message to be sent to its aircraft that are either within 20 minutes of landing or taxiing out for departure.

It can be seen by comparing Figures 1 and 2 that the DLP function is carried out in the test system configuration by the AFUNC database and the airline host computers. The ARINC database carries out the DLP request/reply data basing function and some of the DLP request/reply routing functions. The airline host computer carries out the analogous functions for the forced messages.

2.3. Interfaces

The NAS interface between the ITWS and DLP will be an X.25 connection via the NADIN PSN (Packet Switched Network), whereas the test system used a bi-sync interface to the ARINC Data Network Service (ADNS) message switched network. The NAS interface to aircraft is carried out using ATN–compatible data link services, whereas the test system used the character-oriented ACARS VHF data link.

3. DEMONSTRATION DESCRIPTION

3.1. Test Schedule & Locations

The schedule for the test and evaluation activities was as follows:

Location	Dates	Hours	Days
Memphis	5/23/94 – 7/22/94	Noon to 7 p.m. (M-F only)	57
Orlando	7/11/94 – 8/19/94	Noon to 7 p.m. (every day)	39

3.2. Participants

The roles and responsibilities of the participating organizations were as follows.

ACW-200D	Administer air traffic controller questionnaires.
AND-460	Program manager for ITWS.
AND-310	Program Office.
ATQ	Provide demonstration oversight.
MITJLL	Design, implement, and operate TWIP message software for Memphis and Orlando ITWS testbeds. Provide TWIP messages to ARINC via ADNS interface. Develop pilot and controller questionnaires and training material.
ARINC	Store and transmit Memphis and Orlando Terminal Weather text and character graphics messages to requesting airline aircraft. Distribute and collect pilot questionnaires. Collect ACARS and data base performance statistics.
Participating Airlines	Notify pilots of Memphis and Orlando demonstration and provide suitable training materials. Distribute and collect pilot questionnaires. Provide ancillary information such as aircraft ACARS equipage.

3.3. Test and Specialized Equipment

The following test and analysis tools were employed for the TWIP demonstration:

- Pilot questionnaires including:
  - ARINC pilot questionnaires distributed to American, Delta, Federal Express, UPS and USAir
  - Northwest pilot questionnaires

- Controller questionnaires

- TWIP message and status logs including:
  - ARINC request/reply message logs
  - ARINC message statistics reports
  - Lincoln text and character graphics message logs
  - Lincoln testbed status logs

- Ancillary data including:
  - Flight plan and aircraft beacon data (Memphis only)
  - Airline schedule and ACARS equipage data
  - ATC/pilot radio transmission recordings
  - Surface aviation observations (SAOs)

- Software tool (WeatherShell) for displaying:
  - Terminal weather conditions
  - TWIP messages
  - Surface observations
  - Aircraft beacon locations

- Software tool (IDL) for analyzing:
  - Pilot and controller questionnaire responses
  - TWIP message traffic

- Software tools for reducing data:
  - ARINC message logs
  - Lincoln message logs
  - Surface observations
  - Flight plan and aircraft beacon data

3.4. Test Objectives/Criteria

The following are critical operational issues related to TWIP that must be addressed during the demonstration:

- Do the TWIP products improve pilot situational awareness of terminal weather hazards over currently available products such as ATIS? Were the products provided in a readily understandable form? Did pilots use the TWIP information in making operational decisions?

- Were the TWIP products provided in a timely and reliable fashion? Is there any increase in pilot workload associated with these products? Should these products be provided on a request/reply or forced-update basis?

- Do the TWIP products decrease controller workload by reducing the demand for weather briefings from pilots? Are there any increases in radio traffic that are attributable to the TWIP product availability?

3.5. Testing Descriptions and Analysis Procedures

The following evaluations were carried out for the TWIP demonstration:

1) Pilot Questionnaire Evaluation

2) Controller Questionnaire Evaluation

3) Message Statistics Evaluation

4) Case Analysis Evaluation

5) Radio Traffic Evaluation

These evaluations are briefly described below.

The primary objective of the Pilot Questionnaire Evaluation was to determine whether the TWIP messages improve pilot situational awareness of terminal weather hazards and if there is any impact on pilot workload. Secondary objectives were to evaluate the product format, response speed and related issues. Two types of questionnaires were distributed to pilots during the demonstration. The airlines using the request/reply method (American, Delta, Federal Express, UPS and USAir) distributed a questionnaire provided by ARINC. The airline using the forced update method (Northwest) distributed a separate questionnaire for its pilots. Responses from the questionnaires were tabulated and evaluated statistically.

The primary objective of the Controller Questionnaire Evaluation was to determine whether the TWIP messages reduce requests for pilot briefings and if any increase in radio traffic occurred. The controller questionnaires were distributed after the end of the demonstration period. Responses were tabulated and evaluated statistically.

The objectives of the Message Statistics Evaluation were to determine: 1) how often TWIP messages were requested by or forced to aircraft, 2) what percentage of ACARS–equipped aircraft received messages, 3) whether the number of requests increased during times of weather impact, 4) the reliability of message delivery and 5) how often the TWIP messages were not available. These statistics were derived from five sources: ARINC request/reply logs, Lincoln message logs, ARINC message reliability reports, Lincoln testbed logs, and ancillary data such as airline schedules.

The objective of the Case Study Evaluation was to evaluate the improvement in terminal weather situational awareness obtained from the TWIP messages using the request/reply and forced update approaches. A selected number of terminal weather impact cases were evaluated by comparing ITWS weather graphics, TWIP messages and SAOs. The accuracy and timeliness of the TWIP messages was scored relative to the SAO information found in the current ATIS messages.

The objective of the Radio Traffic Evaluation was to quantitatively determine the impact of the TWIP messages on radio traffic, and therefore on controller workload. Recordings of ATC/pilot radio conversations were made at Memphis and Orlando before, during and after the demonstration period. Selected cases of heavy weather impact were examined to determine whether the availability of TWIP messages decreased the number of requests for pilot weather briefings or caused any increase in weather-related questions from pilots. For each case in which a pilot made a weather briefing request, it was determined whether the aircraft was able to receive the TWIP messages. The aircraft equipage was determined by examining airline schedules and (in the case of Memphis) ATC flight plan data.

4. RESULTS AND DISCUSSION

4.1. Pilot Questionnaire Evaluation

The pilot questionnaires were gathered by the airlines. There were two different questionnaires: one used by the airlines employing the request/reply method and another used by the airline employing the forced message approach. Figure 3 summarizes the pilot rating of the TWIP text message for the airlines using the request/reply method. A total of 73 questionnaires were returned: 41 from American (2 had comments only), 3 1 from Delta, and 1 from USAir. As can be seen from the figure, the pilots gave the TWIP text message high ratings and indicated minimal impact on pilot workload. These results are consistent with the pilot questionnaire results from the 1993 demonstration.[1]

Figure 4 summarizes the pilot rating of the TWIP text message for the airline using the forced update method. Fourteen questionnaires were returned by pilots. The pilots gave the TWIP text message a highly favorable rating in terms of enhancing situational awareness and assisting decision making. However, a few of the pilots gave negative ratings on the clarity, layout and impact on workload. The comments indicated some concern about the length and format of the messages.

