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THE TERMINAL WEATHER INFORMATION FOR PILOTS PROGRAM*†

Andrew P. Denneno*, Steven D. Campbell, C. R. Storm, and R. K. England

Lincoln Laboratory
Massachusetts Institute of Technology
Lexington, Massachusetts, U.S.A.

1.0 INTRODUCTION

The Federal Aviation Administration (FAA) is currently sponsoring programs such as the Terminal Doppler Weather Radar (TDWR) and the Integrated Terminal Weather System (ITWS) which will significantly improve the aviation weather information in the terminal area. Given the great increase in the quantity and quality of this information, it would be highly desirable to provide this data directly to pilots rather than having to rely on voice communications. Providing terminal weather information automatically via data link would both enhance pilot awareness of potential weather hazards and reduce air traffic controller workload.

The Terminal Weather Information for Pilots (TWIP) program was created to address these needs. This paper will describe the philosophy behind the product, the format of the TWIP messages, and the system design. An interesting weather case from the operational demonstration currently underway will be shown, and plans for the national deployment of the TWIP capability at all TDWR–based airports will be discussed.

2.0 TWIP BACKGROUND

The TWIP product was originally designed to be a part of an operational ITWS. Feedback from pilots was very favorable, with the exception of the problem of availability. (Campbell, 1995). Currently, ITWS capability is provided by experimental functional prototype systems only, and availability is limited. Pilots found it frustrating that the TWIP message was unavailable when ITWS was not in operation. In order to provide TWIP messages on a 24 hour per day, 7 day per week basis, it was decided to obtain the weather products necessary to generate TWIP messages from an operational TDWR by using an "outboard" engineering workstation attached to the TDWR product port. These products include graphical microburst information, graphical gust front information, precipitation information, wind shear alert, and microburst alert information. Washington National Airport was the first site to provide TWIP service utilizing TDWR products on a continuous basis starting in September 1995. Atlanta Hartsfield Airport became the next 24–hour operational TWIP demonstration site the following month. Logan International Airport in Boston, MA and Charlotte Airport in Charlotte, VA were added in July and August 1996, respectively. Two more airports, Denver International Airport and O'Hare Airport in Chicago, are scheduled to become TWIP demonstration sites later in 1996.

3.0 TWIP MESSAGE FORMATS

Two types of Terminal Weather Information for Pilots (TWIP) messages are generated: a text–only message and a character graphics map. In order to ensure their operational utility, these products were developed in consultation with a group of experienced aircraft line pilots. The TWIP Text Message is intended for typical ACARS cockpit displays, which are roughly 20 characters wide by 10 lines high. The TWIP Character Graphics Depiction is intended for the cockpit printers (available on some aircraft) that are at least 40 characters wide. Both products are intended to provide strategic information to pilots about terminal weather conditions to aid flight planning and improve situational awareness of potential hazards.

3.1 Text Message

The TWIP Text Message consists of four sections: header, runway impact, storms and expected/previous. The header section provides the airport identification and the report time in GMT plus a line identifying the message as terminal weather information.

* This work was sponsored by the Federal Aviation Administration. The views expressed are those of the authors and do not reflect the official policy or position of the U.S. Government.

† Opinions, interpretations, conclusions, and recommendations are those of the authors and are not necessarily endorsed by the United States Air Force.

Corresponding Author Address:
Andrew P. Denneno
MIT Lincoln Laboratory
244 Wood Street
Lexington, MA 02173–9185
e–mail: denneno@ll.mit.edu

The second section (identified by a leading asterisk (*)) is included if any active runway is impacted by a microburst, gust front, heavy precipitation (level 3 or above) or moderate precipitation (level 2). For microburst or gust front impacts, the magnitude of the gain or loss is indicated on the next line. The last line of the section indicates the time the impact began. Only the most severe type of hazard impacting the active runways is reported. Thus, if multiple types of impacts are occurring, then the precedence is microburst (30 knot or greater loss), wind shear with loss (less than 30 knots loss), wind shear with gain (gust front), heavy precipitation and moderate precipitation.

The third section (identified by a leading dash (–)) is included if there are any storms (level 2 or greater) within 15 nm of the airport. The first line of the section indicates the presence of one or more storms. The next lines list the three storms closest to the airport reference point (ARP). If more than one storm exists at a given range, then the most intense is listed first. Each storm is described in terms of distance to the ARP (in nautical miles), azimuthal extent and intensity (moderate or heavy precipitation). The azimuthal extent is given in terms of starting and stopping compass octant (e.g., NE) in the clockwise sense; if the storm is less than 1 nm from the airport, then the azimuth is given as all quadrants (ALQDS).

