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DISSEMINATION OF TERMINAL WEATHER PRODUCTS TO THE FLIGHT DECK VIA DATA LINK

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1. INTRODUCTION

Flight crews need timely information about terminal weather conditions when approaching or departing airports. This paper describes a new concept in providing this information from new ground-based terminal weather sensors currently being deployed via new and existing data link systems.

Currently, pilots rely on ATIS (Automatic Terminal Information System) for airport weather conditions. However, the Surface Observation (SAO) contained in the ATIS message is nominally only updated once per hour. Special observations are issued more frequently, but are difficult to keep current manually in rapidly changing conditions.

The Automated Surface Observing System (ASOS) and Automated Weather Observing System (AWOS) are beginning to supplant manual surface observations in many locations. These automated systems offer the advantage of providing continuous, automated surface observations. However, the surface observations issued by these units lack the remarks section provided by manual observers, including such information as the location and motion of storm activity in the airport area.

The shortcomings of the current ATIS system were illustrated by an incident at Kansas City International Airport (MCI) in the evening of September 8, 1989. An aircraft approaching from the West received an ATIS message indicating 10 miles visibility at the airport. However, unknown to the crew, an intense storm was approaching the airport from the East.

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By the time the aircraft reached the airport (about 30 minutes after the initial ATIS message was received), the visibility had dropped to 1/2 nmi, but the flight crew was not notified. The aircraft subsequently struck power lines while on final approach and was forced to make an emergency landing at an alternate airport.

This example provides a vivid example of current shortcomings in the generation and dissemination of terminal weather information to the flight deck. Besides improving safety, improved access to terminal weather information would provide economic benefits by allowing more efficient flight planning and utilization of air space.

Fortunately, a number of FAA funded programs are currently under development to provide ground systems capable of producing textual and graphical weather products to both ground operations (FAA and airlines) and to the flight deck. The Terminal Doppler Weather Radar (TWDR) program is currently installing 45 radars in the U.S. which will perform automated detection of microburst and gust front wind shear hazards, forecasting of wind shifts and depiction of precipitation levels. The Integrated Terminal Weather System (ITWS) is currently under development to extend these capabilities by integrating multiple sensor systems in order to provide additional products such as terminal winds, weather impacted airspace, lightning, and ceiling and visibility prediction.

The technology and infrastructure for providing existing and near term products to the flight deck exists today. The Aircraft Communications, Addressing and Reporting System (ACARS) provides air/ground connectivity throughout North America, and extends to over 500 airports worldwide. ACARS is currently used to transmit Pre-Departure Clearances (PDC) and in the near future will be used to transmit Digital Automatic Terminal Information System (ATIS) Air Traffic Control messages (Digital ATIS).