The pilot rating of the TWIP text message clarity and layout was lower for the forced update method than the request/reply method. Since the message content was the same in both cases, it may be hypothesized that the difference was related to the method of delivering the message. It is known from the previous summer's demonstration that pilots using the request/reply method usually

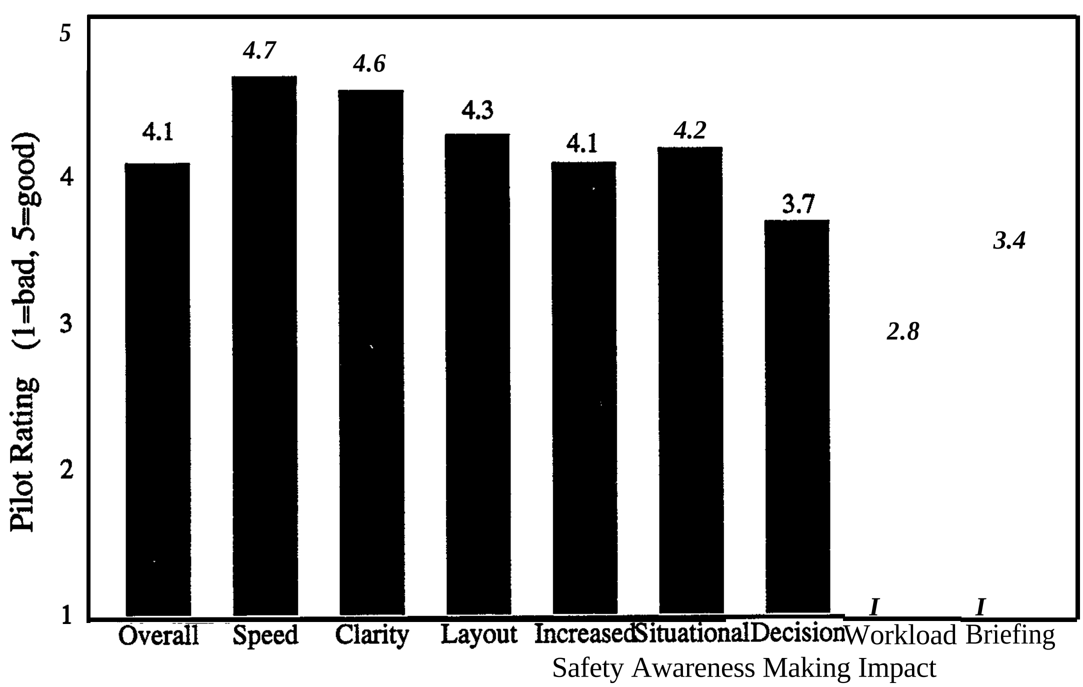
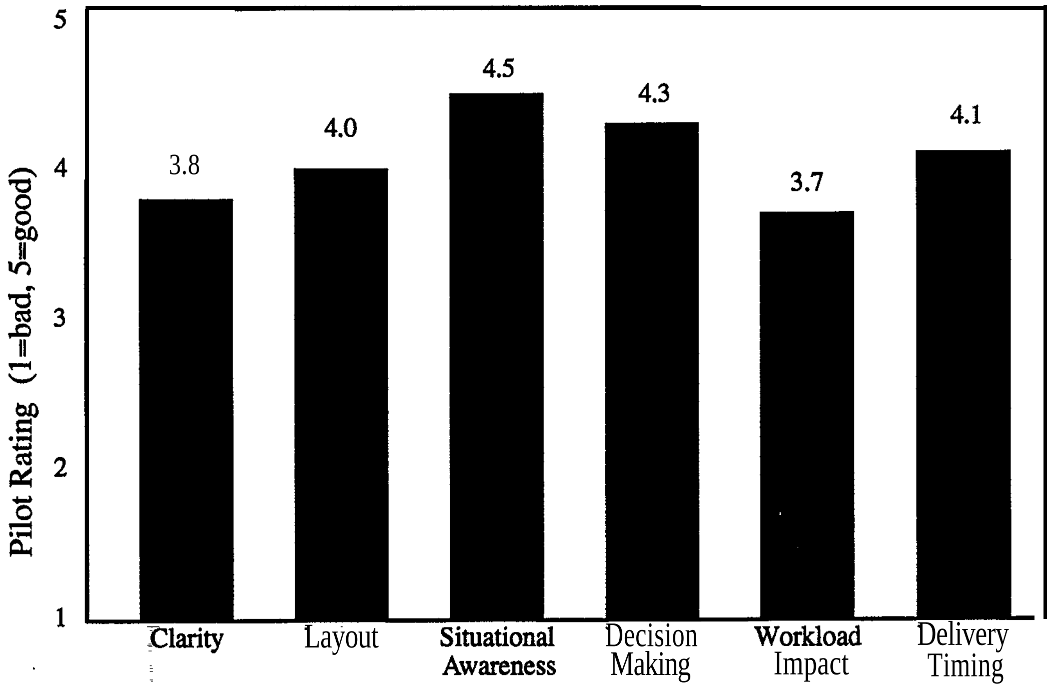


Figure 3. Pilot rating of TWIP text message (requestlreply method).



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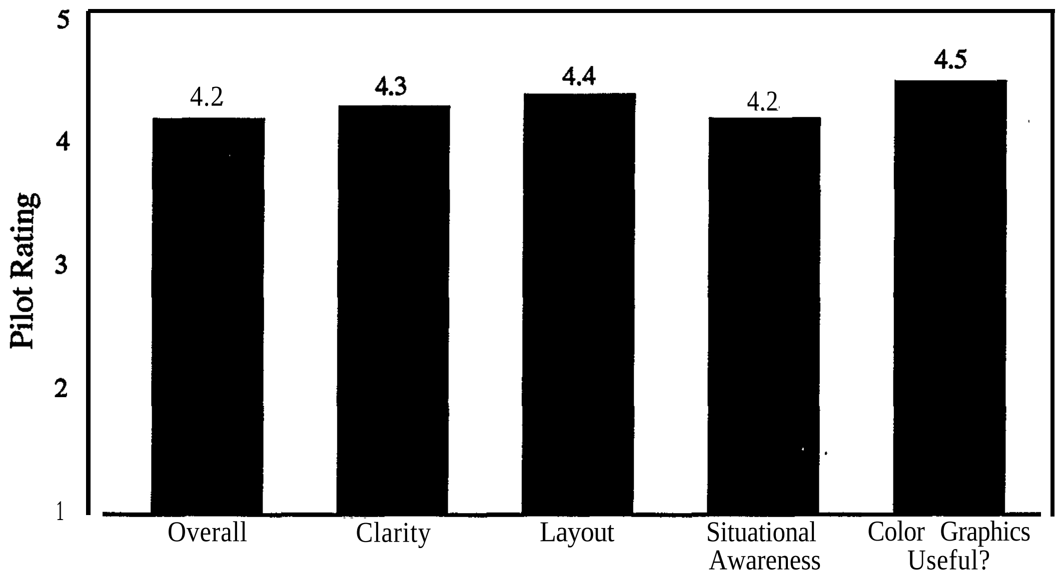
requested the text message about 20 minutes prior to landing at the time of initial descent. At this stage in the flight, the workload is not great and the pilots are beginning to plan the approach. They therefore have the time and the mind set to analyze the text message in detail.

By contrast, the forced update can occur at any time during the approach. The pilot in this case may well receive a message during a high workload period, in which case the forced message may be viewed as a distraction. It may well be that the text message needs to be shortened for forced updates to make the message more readily comprehensible.

On the other'hand, the pilots rated the cockpit workload impact as greater for the request/reply method than the forced update method. The obvious explanation for this difference is that it takes more effort to request the TWIP message than to have it appear spontaneously. It also appears that the pilots receiving the forced updates viewed the messages as contributing to decision making more than those using' the request/reply method. This difference may result since the forced updates occurring at a later point in the flight.

Figure 5 summarizes the questionnaire results concerning the TWIP character graphics product. There were 39 responses: 22 from American and 17 from Delta. Only Delta and American pilots were able to request this message, so the number of responses were lower than for the text message. As seen from the figure, the rating of the character graphics was high, but somewhat lower than the text message. This result seemed to stem from the pilot's lack of familiarity with this new product and with some issues concerning the orientation of the display. The pilots indicated strong support for having a color graphics display in the cockpit for terminal weather.



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The controller questionnaires were administered by the FAA Technical Center to the controllers at the end of the Memphis and Orlando demonstrations. At Memphis there were 22 questionnaires from tower and TRACON Controllers-in-Charge (CICs) and Supervisors. Fifteen controllers reported no change in the number of requests for weather information and no impact on radio traffic in general. Two reported an increase in weather requests and one reported a decrease in weather requests. Two controllers indicated an increase in radio traffic, and two controllers did not express an opinion on either subject. Overall, the impact on number of requests and radio traffic at Memphis was small judging from the controller responses. This result is not surprising since the percentage of aircraft equipped to request the TWIP messages was small in Memphis.

The Orlando controller responses were similar to those from Memphis. There were a total of 21 questionnaires returned from CICs and Supervisors. Of these, 16 indicated that there was no change in requests for weather information or increase in radio traffic and two more expressed no opinion. Three controllers indicated that weather requests and radio traffic increased, and two controllers indicated that both decreased. We conclude that the impact on weather requests and radio traffic was minimal in the controllers' view.