The fourth section of the message (identified by a leading period (.)) is included if there is expected precipitation, previous wind shear or microburst, or no storms within 15 nm of the airport. If moderate or heavy precipitation is expected at the airport within 20 minutes, then the expected precipitation line is issued, followed by a line showing the time the precipitation impact is expected to start. If more than one type of precipitation impact is expected, then only the most severe expected impact will be shown. Also, the expected precipitation must be more severe than the current runway impact in order to be displayed.

If there was a previous microburst or wind shear runway impact which is now over, then the fourth section will note the previous impact (also indicated by a leading period) plus the beginning and ending time of the impact on the following line. Also, in the event that there are no storms within 15 nm of the airport, the fourth section will consist of a single line indicating ".NO STORM WITHIN 15 NM"

Figure 3–1 provides examples of TWIP Text Messages. The left side of the figure shows the weather situation and the right side shows the corresponding text messages. Examples of four messages for the Orlando airport (MCO) at 10–minute intervals, starting at 1800Z (note: the TWIP Text Messages are generated once per minute when weather is near the airport but only every tenth message is shown here for convenience).

The first message at 1800Z shows a storm cell with moderate and heavy precipitation located to the east of the airport and moving west at 15 knots. Note that the message indicates that moderate precipitation is expected to impact the airport in five minutes.

The second message at 1810Z shows that moderate precipitation is now impacting the airport and that the impact began at 1805Z. Note that the message now indicates that heavy precipitation is expected to impact the airport at 1815Z. Note also that a microburst has now started and is showing a 20–knot loss value.

The third message at 1820Z shows that the microburst has intensified to 30 knots loss value and is now impacting the airport. Note that although moderate and heavy precipitation impacts are present, the microburst impact is more severe and takes precedence.

The fourth message at 1830Z shows that the microburst ceased to impact the runways, so heavy precipitation impact is now reported. Note that the previous microburst impact is now reported, with the beginning and ending times on the following line.

The TWIP Text Message is generated once per minute whenever weather is near the airport. When there is no weather within 15 nm, the update rate drops to once every 10 minutes.

Two types of special TWIP text messages are generated in addition to the normal messages. A SEND message is generated when microburst, wind shear or heavy precipitation initially impacts the runways or when heavy precipitation is forecasted to impact the runways. The SEND message consists of a special SEND header plus the normal TWIP text message. The special header gives the type of SEND message (i.e., Microburst Alert, Windshear Alert, Heavy Precipitation or Heavy Precipitation Forecast, in order of precedence) and valid period (generally 20 minutes from the time issued). If more than one SEND condition is in effect, the highest precedence SEND will be issued.

The SEND message remains in effect until it: 1) expires, 2) is superceded by another SEND or 3) is cancelled. The SEND message expires following the end of the valid period. A SEND message can be superseded by another SEND message, such as a Microburst Alert following a Wind Shear Alert.

A Cancel (CANC) message is issued whenever the SEND message condition ceases to be in effect for an adaptable time period (nominally five minutes), provided the message is not due to expire within another

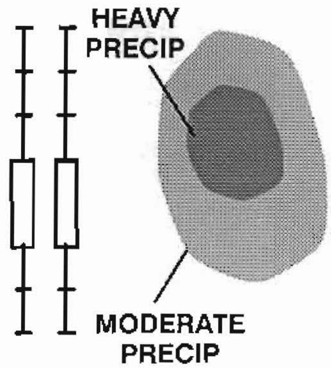
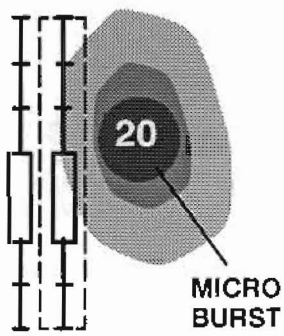
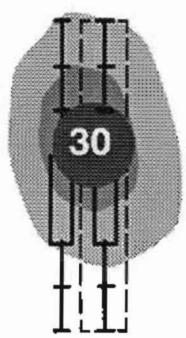
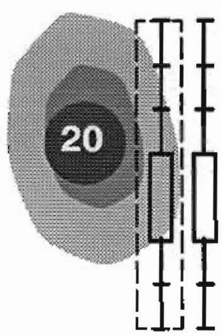
WEATHER SITUATION	TWIP TEXT MESSAGE
	MCO 1800 TERMINAL WEATHER DEMO –STORM(S) 3NM N–E MOD PRECIP 4NM NE HVY PRECIP MOVG W AT 15KT .EXPECTED MOD PRECIP BEGIN 1805
	MCO 1810 TERMINAL WEATHER DEMO *MODERATE PRECIP BEGAN 1805 –STORM(S) ARPT ALQDS MOD PRECIP 1NM N–E HVY PRECIP MOVG W AT 15KT .EXPECTED HVY PRECIP BEGIN 1815
	MCO 1820 TERMINAL WEATHER DEMO *MICROBURST ALERT 30KT LOSS BEGAN 1815 –STORM(S) ARPT ALQDS HVY PRECIP ARPT ALQDS MOD PRECIP MOVG W AT 15KT
	MCO 1830 TERMINAL WEATHER DEMO *HEAVY PRECIP BEGAN 1825 –STORM(S) ARPT ALQDS MOD PRECIP 1NM W–NW HVY PRECIP MOVG W AT 15KT .PREVIOUS MICROBURST BEGAN 1815 END 1825

Figure 3–1. Examples of TWIP Text Messages.

adaptable time period (also nominally five minutes). The CANC message is suppressed if a lower priority SEND message is issued following higher priority SEND message expiration.