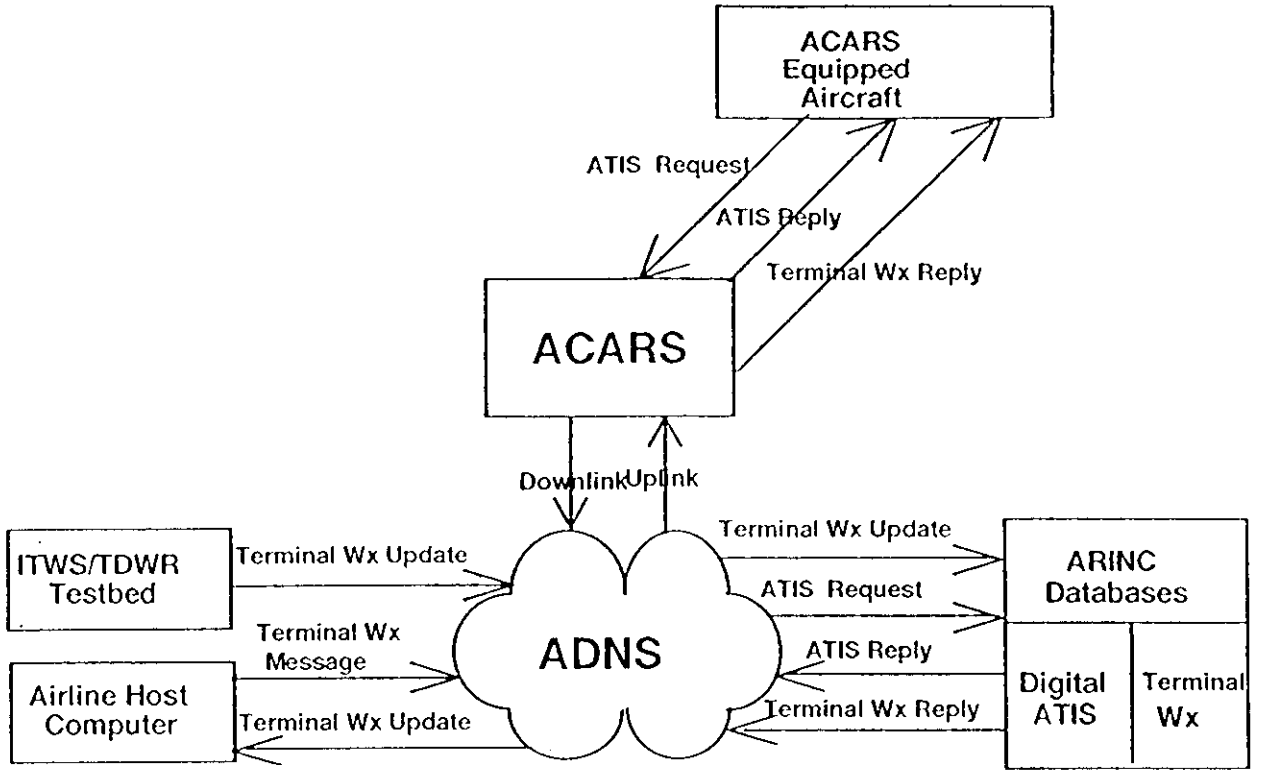

Figure 1. ACARS Terminal Weather demonstration architecture.

Improvements are also planned in the area of providing enhanced data links between the air and ground. The Aviation VHF Packet Network (AVPAC) and VHF Digital Radio (VDR) enhancements to ACARS will be available in North America in 1994. The Mode-S data link will also be initially available in this time frame. By providing increased information transfer rates, these new data link capabilities will facilitate the transfer of graphical products to the flight deck.

Plans are underway to demonstrate the delivery to aircraft via data link of products generated from the Terminal Doppler Weather Radar (TDWR) / Integrated Terminal Weather System (ITWS) test bed in Orlando, Florida during the summer of 1993. The demonstration will provide microburst and gust front wind shear alerts, precipitation levels and wind shift forecasts to the flight deck via ACARS.

This paper will discuss the demonstration at Orlando, including an operational overview, prototype message formats and plans for gauging pilot reactions to the proposed service. The paper will also address short term plans for operational systems and longer term plans for delivering graphical weather products to the flight deck via data link.

2. OPERATIONAL CONCEPT

As shown in Figure 1, the proposed demonstration will use the Digital ATIS platform, which is in the process of being installed in 30 airports (including Orlando) that currently have Pre Departure Clearance (PDC) delivery. As shown in the figure, an ATIS request from an ACARS equipped aircraft will be routed through ACARS and the ARINC Data Network Service (ADNS) to a central database (at Annapolis, MD) containing the current ATIS information. The ATIS processor will uplink the appropriate ATIS response to the aircraft via ACARS.

For the Orlando demonstration, the ATIS request will also trigger a second ACARS reply, which will be a Terminal Weather message. This Terminal Weather message will be retrieved from a second ARINC database which will be updated once per minute from the ITWS/TDWR testbed at Orlando via a direct land-line connection to ADNS.

For the Orlando demonstration, Terminal Weather service will be strictly request-driven (i.e., there will be no forced updates in the basic service). However, if a particular airline wishes to force updates to their

aircraft, this can be done via the airline's host computer. The decision to follow a request/reply protocol, rather than periodic updates, stems from technical and pilot workload considerations.

For the purpose of the demonstration, the request/reply scenario eliminates the possibility of the flight crew receiving forced uplinks during critical phases of flight. If the flight crew desires an update on terminal weather conditions, they can request Digital ATIS again. Forced updates can also be initiated by the airline host computers. ARINC will send every update to the Terminal Weather database received from the TDWR/ITWS testbed (nominally once per minute) to the airline host computers for use in dispatch and for uplink by the airline.

4. MESSAGE CONTENT AND FORMAT

The operational concept and message formats for the Orlando demonstration were developed by an ad hoc airline industry committee. This committee was composed of representatives of five airlines, plus advisors from several research organizations.

A survey of the ACARS equipage among the airlines revealed that 22 characters should be the maximum width of a message line. There is no limit on the number of lines, but the most important information should appear on the first 10 lines, since theses would appear on the first page of the display.

It was decided that the message should contain the following elements:

- Airport identifier and time
- Current runway weather impacts
- Current airport area weather phenomena
- Predicted airport weather impacts

Concerning runway impacts, it was agreed that these should include microbursts (30 knot or greater losses), wind shears (< 30 knot losses and all gains) and precipitation impact. The precipitation impact would be characterized as Moderate (level 2) or Heavy (level 3 or greater). The microburst and wind shear impacts will be listed separately by runway and the precipitation impact will be listed for each runway (if level 2 or greater).