4.3. Message Statistics Evaluation

Analysis of the message statistics for the Memphis and Orlando demonstrations was completed based on ARINC request/reply message logs, ARINC message statistics reports, Lincoln TWIP message archives and Lincoln testbed status logs.

4.3.1. Message Traffic

The two types of message traffic are request/reply (American, Delta, Federal Express, UPS and USAir) and forced (Northwest). The request/reply traffic is determined from the ARINC message logs, whereas the forced message traffic is estimated based on the Northwest aircraft traffic and the Lincoln archives.

4.3.1.1. Request/Reply Traffic

The request/reply message traffic was determined by examining logs of the ARINC database activity. These logs were provided periodically by ARINC via electronic mail during the demonstration period. A database of the requests and replies for both the Memphis and Orlando demonstrations was created at Lincoln and processed to determine the daily activity. The request data included the date and time of the request, plus the aircraft flight number, desired airport and desired product (Text Message or Character Graphics Depiction). The reply data included the actual response sent to the aircraft, including whether the request was outside operating hours or if the system was not available or only partially available.

4.3.1.1.1. Memphis

Figure 6 provides the request/reply message traffic at Memphis on a daily basis. There was an average of 21 text and seven character graphics requests per day through the end of June (note: the number of requests declined in July because the pilots of one airline (USAir) were no longer able to request the text messages due to a change in the airline host computer). The vertical bars indicate times during which the TWIP messages were not available due to ITWS testbed outages.

Note the peak in TWIP requests on June 9th, during which 48 text and 33 character graphics requests were made. This was a day with severe weather impact, including microbursts, gust fronts, heavy precipitation and tornado warnings. The weather impact caused numerous aircraft diversions and at one point caused the tower to be evacuated. The number of TWIP requests consistently increased on days with weather impact,

Figure 7 shows the distribution of message traffic by participating airline (for the five airlines whose pilots could request TWIP messages (American, Delta, Federal Express, UPS, USAir) (note: the "Other" category indicates dispatcher and other miscellaneous requests). The number of requests was lower than 'that observed in Orlando during last summer's demonstration. However, fewer aircraft were also equipped to make TWIP requests (only about 57 aircraft per day). When this difference is taken into account, the rate of TWIP requests for Memphis was comparable to that in Orlando.

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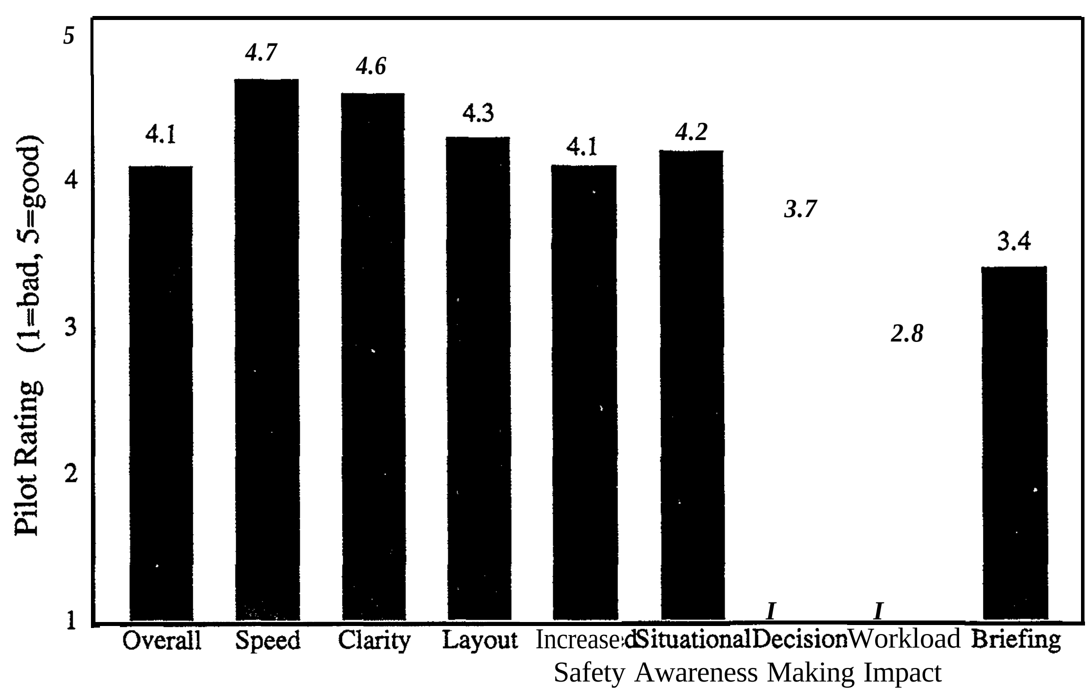

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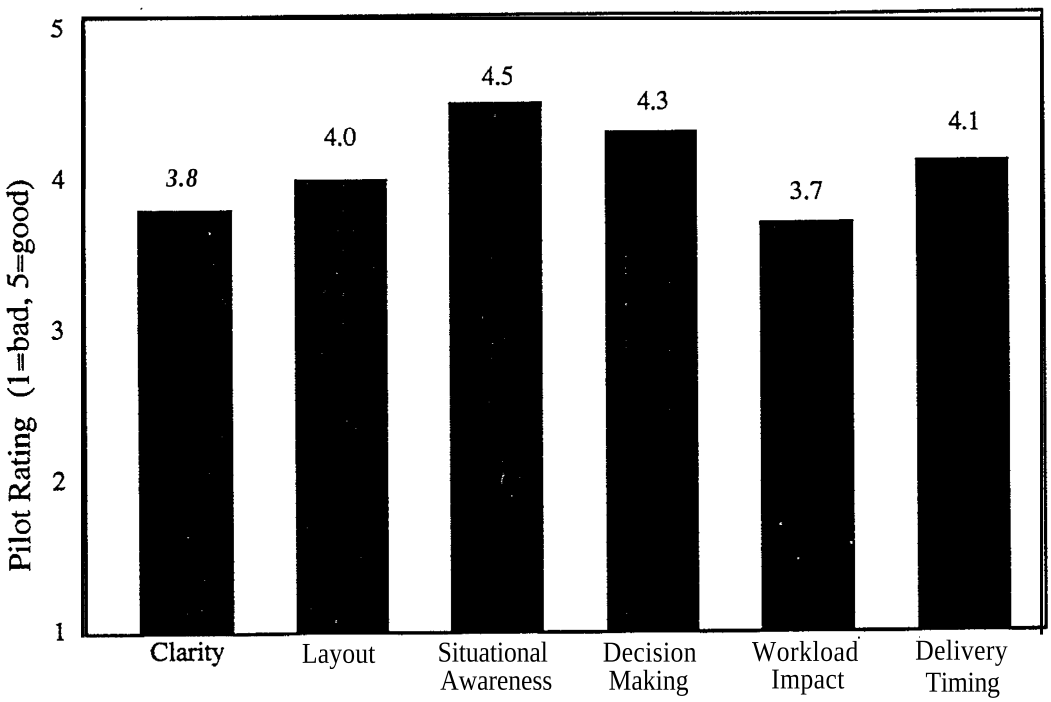

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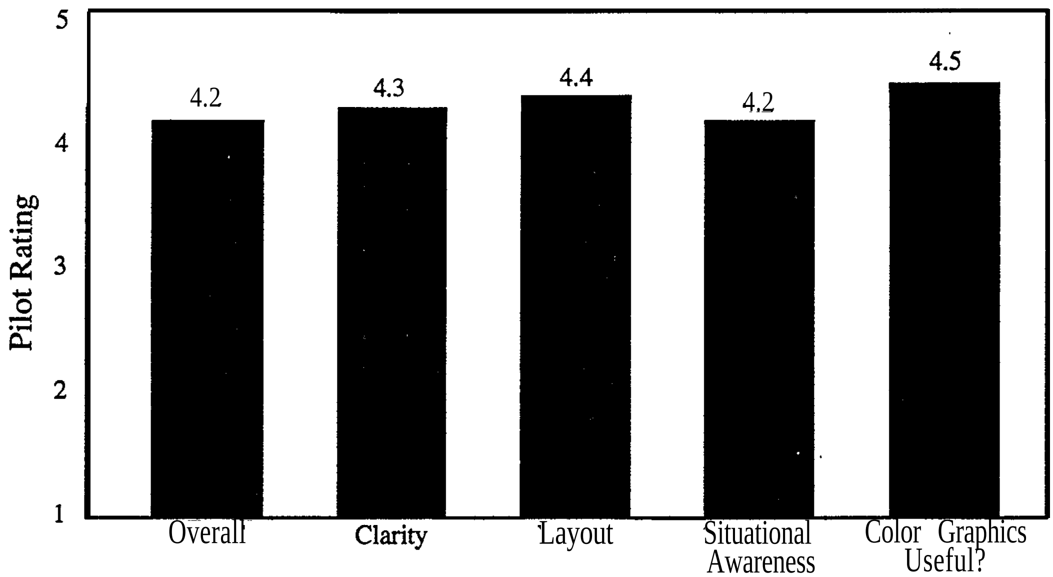