3.2 Character Graphics Depiction

An example of the TWIP Character Graphics Depiction is shown in Figure 3–2. In this case there is a microburst–producing cell to the west of the airport. The moderate precipitation is indicated by "–", the heavy precipitation is indicated by a "+" and the microburst is indicated by the letter "M". There is a gust front impacting the airport in this case, indicated by the "G"s. The runway location is indicated by the "X"s, except where the gust front impacts them as indicated by an asterisk (*). A scale is provided in nautical miles in the horizontal and vertical directions, plus a key to the symbols. The storm motion is also provided.

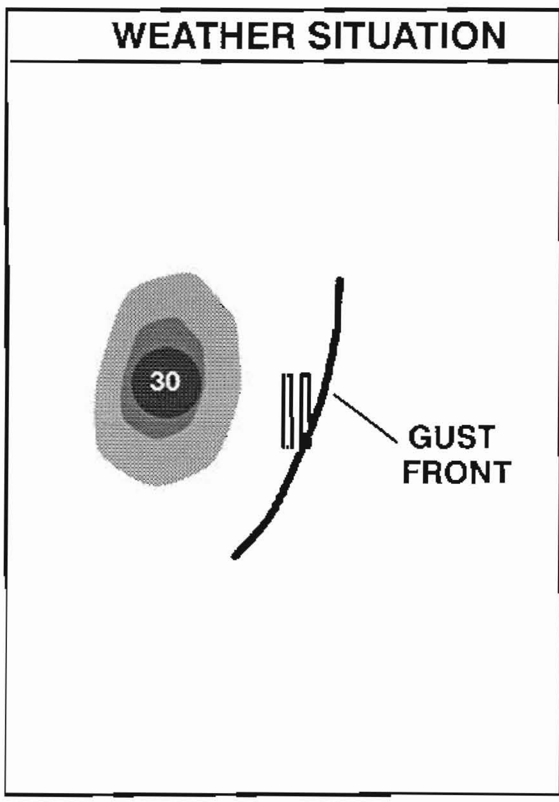
Because of its larger size, the TWIP Character Graphics message is generated once every five minutes if there is weather near the airport. If there is no weather within 15 nm of the airport, then the message is updated only every 10 minutes. In this case, the header section plus the phrase ".NO STORM WITHIN 15 NM" is substituted for the empty map.

4.0 TDWR OPERATIONAL DEMONSTRATION

The TWIP concept was first demonstrated during the summer of 1993 at the ITWS testbed in Orlando, FL. A second demonstration was held during the summer of 1994 at the ITWS testbeds at Orlando, FL and Memphis, TN. Each demonstration was conducted for approximately eight hours per day for a two–month period during the summer only.

The current TWIP demonstration is illustrated in Figure 4–1. There are three ITWS testbed sites (Orlando (MCO), Memphis (MEM) and Dallas/Ft. Worth (DFW)) and four TDWR sites (Atlanta (ATL), Washington National (DCA), Logan International (BOS), and Charlotte (CLT)). Denver and O'Hare are scheduled to come on line later this year as TDWR sites. A total of eight airlines are participating in the demonstration: American, Delta, Federal Express, Northwest, United, UPS, USAir and Air Canada. These airlines have over 2500 aircraft equipped to receive the TWIP Text Message and over 1300 aircraft which can also receive the TWIP Character Graphics Depiction.

The TWIP messages for the ITWS and TDWR sites were sent to a Sun workstation which relayed them to ARINC via an X.25 packet switched connection. The



TWIP CHARACTER GRAPHICS MAP

```
MCO 1830 MAP 15NM
TERMINAL WEATHER DEMO
15      10      5    NORTH    5      10      15

10

           ------
5        ---+++---          G
       ----++++---        G
       ---++MM+---     XX G
W      ---+++++---     XXG                  E
       ----+++----     X*
          ------       G
5                    GG
                     G

10

15      10      5      S      5      10      15
+=HVY  -=MOD M=MB G=GF X=RWY *=RWY MB/GF
STORMS MVG SE AT 6KT
```

Figure 3–2. Example of TWIP Character Graphics Depiction.