After the runway impacts have ceased, there should be a message indicating the time the impact ended (i.e., supplied as an update to the ARINC database) for some time period (e.g., five minutes) after the impact ends. In the event that there is no microburst or wind shear impact on the runway but there is moderate or heavy precipitation on a runway, these impacts may possibly be listed.

The current airport area weather phenomena should include the location and motion of storms, microbursts and gust fronts. The predicted airport weather impacts should include expected time of arrival for moderate or heavy precipitation, microbursts and gust fronts. It should also include (if possible) the expected time at which these phenomena are expected to cease impacting the airport.

A summary of the proposed format is shown in Table 2. (note: this format was originally suggested by Timothy Miner of American Airlines). This example message illustrates all of the elements that can appear in a Terminal Weather message. The first line identifies the message as applying to the McCoy International Airport (MCO) at 1827 Universal Time. The remainder of the message is divided into several blocks to improve readability.

The first block provides all microburst alerts for the

Table 2. TWDLS messsage format.

```
                1         2
col  12345678901234567890123
row
 1   MCO ADVISORY 1827
 2   *MICROBURST**********
 3     RWY18L APP 30KT LOSS
 4           HEAVY PRECIP
 5   *WIND SHEAR**********
 6     RWY17  APP 25KT LOSS
 7         MODERATE PRECIP
 8     RWY18L DEP 25KT GAIN
 9   *PRECIPITATION********
10     RWY17  DEP
11         MODERATE PRECIP
12   --STORM..... 5NM E
13         MOVG W AT 5KT
14   --MICROBURST.....3NM N
15         MOVG S AT 5KT
16   --GUST FRONT   10NM NE
17         MOVG SW AT 10KT
18   ..EXPECTED HVY PRECIP
19     BEGIN 1840 END 1855
20   ..EXPECTED MICROBURST
21     BEGIN 1843 END 1850
```

active runways;. In this case, there is a 30 knot microburst impacting runway 18 Left approach. and there is also heavy precipitation (level 3 or greater) present.

The second block provides any additional wind shear alerts for active runways (note: a wind shear alert is any microburst alert with less than 30 knots loss or any gust front (gain) alert). In this case, there are two alerts, a 25 knot loss on runway 17 approach and a 25 knot gain on runway 18L departure. (Note: a "LOSS ENDED" message will be issued for the last runway impacted for five minutes after the impact ends).

The third block provides messages for any runways with no wind shear but with moderate or heavy precipitation. In this case, runway 17 departure had moderate precipitation impact. (Note: each of these three blocks only appears if microburst, wind shear or precipitation impact the runway).

The next block indicates the presence of a storm five nmi East of the airport moving West at 5 knots. The next two blocks similarly note the presence of a microburst and a gust front near the airport.

The last two blocks indicate that heavy precipitation is expected to begin at the airport at 1840 and to end at 1855. Similarly, the last block indicates that a microburst is expected at the airport at 1843 and to end at 1850.

An example of a Terminal Weather message is shown in Figure 2. The left-hand window shows the weather impact on the airport graphically, while the upper and lower right windows show the corresponding TDWR and Terminal Weather messages. In this case, a 30 knot microburst is impacting runway 17 approach at 3 miles final. This is indicated by the TDWR message by "17A MBA 30KT- 3 MF" (the last two numbers are the threshold winds).

The lower right window shows the Terminal Weather message for this case. The microburst alert appears first after the header and includes the notation that heavy precipitation is present. Next, it is noted that moderate precipitation is impacting runway 18 approach. Following this, the presence of the microburst and storm at the airport is noted along with the speed and direction of motion. Finally, there is a notation that the heavy precipitation is expected to end in ten minutes.

4. ORLANDO DEMONSTRATION

The Orlando demonstration will be conducted from July 1st through September 30th, 1993. As of this writing, five airlines serving the Orlando airport plan to participate in the demonstration. In order to gauge the reaction of pilots to the proposed service, questionnaires will be made available to the flight crews of participating airlines. It is also planned to make a toll-free telephone number available for pilots to provide their comments directly.

Pilot surveys will include such questions as:
- Did you receive a Terminal Weather message?
- If so, did it affect your decision-making?
- What elements were good and bad?
- What changes should be made?
- Should the system be made operational?

In addition, it is planned to collect statistics on the frequency of Terminal Weather requests during the demonstration period.

5. FUTURE WORK

Two additional demonstrations are planned for the summer of 1994. An improved version of the Terminal Weather text message service will be demonstrated at the Integrated Terminal Weather System (ITWS) testbed at Dallas/Ft.Worth (DFW) airport. This version will incorporate advanced ITWS products for microburst prediction and detection, gust front detection and weather impacted airspace. Demonstrations of the basic service may also be conducted at selected operational TDWR sites.