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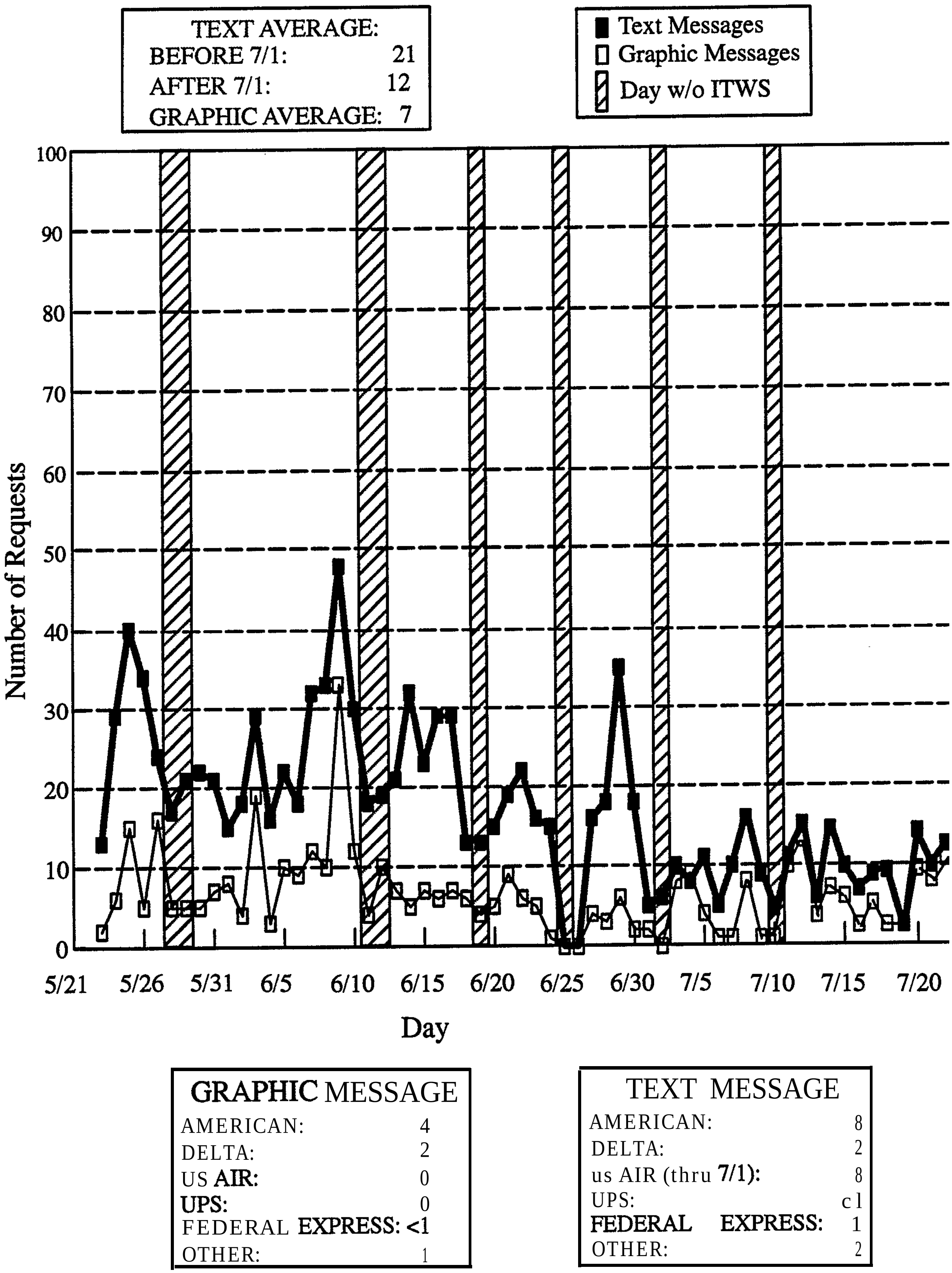

Figure 6. TWIP message requests per day (Memphis).

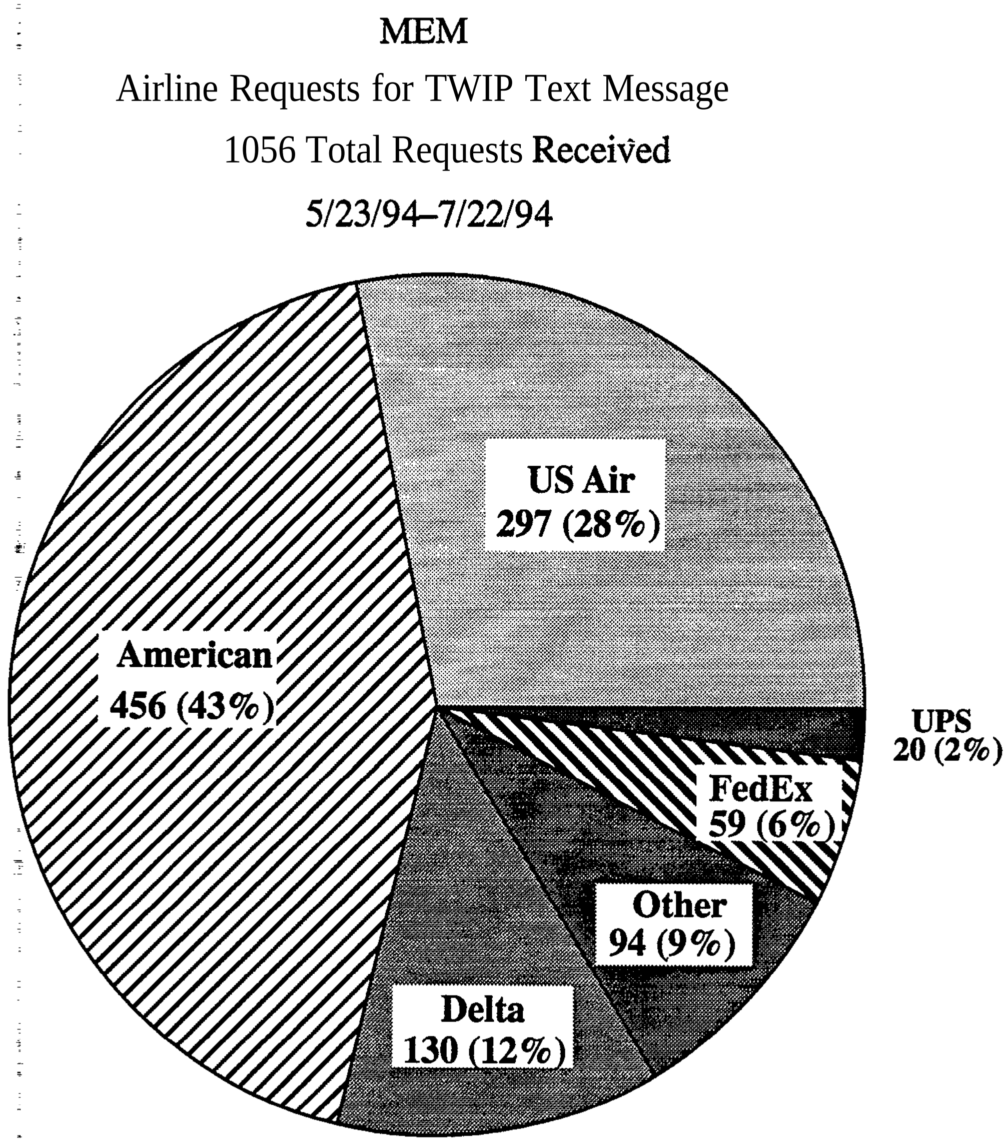

Figure 7. Airline requests for MEM TWIP Text Message (1056 total requests received, 5/23/94–7/22/94).