TWIP products were stored in a database at ARINC headquarters in Annapolis, MD.

Aircraft from seven airlines (American, Delta, Federal Express, United, UPS, USAir and Air Canada) were able to request these products by making Digital ATIS requests via ACARS. Another airline (Northwest) was sent a special TWIP message whenever wind shear activity started or stopped at an airport; the airline host computer then relayed the message to its aircraft that were either within 40 minutes of landing or taxiing out for departure.

4.1 ITWS Testbeds

The TWIP products are being generated in the ITWS testbeds as part of a demonstration of the ITWS Initial Operating Capability (IOC) products. The ITWS testbeds generate TWIP messages on an 18–hour per day, Monday–Friday schedule during July and August, plus limited coverage on weekends. After this time, the ITWS testbeds will continue to generate TWIP messages on a weather–contingent basis.

4.2 TDWR–based Sites

Prior to September 1995, the TWIP demonstrations operated for limited hours per day and for limited time periods. A key objective was to provide a 24–hour per day, 7–day per week TWIP demonstration for an extended period of time. In order to do this, it is necessary to adapt the existing the TWIP software to operate from products generated by an operational TDWR.

The TWIP Data Processor (TDP) was created to fulfill this role. The TDP is a Sun workstation modified to accept TDWR weather products, generate the TWIP messages, and provide the messages over the FAA's NADIN Packet Switched Network (PSN). The TDP accepts TDWR products from a serial port on the TDWR Display Function Unit (DFU) and is able to interface to the NADIN PSN via the Digital Multiplexing Network (DMN). (Note: because NADIN II was not available in time, the TWIP messages were sent directly to ARINC via an X.25 leased line connection). The TDP software design is discussed in more detail in the next section.

The TDWR–based sites began operating on a limited basis during the summer of 1995. The Atlanta site began operating on a 24–hour basis in September 1995, and the Washington National site began operating on a 24–hour basis in October of 1995. Boston and Charlotte came on line in July 1996. The latter two sites were the first to use the FAA's NADIN II PSN to send TDWR DFU weather products to Lincoln Laboratory for message generation.

4.3 TWIP Availability and Message Traffic

Figure 4.3a shows the availability of TWIP at the 24–hour TDWR–based sites. The TWIP messages were

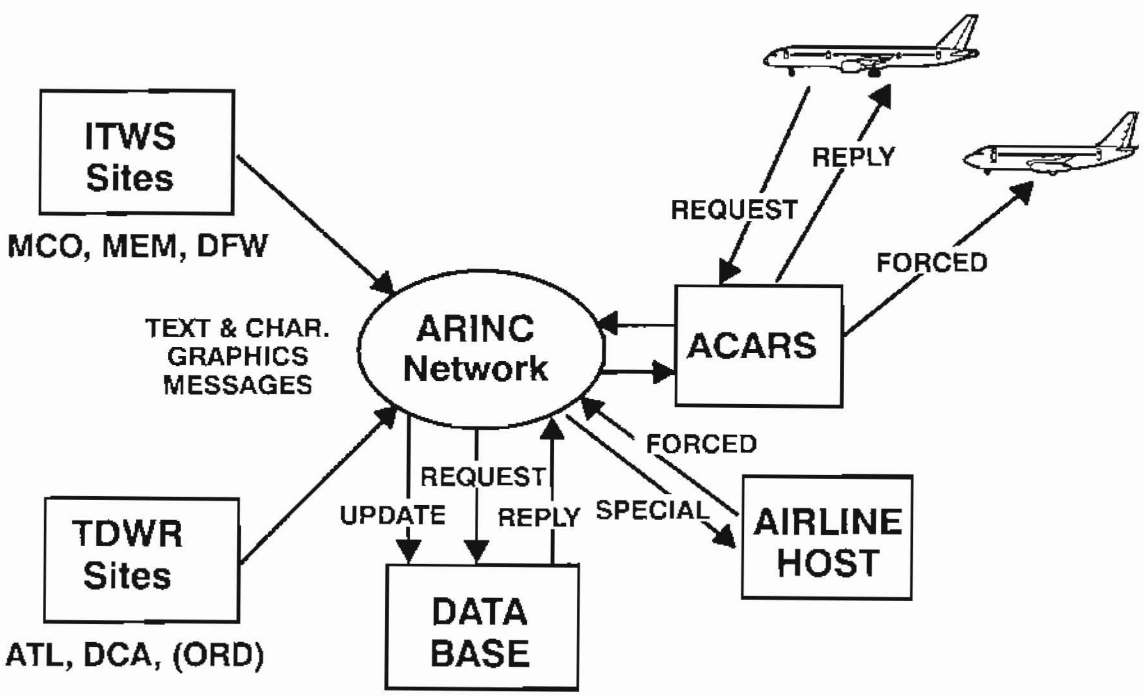


Figure 4–1. Terminal Weather Information for Pilots (TWIP). 1995–1996 Demonstrations at ITWS and TDWR sites.

available over 90 percent of the time when the TDWR was operational at these sites. Downtime was primarily due to communications outages from each remote site to Lincoln. (Currently, dedicated leased lines are used to send the TDWR DFU weather products to Lincoln from Atlanta Hartsfield and Washington National airports). Communication–based system outages are expected to decrease once the NADIN II PSN is used to disseminate TDWR products to Lincoln for TWIP message generation.