A second demonstration is planned of providing graphical Terminal Weather products to aircraft via ACARS. This effort will take advantage of work at Lincoln Laboratory in the development of weather radar data compression techniques (Gertz, 1990). These techniques allow the compression of weather radar maps to 1 to 2 kilobits for transmission via data link. For this demonstration, a Terminal Weather graphical image will be generated by the ITWS testbed, and compressed for ACARS transmission as free text.

A suitably equipped air carrier aircraft will receive the ACARS message and present it to an on-board computer for processing. This computer will decompress the message and pass it on a radar display. It is planned to install at least one such system in an air carrier aircraft in regular service to the DFW airport.

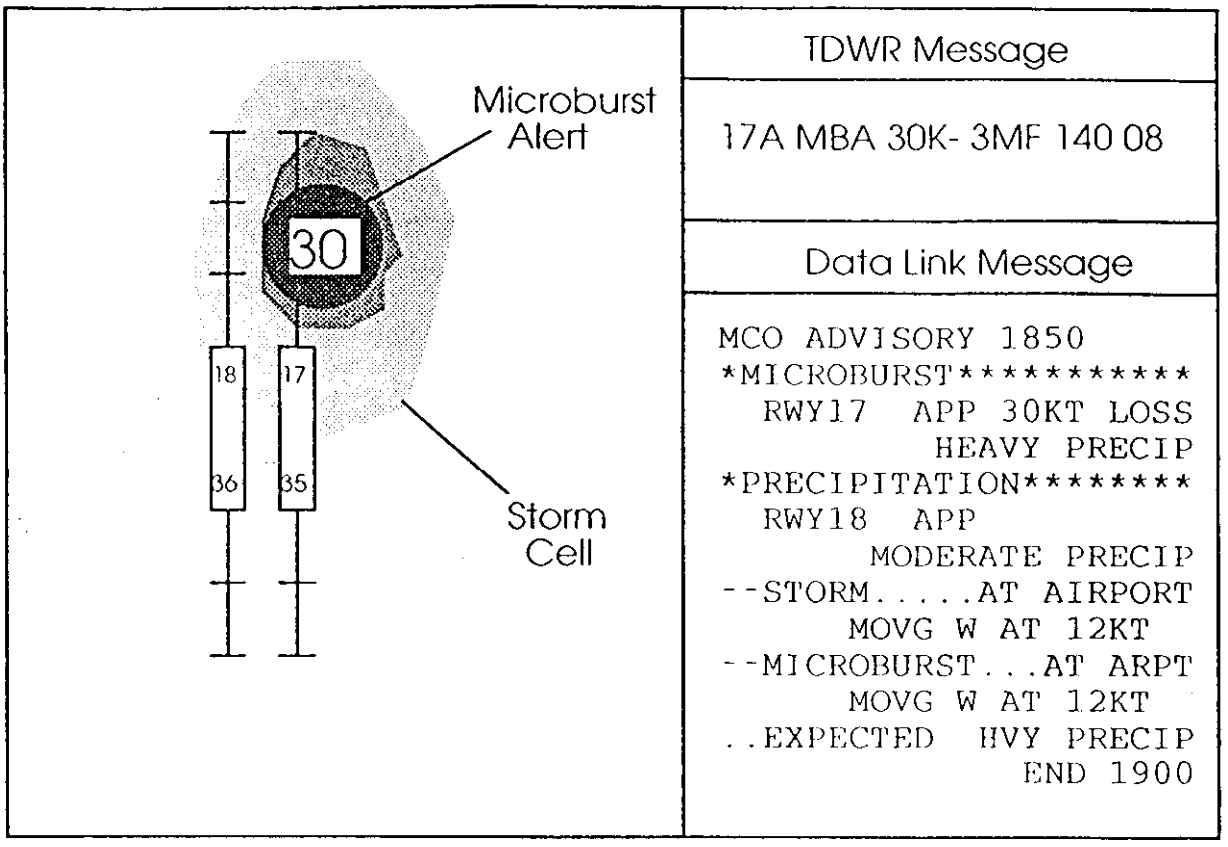

Figure 2. Example of Terminal Weather text messsage.

6. SUMMARY

A new concept for providing up-to-the-minute terminal weather information based on ground radar and other information was presented. The proposed Terminal Weather Data Link Service would provide near real-time information about 1) runway wind shear, and precipitation impact, 2) microburst, gust front and storm cell location and motion near the airport and 3) forecasted wind shear, precipitation and wind shift impact at the airport.

The proposed service makes use of the existing ACARS data link capability found in many air carrier aircraft and the new ground-based weather sensing systems, such as TDWR, which are currently being deployed. A demonstration of the proposed service is planned during the summer of 1993 at Orlando, FL involving up to five air lines. Additional demonstrations are planned for 1994 involving the use of advanced Integrated Terminal Weather System weather products and the transmission of graphical weather products via ACARS.

7. ACKNOWLEDGMENTS

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