4.3.1.1.2. Orlando

Figure 8 provides the request/reply message traffic at Orlando on a daily basis. There was an average of 112 text and 20 character graphics requests per day through the end of the DemVal. The number of TWIP requests was considerably higher than for Memphis, where the dominant airline (Northwest) used the forced message method instead of request/reply. The number of requests never fell below 80 after the first day of operation and rose to a peak of 164 requests on August 6th.

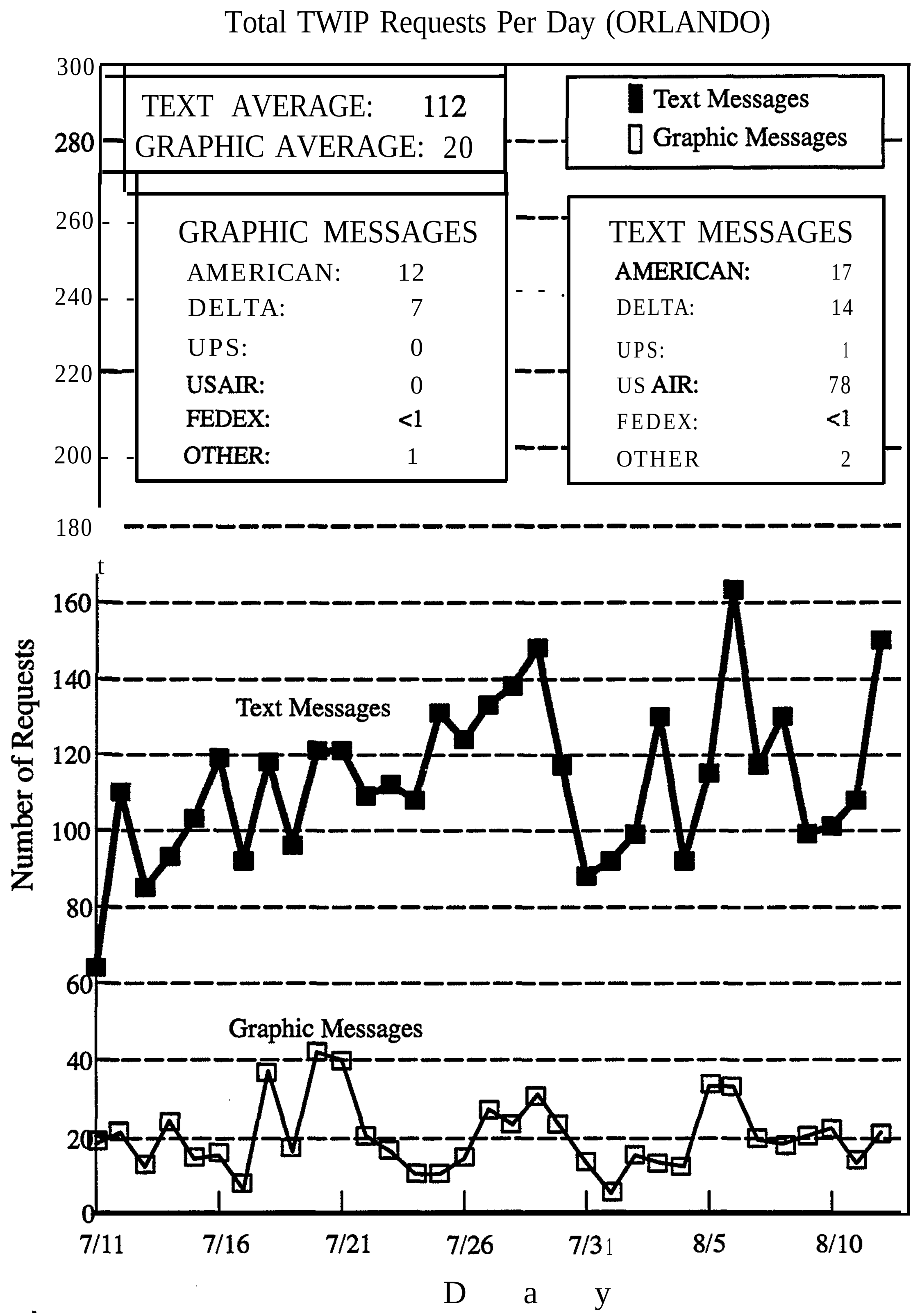

Figure 8. TWIP message requests per day (Orlando).

Figure 9 shows the distribution of message traffic by participating airline (for the five airlines whose pilots could request TWIP messages (American, Delta, Federal Express, UPS,USAir) (note: the "Other" category indicates dispatcher and other miscellaneous requests). It can be seen that USAir had the largest number of requests, with 69 percent of the total. This high number is explained by the fact that in the USAir host computer the TWIP request was tied to a request for MCO weather information. For the other airlines (except for Northwest), the pilot needed to make a non-routine Digital ATIS request in order to obtain the TWIP messages.

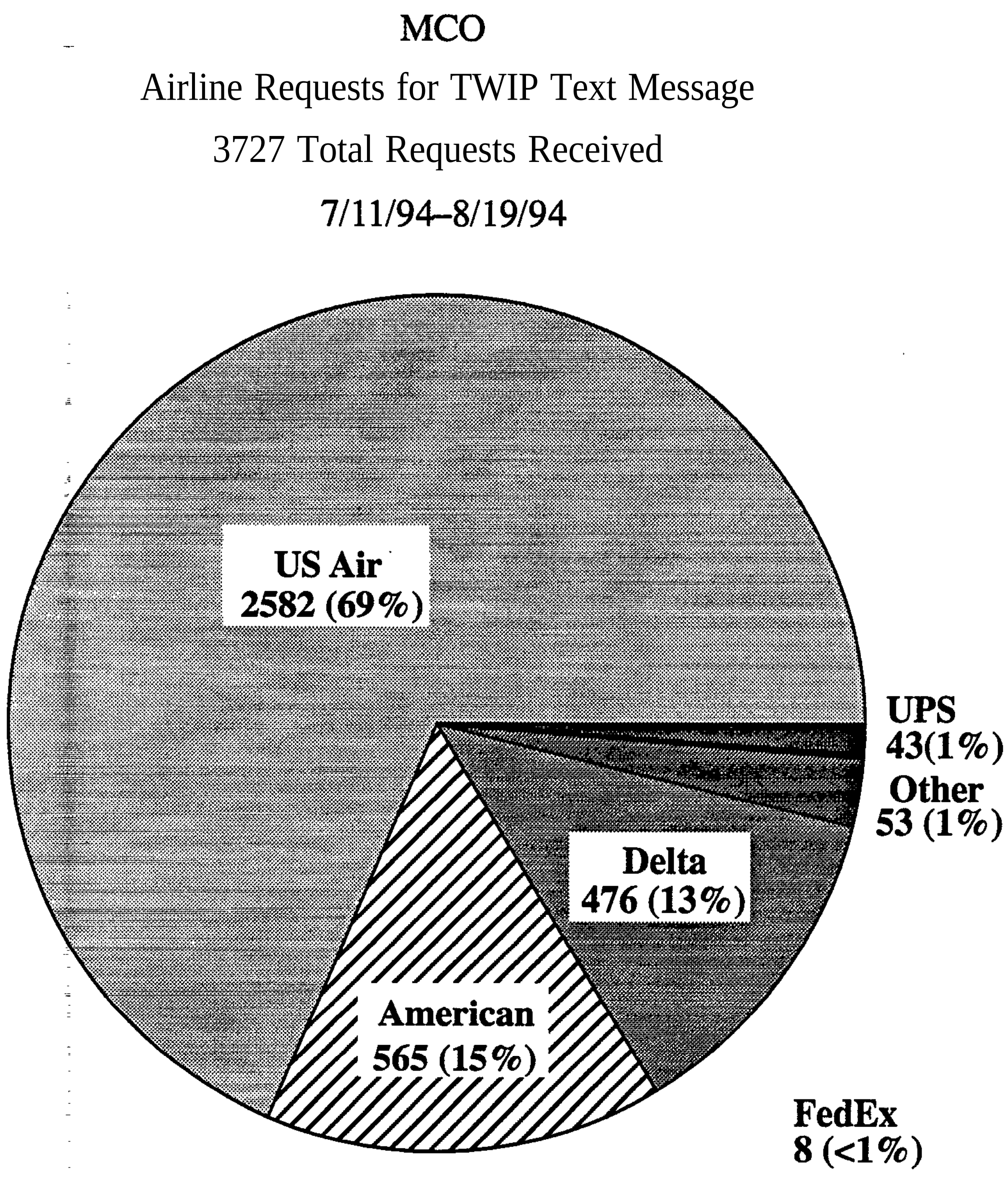

Figure 9. Airline requests for MCO TWIP Text Message (3727 total requests received, 7/11/94–8/19/94).