ARINC provided data on the message traffic for five of the TWIP sites (including the ITWS sites) starting in July 1995. Figure 4.3b shows the number of requests for TWIP messages at the 24–hour TDWR–based sites. For Atlanta, the average message traffic for the September 1995 to April 1996 period was 735 requests per month. For Washington National, the average message traffic for the July 1995 to April 1996 period was 2851 requests per month. Statistics of message traffic at the ITWS sites have been documented in previous reports (Campbell, 1995).

4.4 Weather Summaries at the 24–hour TWIP sites

Figure 4.4a shows the number of occurrences of storms near (within 15 nautical miles) two of the 24–hour operational TDWR–based TWIP sites. Figure 4.4b shows the occurrences of wind shears, microbursts, moderate, or heavy precipitation at these airports. Some cases of extreme weather at these sites include a 90–knot microburst at DCA occurring on June 6th, 1996 and a significant storm impacting the Atlanta Hartsfield Airport on January 28th, 1996.

5.0 TDP SOFTWARE DESIGN

The TWIP Data Processor consists of several software modules for decoding and processing the weather radar data, generating the TWIP weather messages, monitoring the messages for syntax and accuracy, and formatting and sending them out over the FAA's NADIN II packet switched data network using the X.25 protocol. Figure 5.1 is a block diagram depicting the current system. The box labelled "GENERATE TWIP MESSAGES" contains several processes necessary to generate the TWIP messages from raw TDWR DFU data. Some of these processes are briefly described in the following sections.

5.1 TDP Data Flow

TDWR product data is read from the serial port of the remote site's tower or TRACON DFU into a Sun workstation. The products are buffered and sent via NADIN II PSN to Lincoln Laboratory using the X.25 protocol. The data is then read by an X.25 receive process running at Lincoln which transmits the DFU data to the DFU Data Decoding process via a TCP/IP stream. The decoder decodes the DFU data records and sends each weather product out on an independent TCP/IP stream in an internal Lincoln format. These streams are then fed to the processes which generate the TWIP messages. Once the messages have been generated, they are passed through the Automated Monitor which checks each message for syntax and accuracy. Finally, the messages are transmitted to ARINC over NADIN II by a process which encodes each message, again using the X.25 protocol. These processes are briefly described in the following sections.

5.2 DFU Data Decoder

The DFU data decoder reads DFU data over a TCP/IP stream from the X.25 receive process. It generates several TCP/IP streams containing Lincoln–formatted weather products which are read by the TWIP Message Generation processes. Weather products disseminated to the message generation software include graphical gust front, graphical microburst, precipitation, runway alerts, and runway configuration records.

5.3 Message Generation

Five processes make up the message generation software. They are: precipitation impact processor, cell detection, storm motion, text message generation, and character graphics message generation. The precipitation impact processor computes which arenas are impacted with precipitation and the intensity (moderate or heavy) of the impact. Using storm motion output, it also calculates expected precipitation impacts up to 30 minutes in the future. This is done by advecting the arenas opposite the average storm motion vector and re–calculating the impacts.

The text message generator forms the TWIP text message. It reads the runway alerts stream to determine if there are any wind shear or microburst alerts in effect. It reads the precipitation impact processor output stream to determine if precipitation is impacting, or is expected to impact, the runways. It reads the storm cell detection output stream to determine the intensity and proximity of storms around the airport. Finally, it reads the storm motion stream to determine the motion of the storms in the terminal area. It also keeps track of previous weather at the airport for the .PREVIOUS section of the text message.

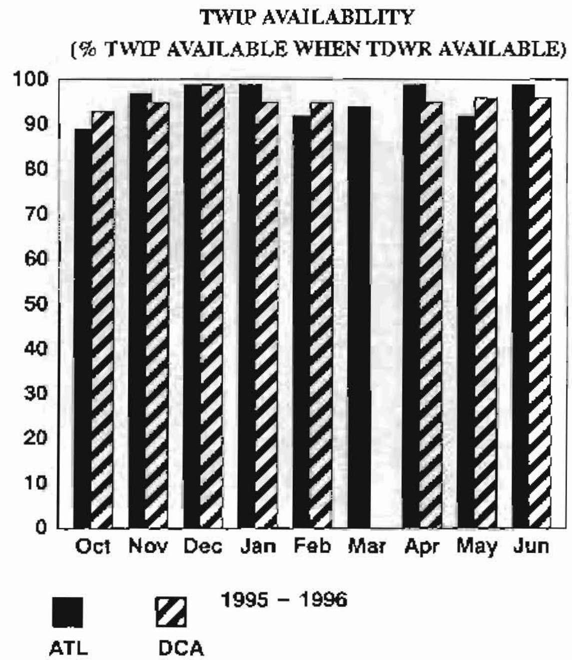


Figure 4.3a: TWIP Availability vs TDWR up time per airport per month from October 1995 to June 1996.

