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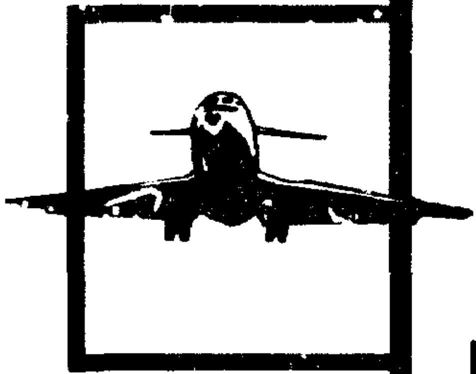

# NATIONAL TRANSPORTATION SAFETY BOARD

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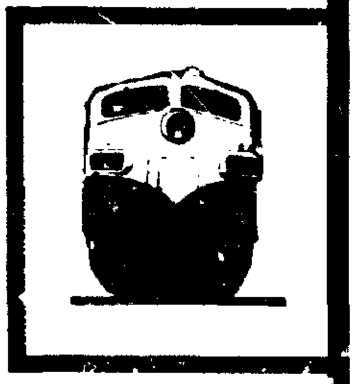
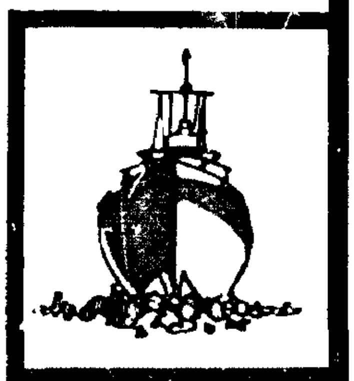
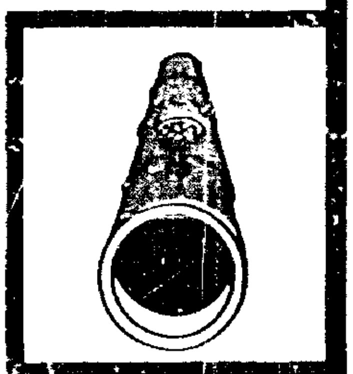


## AIRCRAFT ACCIDENT REPORT



**AIR WISCONSIN, INC., SWEARINGEN SA-226 METRO, N650S VALLEY, NEBRASKA JUNE 12, 1980**



NTSB-AAR-80-15

UNITED STATES GOVERNMENT

TECHNICAL REPORT DOCUMENTATION PAGE

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15. About 1546 c.d.t., on June 12, 1980, an Air Wisconsin, Inc., Swearingen SA-226 Metro, operating as Flight 965, crashed near Valley, Nebraska. Flight 965 encountered severe thunderstorms while at an altitude of less than 6,000 ft and experienced a simultaneous loss of power to both engines because of massive water ingestion. Although the engines were subsequently restarted the aircraft crashed in a field and was destroyed. Of the 15 persons aboard Flight 965, 13 were killed and 2 were injured seriously.

These had been the thunderstorm activity in the vicinity of the accident site for several hours, and a severe storm warning had been issued for the Omaha area. The meteorologists in the Minneapolis Air Route Traffic Control Center (ARTCC) had alerted supervisory air traffic control personnel of the severity of the weather conditions; however, the information was not disseminated to the controllers or to the flightcrew of Flight 965.

The National Transportation Safety Board determines that the probable cause of the accident was the flightcrew's continued flight into an area of severe thunderstorms, and the resultant precipitation induced flameout or loss of power of both engines at an altitude from which recovery could not be made.

Contributing to the cause of the accident was the failure of the flightcrew to utilize all available sources of weather information and the failure of the air traffic control system to disseminate critical weather information to the air traffic controllers and to the crew of Flight 965, the failure of air traffic control supervisory personnel to accomplish key job functions, and the failure of Center Weather Service Unit meteorologists to disseminate critical weather information to the Omaha Radar Approach Control Facility supervisors. Also contributing was the precipitation induced X-band radar attenuation which limited the ability of airborne weather radar to detect the extent and intensity of the weather disturbances.


| | | | |
|---|---|---|---|
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NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C. 20594

AVIATION ACCIDENT REPORT

Adopted: December 9, 1980

AIR WISCONSIN
SWEARINGEN SA-226 METRO, N650S
VALLEY, NEBRASKA
JUNE 12, 1980

## SYNOPSIS

About 1546 c.d.t., on June 12, 1980, an Air Wisconsin, Inc., Swearingen SA-226 Metro, operating as Flight 965, crashed near Valley, Nebraska. Flight 965 encountered severe thunderstorms while at an altitude of less than 6,000 ft and experienced a simultaneous loss of power to both engines because of massive water ingestion. Although the engines were subsequently restarted the aircraft crashed in a field and was destroyed. Of the 15 persons aboard Flight 965, 13 were killed and 2 were injured seriously.