The number of character graphics requests was lower than the number of text message requests. However, the number of aircraft capable of displaying the character graphics message was also lower. It appears that about 93 operations per day had the necessary equipment for requesting and displaying the character graphics message (all American aircraft and roughly 1/3 of the Delta aircraft). Thus, it appears that the average of 20 requests per day reflects a substantial interest in this product.

4.3.1.2. Forced Message Traffic

The number of forced messages was estimated by finding the special messages in the Lincoln TWIP message archives and determining how many flights should have received a forced message from the Northwest Airlines host computer. These estimates were compared with information received from Northwest concerning the actual number of aircraft that received forced messages for four of the incidents; the estimated and actual numbers were found to agree closely.

4.3.1.2.1. Memphis

There were 18 cases in which special messages were sent to the Northwest host computer, and these triggered approximately 150 forced messages to Northwest aircraft. Thirteen of the cases were wind shear alerts and the other five were microburst alerts. An estimated 22 aircraft received forced messages on June 9th, a day of heavy weather impact. As noted earlier, there were 48 TWIP Request/Reply requests for that day.

During the daily noon to 7 p.m. operations, there are roughly 83 Northwest operations and 27 operations by the other five airlines at Memphis (considering only aircraft with the appropriate ACARS equipage). Thus, there are roughly three times as many Northwest aircraft that could participate in the demonstration as all the other airlines combined. All other things being equal, we might have expected approximately 150 TWIP messages sent to Northwest aircraft, if they had been capable of making requests, instead of the 22 messages actually sent. The conclusion is that the number of forced messages was much lower than would have been expected had Northwest been using the request/reply approach.

One explanation for the lower number of forced messages is that the number of special messages was much lower than anticipated. The primary reason is that the special messages are triggered only by the onset of wind shear activity at the airport. In Orlando, wind shear activity usually accompanies heavy precipitation, but this is not the case in Memphis. The result is that heavy precipitation often impacted the airport without causing wind shear alerts. As a result, a special message was not generated even though the airport traffic was adversely affected. As discussed in the next section, this prompted an examination of the triggering criteria for the special messages.

4.3.1.2.2. Orlando

There were a total of 61 wind shear and 19 microburst special messages sent from the Orlando testbed to the Northwest host computer over the six-week demonstration period. Approximately 40 Northwest aircraft received one or more of these messages. Although there were many more special messages generated in Orlando than in Memphis (80 vs. 1 S), there were far fewer aircraft affected (40 vs. 150). This difference reflects the fact that Northwest has many fewer operations per day (between noon and 7 p.m.) at Orlando than Memphis (14 vs. 83).

The special messages were generated much more frequently in Orlando than in Memphis. In Memphis, there were nine out of 57 days with special message requests, or once every 6.3 days. In Orlando, there were 28 days with special message requests over the 39–day period, or once every 1.4 days. This result is not surprising, since Orlando has many more microburst events than Memphis.

4.3.2. Availability, Reliability and Timeliness

4.3.2.1. Availability

The availabihty of the TWIP messages at Memphis was reduced by several factors. One factor was that the ITWS testbed did not operate on weekends due to limited site personnel. Another factor was that there were several hardware and software failures in either the ITWS testbed or sensors supplying data to the ITWS testbed. As a result the message was not available for eight of the 6 1 days during the demonstration period. Also, as noted earlier, the ITWS testbed normally only operated from noon to 7 p.m. (although it did operate outside of normal hours on days with significant weather).

Of the total of 1056 Memphis TWIP requests, 416 (39 percent) were outside the hours of operation. Another 16 percent of the responses to requests lacked wind shear information (due to a breakdown in the Memphis TDWR), two percent lacked precipitation information (due to problems with the ASR-9 weather channel data or the NEXRAD), and three percent showed the system as unavailable. Only 420 (40 percent) of the responses were made during the hours of operation and contained complete information. However, of the 586 messages containing at least precipitation information, 286 (42 percent) contained storm cell information,

The availability of the TWIP messages for Orlando was much better than for Memphis. During the normal hours of operation (noon to 7 p.m.) the message was unavailable four percent of the time, partially available (wind shear, precipitation or storm motion unavailable) six percent of the time and fully available for 90 percent of the messages. As in the previous summer's demonstration, there were a substantial number of requests outside of the normal operating hours (49 percent of the requests), pointing up the need for a 24 hour per day demonstration.

4.3.2.2. Timeliness and Reliability

Statistics were provided by ARINC concerning the timeliness and reliability of TWIP message delivery. The message deliver failure rate was quite low during most of the demonstration, except for a Tandem/ACARS Front-End Processor (AFEPS) time synchronization problem during June 29th through July 5th. This time synchronization problem raised the failure rate to 3.6 percent, but if this period is discounted the failure rate was only 0.7 percent over the demonstration time period.

The average time to deliver the TWIP messages depended on the airline configuration. American, Federal Express and UPS requests went directly to the Tandem database and back to the aircraft. The average time from request to message delivery was 14.7 seconds for these users. USAir and Delta requests are relayed to the airline host computer, then to the database and then sent directly back to the aircraft, which is a more time consuming process. The average time for delivering these messages was 21.5 seconds for these airlines.

The character graphics messages take longer to deliver than the text messages because they consist of multiple blocks. A problem was encountered with the American Airlines avionics which slowed delivery of some character graphics messages. Discounting the effect of this avionics problem, the average message delivery time was 42 seconds.

4.4. Case Analysis Evaluation

The case analysis evaluation was begun based on the Lincoln data archives, which include the TWIP messages, ITWS graphical products and National Weather Service (NWS) SAOs. Aircraft delay information also was received from Northwest for analysis of the special messages.

4.4.1. Request/Reply Message Case Analysis

Analyses of the request/reply text and character graphics messages were carried out for Memphis and Orlando cases. Two cases were considered: a 100–minute period at Memphis from 1703 to 18432 on July 9th and a two-hour period at Orlando starting at 20002 on August 5th. Plots were generated showing the TWIP text and character graphics messages, ITWS graphical products, ITWS ribbon display messages and SAO at four-minute intervals during the period under consideration. For each plot, the TWIP text message, TWIP character graphics and SAO were compared to the ITWS graphical plot to determine whether the TWIP messages or SAO provided a more accurate representation of the weather situation.

For the Memphis case, it was found that the TWIP text message provided a better representation of the terminal weather situation in all 25 instances. For eight of the plots, the TWIP message showed storm cells within 15 nm of the airport, whereas the SAO provided no indication of storm cell activity. For six of the plots, the SAO provided an indication of storm cell activity but did not indicate the direction of motion (whereas the TWIP message did), and in six of the plots the SAO provided the direction of movement but not the speed (which was provided by the TWIP message). For one plot, the TWIP message indicated the presence of a wind shear alert at the airport, which the SAO does not provide. Finally, in four of the plots, the SAO indicated that the weather was overhead, whereas the TWIP message correctly noted that the weather had actually moved to the northeast and was no longer a factor. The TWIP character graphics product depicts the weather situation even more clearly than the text message, for those users with the necessary display capability.