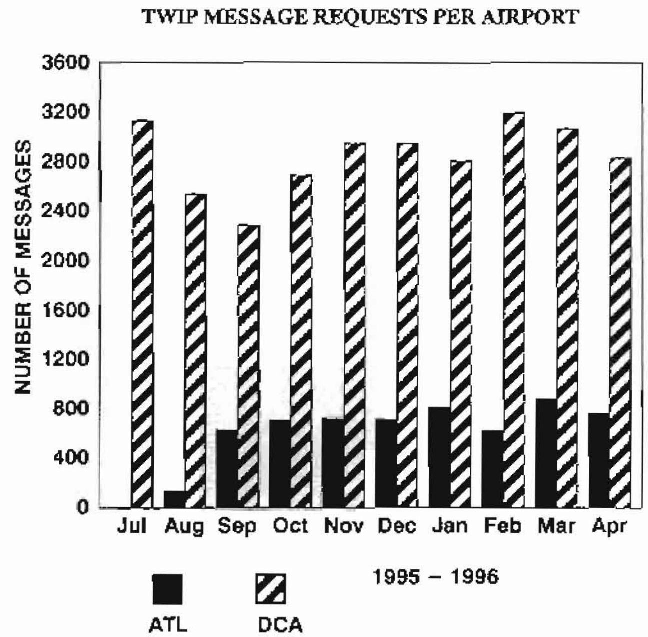


Figure 4.3b: TWIP Message Requests per airport per month from July 1995 to April 1996.

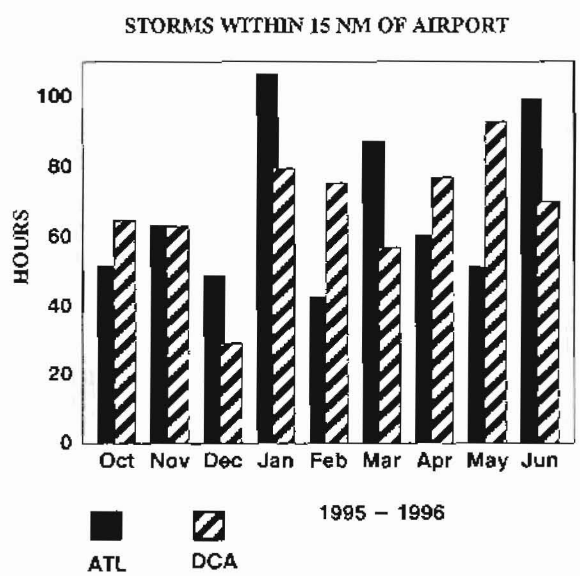


Figure 4.4a: Hours of Storms near airport per airport per month from Oct. 1995 to June 1996.

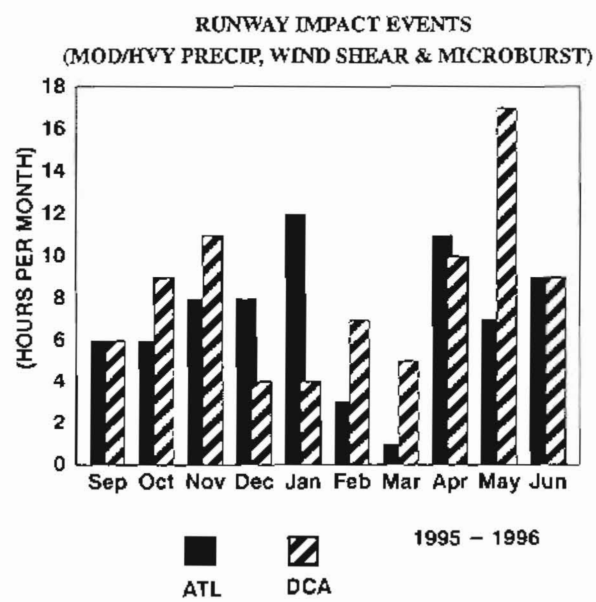


Figure 4.4b: Hours of Runway Impacts per airport per month from September. 1995 to June 1996.