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# 1. FACTUAL INFORMATION

## 1.1 History of the Flight

On June 12, 1980, Air Wisconsin, Inc., Flight 965, a Swearingen SA-226TC Metro, N650S, was operated as a scheduled commuter passenger flight from Appleton, Wisconsin, to Lincoln, Nebraska, with an intermediate stop at Minneapolis, Minnesota.

Air Wisconsin, Inc., holds an Air Carrier Operating Certificate and operates under the rules of 14 CFR 121, "Air Carriers and Commercial Operators." However, 14 CFR 121.9 requires Air Wisconsin to operate the Swearingen Metro under 14 CFR 135, "Air Taxi Operators and Commercial Operators."

The flightcrew reported to Air Wisconsin flight control and conducted preflight activities according to Air Wisconsin procedures. Flight 965 departed Appleton at 1246 1/ on an instrument flight plan and arrived at Minneapolis/St. Paul International Airport at 1402. Flight 965 departed Minneapolis at 1420 with 13 passengers and a flightcrew of 2. Although the Air Wisconsin station at Minneapolis had a self-weather-briefing facility for pilots, the Safety Board could not determine that the crew used the facility to receive the most recent weather and convective SIGMET's 2/ information. However, while on final approach to Minneapolis, the crew talked by radio to an Air Wisconsin pilot who had just returned from Lincoln. He reported that the weather west of his route of flight was dissipating and that he had no problems with it.

At 1433:47, Flight 965 contacted Minneapolis Air Route Traffic Control Center (ARTCC) and requested a 20° deviation from the assigned heading. At 1451:08 Flight 965 requested and received clearance to maintain an altitude of 12,000 ft. 3/ At 1459:07, the Minneapolis controller broadcast convective SIGMET 41C on Flight 965's frequency. The SIGMET did not apply to Flight 965's route.

At 1511:23, the Minneapolis ARTCC O'Neill low controller said, "Wisconsin 965, there's a large area of weather twelve o'clock and about thirty five miles and extends from east of Neola up around Sioux City and down the west side to Fremont. Had one aircraft at flight level two zero zero went around the area. Another one at nine thousand inbound to Lincoln, found his way through it. Don't know how bad it is, anything else. He said he could pick his way through pretty good, though." (See figure 1.)

1/ All times herein are central daylight, based on the 24-hour clock.
2/ A weather advisory concerning convective weather significant to the safety of all aircraft. It includes tornadoes, lines of thunderstorms, embedded thunderstorms, areas of thunderstorms containing intensity level 4 and above, and hail 3/4 inch or greater.
3/ All altitudes herein are mean sea level unless otherwise indicated.