For the Orlando case, it was found that the TWIP text message provided a better representation of the terminal weather situation in all 30 instances. For 13 of the plots, the TWIP message showed storm cells within 15 nm of the airport, whereas the SAO provided no indication of storm cell activity (in fact, the SAO provided no remarks on storm cell activity at all during the two–hour period of weather impact). For the remaining 17 plots, the TWIP message provided the following indications: moderate precipitation (2), heavy precipitation (5), wind shear alert (8) and microburst alert (2). The TWIP character graphics product depicted the weather situation even more clearly than the text message (for those users with the necessary display capability), showing the presence of precipitation, gust fronts and microbursts in the airport vicinity.

These case analyses show that the TWIP messages provide substantially more accurate and timely information about the terminal weather than the SAO. This supports the conclusion that the TWIP messages improve pilot situational awareness of terminal weather hazards over SAO. It should be noted further that the remarks section of the SAO (containing storm cell location and motion information) is not provided in the ATIS message. Furthermore, this storm cell information is not provided at all for automated surface observations provided by ASOS/AWOS.

There are two types of information provided in the SAO that are not currently provided in the TWIP text messages but which might potentially be considered for inclusion: lightning and wind speed/gusts. The Pilot's User Group has been asked whether lightning information should be included in the TWIP message and the answer has been consistently negative. It appears that lightning information is viewed as unnecessary by air carrier pilots if the precipitation severity (moderate, heavy, hail) is known. The wind speed and gust information could be provided in the TWIP message, but no requirement has emerged from the pilot user group.

4.4.2. Special Message Case Analysis

Figure 10 provides an analysis of a special message case which occurred on June 8th at Memphis. As seen in the figure, the TWIP messages began including a "expected heavy precipitation" notice at about 12502 and began reporting "heavy precipitation" at about 1305Z. Three Northwest aircraft were scheduled to land in the next 10 minutes. Due to this weather, two of these aircraft were forced to hold for 50 and 75 minutes, respectively, and the other aircraft was diverted to Nashville. None of these aircraft received a TWIP message because there was no wind shear activity, even though they were substantially affected by the heavy precipitation at the airport.

A special message was issued at 13492 about the time another Northwest aircraft was about to take off. This special message occurred after the heavy precipitation had passed and was cancelled about the time the aircraft took off. The special message therefore did not appear to affect the pilot's decision to depart.

Figure 11 provides an analysis of a special message case which occurred on July 14th at Orlando. The figure shows the alphanumeric wind shear alerts provided to the controllers and the corresponding TWIP special messages. As can be seen in the figure, a large number of special messages were issued starting at 19452 and continuing through 21352. Many of these messages

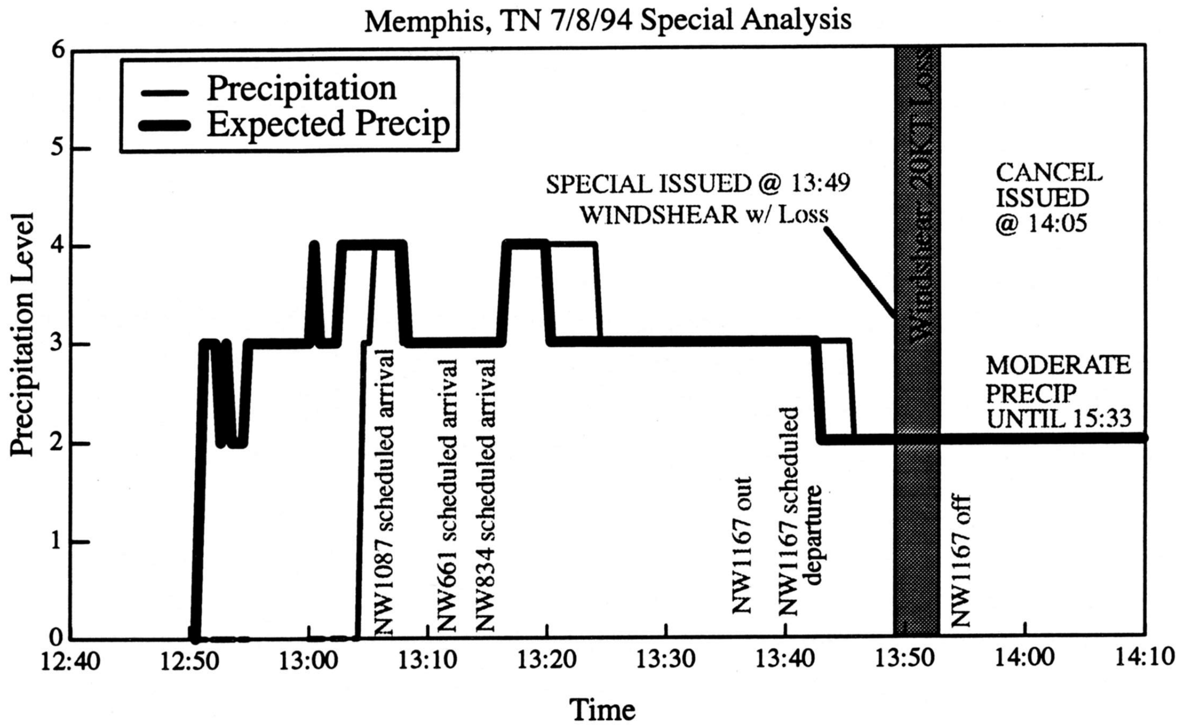

Figure 10. Analysis of special TWIP messages for June 8, 1994 case at Memphis.

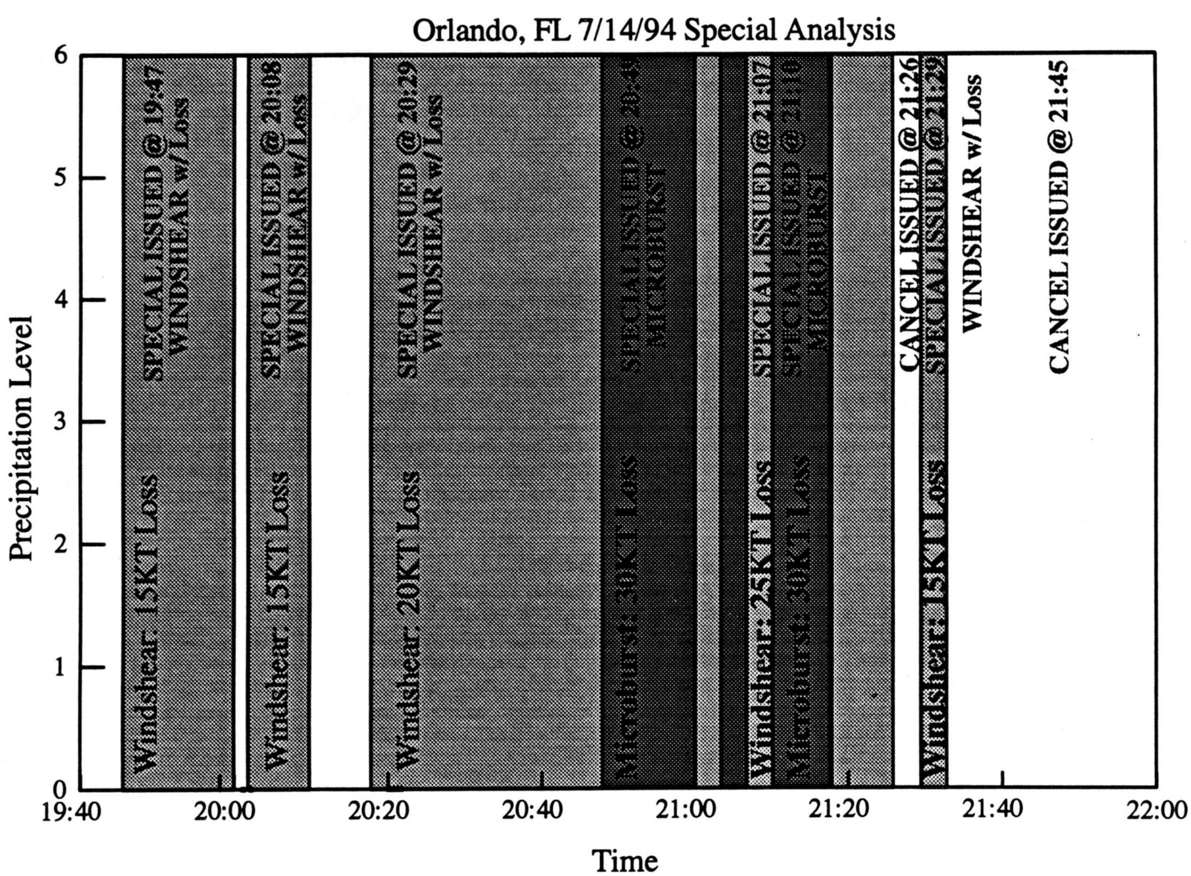

Figure 11. Analysis of special TWIP messages for July 14, 1994 case at Orlando.

were for weak wind shears that would not be expected to cause operations to cease. There was also a period between 2050Z and 2115Z where the special messages rapidly alternated between wind shear (<30 kt loss) and microburst (30 kt or greater) levels. It appears from this case that the criteria for issuing special messages should be revised.