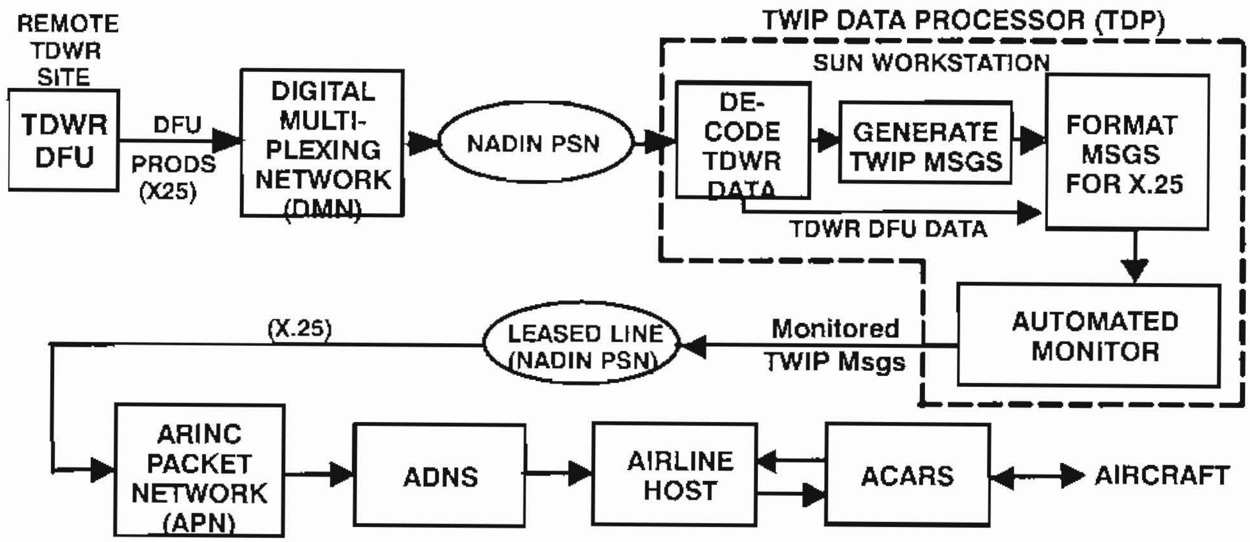


Figure 5.1 TWIP Data Processor (TDP) implementation.

The character graphics generation module reads microburst and gust front shapes and precipitation from the decoder and storm motion output from the storm motion module. It then re–scales this information and generates separate maps for microbursts, gust fronts, precipitation, and the border containing scale information and runway locations. Then the maps are overlaid on each other in succession to create the final full character–graphics map.

5.5 Message Formatting

An ADNS header is placed in each message generated. This header contains the time, airport ID, and ADNS addressing information. The completed messages are now ready to be sent via the X.25 send process to the ARINC database for dissemination to their ADNS destination.

5.6 Automated Monitor

After the TWIP Messages have been assembled and are ready for transmission over NADIN II, a final check is done by the Automated Monitor (refer to figure 5.1). This process checks the messages for proper syntax and compares them against the raw DFU data for accuracy. The Automated Monitor is an independent check of the TWIP products. If, for any reason, a TWIP message has an improper syntax construct or does not accurately reflect the current weather scenario as depicted by the DFU data, a "SYSTEM UNAVAILABLE" message is swapped in to replace the incorrect message. In addition, the monitor will automatically beep Lincoln TWIP personnel with an error code alerting them to the specific problem and to the specific site at which the problem was detected.

6.0 EXAMPLE WEATHER CASE

Figures 6.1 is a snapshot of the TWIP analysis display showing an August 19th storm at Atlanta. The analysis display is a tool developed to simultaneously show the TDWR graphics image (upper left), the TWIP character graphics message (upper right), the TWIP text message (lower right), the ribbon alert display (lower left), and the currently valid Automated Surface Observing System (ASOS) report (lower middle). This image is representative of how the TWIP Text Messages and the TWIP character graphics messages portray an isolated convective storm in comparison with Surface Observations provided by ASOS.

At the time of this snapshot, 22:56Z, the storm was producing microburst strength shears at the airport, causing the TWIP Character Graphics Depiction to show microburst impacts while forcing the TWIP Text Message to alert its users of the presence of a 40–knot loss induced by a microburst. But note, the ASOS message gives no warning of the microburst strength impacts occurring over the runways (nor was it designed to do so). Also, ASOS doesn't have the capability to provide storm motion estimates to give pilots a "heads up" to approaching inclement weather.