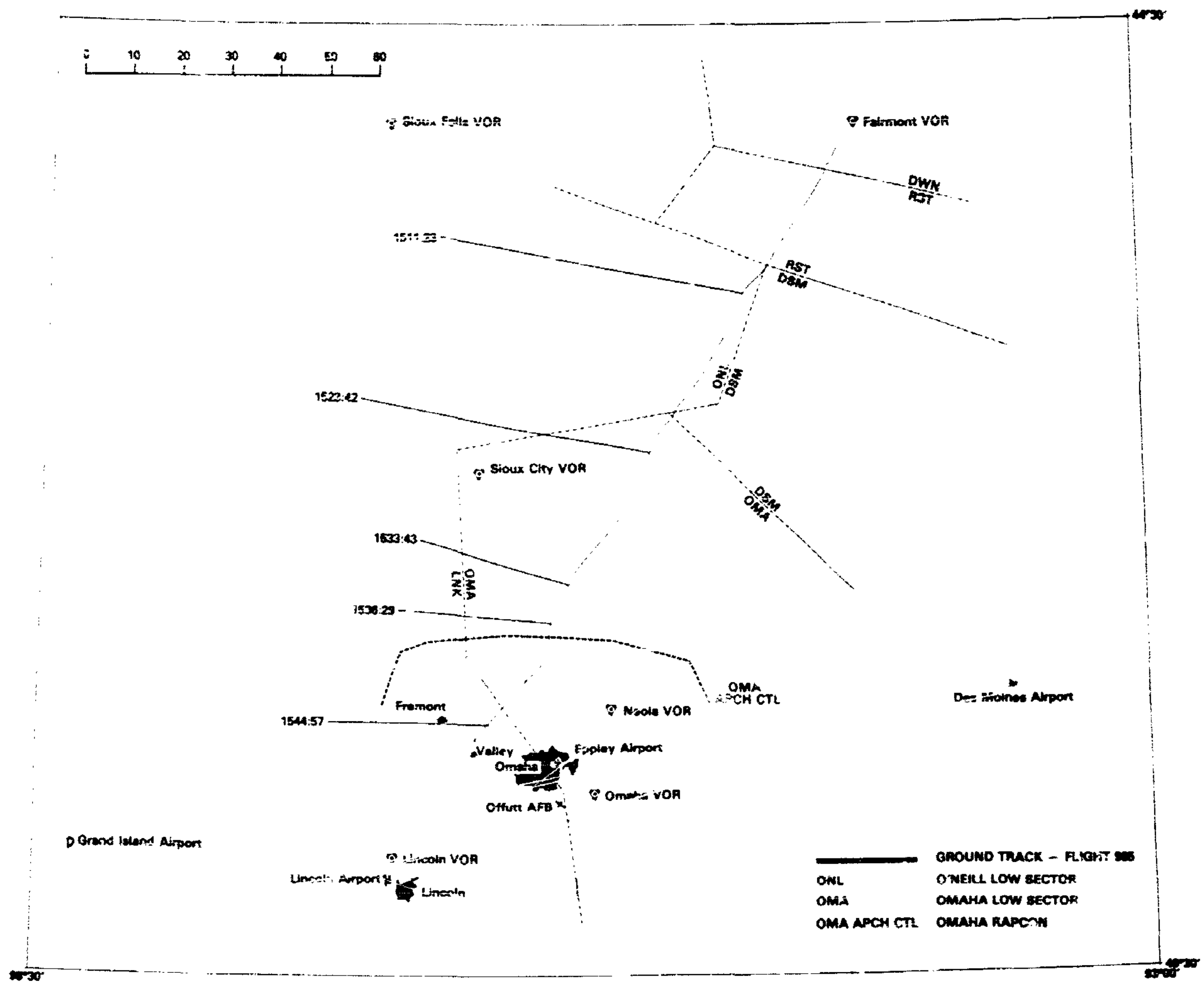


Figure 1.—Probable Ground Track

Flight 965 responded, "Wilco, according to our radar, it looks okay for us; right now, we're nine six five, we'll continue direct for the time being."

The O'Neill low controller was aware of an area of weather in the vicinity of Omaha . He recalled that the entire area on his radar scope around Omaha was covered by lines and H's. Lines on the radarscope indicated light to moderate precipitation and H's indicated moderate to heavy precipitation. Although he was aware of the forecast of thunderstorms, he could not locate thunderstorm activity from viewing his radar-scope. He had not received convective SIGMET 42C, nor was he advised by any supervisory ATC personnel of the severe thunderstorms in the Fremont area. However, he had been told by the controller he relieved that there was weather around Omaha and that some aircraft were going through it.

At 1514:19, the O'Neill sector controller discussed Flight 965's route with the Minneapolis ARTCC Omaha low controller by telephone. The O'Neill sector controller stated that Flight 965 was "aware of that weather up there but he wants to try to go through it, he said at six." The Omaha sector controller replied, "Okay, tell him earlier reports indicate light to moderate precipitation and smooth rides." This information was passed to Flight 965 at 1514:31.

At 1516:02 Flight 965 contacted the Omaha low sector controller. While Flight 965 was on that controller's frequency there were two transmissions from other aircraft concerning the weather. One was from the pilot of an aircraft at 13,000 ft who reported a smooth ride but heavy precipitation. The second was from the pilot of an aircraft at 23,000 ft. The crew reported a "pretty good size cell about 16 to 20 miles off the right wing. . . extending up to about 35,000 ft." That aircraft also reported "light chop."

The Omaha low sector controller stated that while he was handling Flight 965 his total traffic workload was light. He was aware of thunderstorm activity west of Omaha, but had not received information from supervisory ATC personnel indicating it was an unusually severe storm area. He recalled seeing H's and lines on the radarscope but could not correlate the data with thunderstorm intensities.