4.5. Radio Traffic Analysis

Due to logistical and other considerations, it did not prove feasible to record the pilot/controller radio conversations at Memphis. Radio conversations at Orlando were recorded both before and during the demonstration. These conversations were transcribed for two days, July 6th (1703–1959Z) and July 28th (1849–2136Z). There were 12 requests for weather information on July 6th (prior to the demonstration), of which five (42 percent) were from participating airlines.

There were five requests for weather information on July 28th (during the demonstration), of which only one (20 percent) was from a participating airline, The pilot of this aircraft carried on a lengthy conversation with the tower concerning weather conditions in the terminal area. A subsequent check showed that although this aircraft was equipped to receive both the text and character graphics messages, the pilot (for some unknown reason) did not request either TWIP message.

It is interesting to note the nature of the weather requests. Of the 17 instances on the two days, the requests can be categorized as follows: general weather conditions (35 percent), microburst/wind shear alerts (29 percent), cell location/strength (12 percent), cell motion (12 percent) and surface winds (12 percent). It can be seen that the TWIP messages provide the requested information in all cases except surface winds (which is available via ATIS).

5. CONCLUSIONS

The number of aircraft participating in the Memphis demonstration was lower than in last year's Orlando demonstration. However, the cause of this difference is the lower number of aircraft at Memphis capable of requesting the TWIP message. When the lower number of aircraft capable of requesting the TWIP messages is considered, the percentage of aircraft making requests is comparable to Orlando. The number of TWIP requests was found to increase dramatically on days with weather impact. The rate of character graphics requests was found to be high at Memphis, considering the limited number of aircraft capable of requesting and displaying the message. A particularly large number of character graphics requests was made on the day with the worst weather impact of the demonstration period.

The number of TWIP text message requests per day at Orlando was much higher than at Memphis (112 per day vs. 21 per day). This difference was mainly due to the larger number of aircraft at Orlando that could make TWIP requests. The number of TWIP character graphics requests also was higher (20 per day at Orlando vs. seven per day at Memphis) for the same reason. The airline with the highest rate of pilot participation (other than USAir for which the TWIP message was tied to Orlando weather requests) was American, with 34 percent of the flights requesting the text message and 24 percent of the flights requesting the character graphics message. Given the short duration of the Orlando demonstration, limited ITWS testbed operational hours and other factors, this level of participation reflects substantial interest in the TWIP products and is consistent with the previous summer's demonstration.

The percentage of aircraft receiving the forced updates was small at Memphis because of the criteria used to trigger the special messages. Currently, these messages are triggered by the onset of microburst or gust front alerts at the airport. However, heavy weather often impacted the Memphis airport and disrupted operations without generating wind shear alerts. The criteria for triggering the special messages therefore should be reexamined, with the possible consideration of using "expected heavy precipitation" as a triggering condition.

The number of aircraft receiving the special messages was small in Orlando, averaging less than one per day. Although there were many more special messages in Orlando than Memphis (80 in Orlando vs. 18 in Memphis), there were fewer aircraft affected (40 in Orlando vs. 150 in Memphis) due to less Northwest traffic at Orlando. Analysis of the July 14th case showed that a large number of special messages were generated under the current triggering criteria. While few aircraft received special messages, those that did tended to receive several. The criteria for generating these messages should therefore be reexamined to reduce the number of forced updates.

The pilot questionnaire results also suggested that some of the pilots receiving the forced updates thought that the messages were too long and complex. Given that pilots may be receiving these forced updates in a critical phase of flight, consideration should be given to shortening and simplifying the special messages. Reducing the frequency of these updates would also be helpful in this regard.

The pilot questionnaires also indicated a positive response to the character graphics message. There was some confusion over the map symbols and orientation (Note: These problems will be corrected in the next year's demonstration.). The pilots indicated a strong desire for a color graphics depiction of the terminal weather situation.

The controller questionnaires indicated that providing the TWIP messages to pilots did not substantially increase the number of requests for weather information or the level of radio traffic in general. The analysis of the radio transmissions suggested that the availability of TWIP messages could reduce controller workload in providing terminal weather information over the radio.

As in the previous year's demonstration, the limited hours of operation (noon to 7 p.m.) and limited demonstration time period (six weeks) hampered the effectiveness of the demonstration. However, the usefulness of the TWIP text and character graphics products were demonstrated by the requests generated by pilots for this information. Moreover, case analysis shows the TWIP messages provide greater situational awareness than the SAO.

In summary, the demonstration was highly successful. As in the previous year's demonstration, the Terminal Weather Text Message was rated very favorably by the pilots. The new Terminal Weather Character Graphics product was also rated favorably, despite some confusion over symbols and map orientation. Pilots indicated that the TWIP products increase situational awareness of terminal weather hazards and would like to see these products made available 24-hours per day.

6. RECOMMENDATIONS

As shown in the June 8th case analysis, it appears that using "expected heavy precipitation" as the trigger for the special message would have improved the usefulness of the TWIP messages to Northwest Airlines aircraft. It also would have provided an advance notification to Northwest dispatchers of the developing weather situation. It is therefore recommended that "expected heavy precipitation" should be examined as a triggering condition for the special message. Consideration also should be given to simplifying the special messages and to reducing the number of forced updates in rapidly changing weather conditions in order to decrease impact on crew workload.

Changes should be considered in the character graphics map to make the symbols easier to understand. Also, the orientation of the map (north up) should be clearly indicated. The possibility of demonstrating the character graphics map on devices other than printers (such as the Bendix touchscreen display) should be pursued.

The TWIP demonstration was somewhat hampered by the limited operational hours of the ITWS testbed (noon to 7 p.m. on weekdays only), the limited length of the demonstration (two months), limited number of aircraft that could request the TWIP messages and a variety of hardware/software problems in the ITWS testbed that frequently interrupted service. It is recommended that a high priority be attached to a demonstration that operates 24 hours per day, seven days per week next summer, using an operational TDWR at an airport with a high concentration of aircraft that can request the text and character graphics messages. Based on the success of the demonstrations, additional sites should be selected for demonstrations in 1995 to evaluate the use of TWIP in other weather environments.

It is also recommended that greater emphasis be placed on determining the impact of TWIP message availability on pilot decision making. The pilot questionnaire format should be modified to capture cases in which an operational decision was changed based on TWIP information (i.e., holding in order to avoid expected heavy precipitation impact). Consideration should also be given to simulator experiments to quantify these effects.

GLOSSARY

ACARS	Aircraft Communications Addressing and Reporting System
ADNS	ARINC Data Network Service
AFEPS	ACARS Front-End Processor
ARINC	Aeronautical Radio, Inc.
ASOS/AWOS	Automatic Surface Observation System/Automated Weather Observing System
ATIS	Automatic Terminal Information Service
ATN	Aeronautical Telecommunications Network
CIC	Controller in Charge
DLP	Data Link Processor
FAA	Federal Aviation Administration
FAATC	Federal Aviation Administration Technical Center
IOC	Initial Operating Capability
NADIN PSN	National Airspace Data Interchange Network Packet Switched Network
NAS	National Airspace System
NWS	National Weather Service
TWIP	Terminal Weather Information for Pilots
ITWS	Integrated Terminal Weather System
SAO	Surface Aviation Observation

REFERENCE

1. S.D. Campbell, "Terminal Weather Message Demonstration at Orlando, FL, Summer," Lexington, MA, MIT Lincoln Laboratory, DOT/FAA/RD–94/3 ATC–210, 4 March 1994.