In this case, not until 23:02Z was another ASOS message issued which indicated the presence of winds gusting to 25 knots and heavy rain, but by this time the cell was almost centered over the airport. This situation shows that the ASOS message lagged approximately five

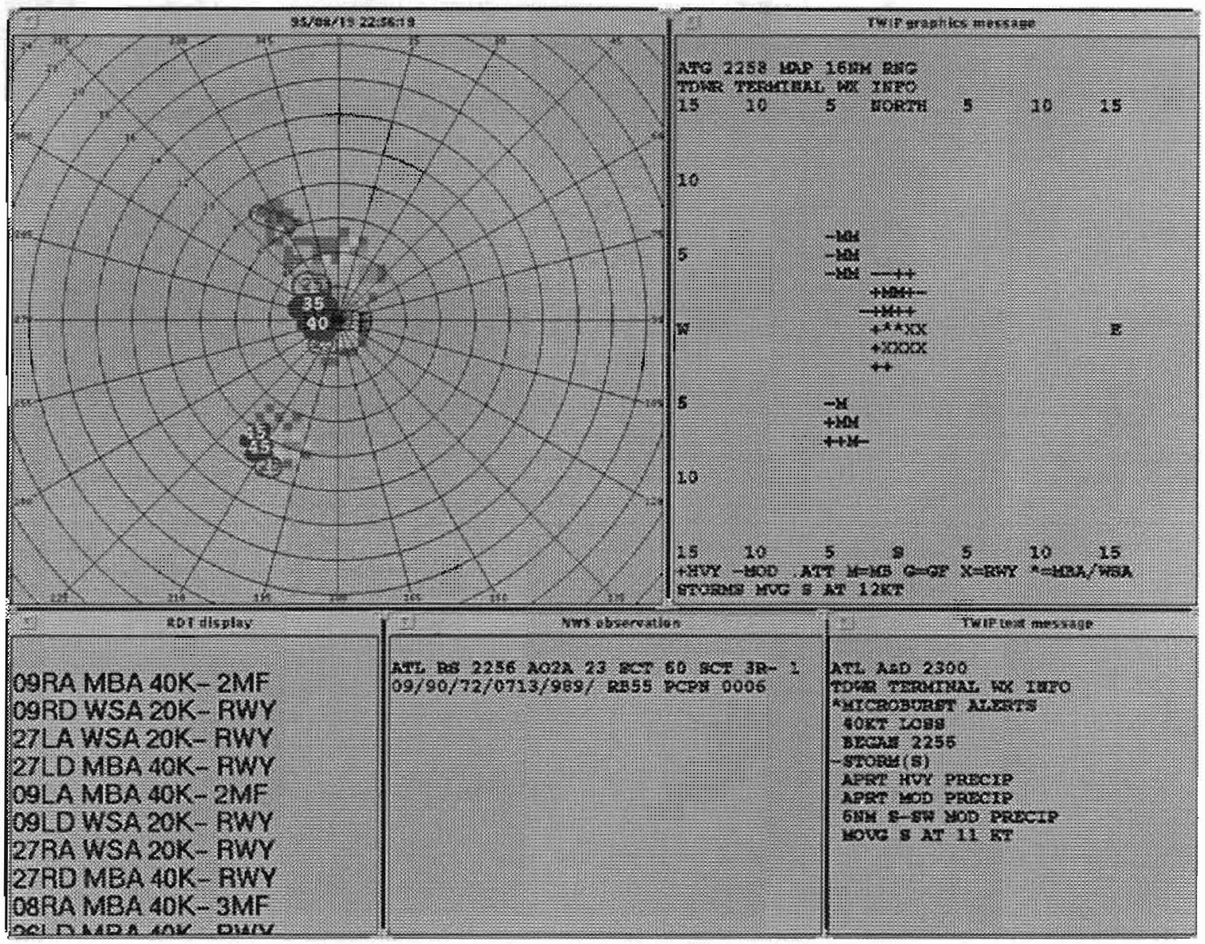


Figure 6.1: The TWIP Analysis Display depicting a storm at the ATL airport on August 18, 1995 at 22:56Z. The upper left panel shows the TDWR display. The range rings have a 2 nautical mile resolution. The upper right panel shows the TWIP character graphics depiction. The lower left panel shows the ribbon alert display. The lower middle panel shows the ASOS report and the lower right panel shows the TWIP text message.

minutes behind TWIP's issuance of a microburst alert. It also shows that ASOS does not match the precision of the TWIP message in reporting the location and intensity of potentially hazardous weather over the airport. ASOS was not designed to give the kind of near real–time, airport–specific weather, including microburst and wind shear information, which TWIP can obtain from operational TDWRs.

7.0 TWIP NATIONAL DEPLOYMENT

Work is currently underway to modify the software being deployed in operational TDWRs to add the TWIP message generation capability. The software upgrade will allow transmission of TWIP messages and TDWR products over the FAA's NADIN II PSN. This will enable airline host computers and airline dispatchers to obtain near real–time weather products at any of the TDWR–equipped airports across the country. Lincoln Laboratory is working closely with Raytheon to expedite the upgrade. It is hoped that by the mid–1997 TWIP capability will start to be deployed at all 45 TDWR airports.

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