At 1523:42 the Omaha low controller transmitted:

> "Wisconsin Nine Sixty Five, all reports I've got so far at your altitude indicate that you're going to encounter light to moderate precipitation and smooth ride. A Citation reported light to moderate chop and moderate rain, but he was up to about twenty-three thousand."

Flight 965 acknowledged the transmission. At 1528:19 the Omaha low controller broadcast convective SIGMET 41C, which had been broadcast by a Minneapolis ARTCC at 1459:07.

At 1528:43 Flight 965 requested a descent to 8,000 ft. At 1533:45 the Omaha low controller asked Flight 965 what kind of turbulence it was encountering and the crew replied, "Six five, sir, light to moderate chop, moderate precip." Both Minneapolis ARTCC controllers stated that if they had been aware of the severity of the thunderstorms in the Fremont area they would have advised the pilots on their frequencies. However, they would not have initiated vectors based upon knowledge of the storms but rather would expect the pilot to initiate a request for a vector.

Flight 965 was transferred to the Omaha radar approach control (RAPCON) controller at 1536:06. In the 2 minutes before Flight 965 was transferred to the Omaha RAPCON controller, there were two controller-pilot discussions about the weather northwest of Omaha. With regard to a cell in the area, one pilot stated, "Pretty good size, isn't it." At 1534:07, the Omaha RAPCON controller stated, ". . . the precip I'd show it runs from about a line right through Eppley (airport) east-west through the area and north of that line." At 1534:32, a secondpilot asked, "you showing significant weather west of us toward Norfolk." The Omaha RAPCON controller responded, "Roger I do show a lot of precip out to the northwest of Omaha and you can contact radio flight watch twenty two zero for any weather updates. There is a SIGMET out for that area." There were also discussions between the controller and pilots concerning the most favorable routes around the weather.

The Omaha RAPCON controller was aware of the weather near Fremont but not of its severity. He stated that when he received the handoff of Flight 965 it was east of the precipitation indicated on his radarscope and that Flight 965 had "a clear route to Lincoln."

At 1536:25 Flight 965 contacted Omaha RAPCON and the Omaha RAPCON controller transmitted, "Wisconsin nine sixty five Omaha roger descend at your discretion to six thousand direct Lincoln and how is your ride so far through that precip area?" Flight 965 replied, "Moderate precip with some lightning strikes to the left and to the right. We got pilot's discretion down to six thousand. Wisconsin nine sixty-five, we're out of eight for six at this time."

At 1543:28 Flight 965 requested and received a further descent clearance to 4,000 ft. The controller testified that most aircraft remain at 6,000 ft to Lincoln. At 1544:05 the controller asked Flight 965 about any turbulence they were encountering, and the crew replied, "Yes sir its moderate to severe now out here."

At 1544:22 Flight 965 requested a lower altitude. The Omaha RAPCON controller transmitted, "Roger nine sixty-five descend and maintain 3,000. That's as low as I can give ya."

At 1545:02, after Flight 965 said it was descending to 3,000 ft, the crew transmitted, "Nine sixty-five, we have lost both engines." At 1545:06 the controller asked Flight 965 to repeat the last transmission. At 1545:16 the crew transmitted, "Nine sixty-five, we gottem both, both of them going." Immediately after this, at 1545:19 the controller transmitted, "Wisconsin nine sixty-five, low-altitude alert, your MS, a minimum vector altitude for your area is two thousand, correction, three thousand feet." There was no response from Flight 965, nor were any further communications heard from it. The aircraft had crashed into a field at about 1546.

The two surviving passengers did not recall the initial or any subsequent impacts with the ground. Neither recalled seeing the ground while at a low altitude and as a result neither assumed a protective brace position before impact. One survivor did state that he had placed his right leg out into the aisle and was holding onto the seat in front of him to steady himself against the turbulence.

The survivor who had placed his leg in the aisle to brace himself was seated on the left side of the aircraft in the next-to-last row. He recalled a smooth flight for about an hour when they began to encounter light rain and light turbulence. He stated they then "ran into a wall of wind and rain." This was accompanied by severe turbulence. The turbulence lasted 3 to 5 minutes before the flight entered smoother air. The aircraft started a slight right turn when they encountered a second area of heavy rain and turbulence. He observed that although all passengers were in their seats, and restrained by seatbelts, they were being thrown around. Materials were being thrown around the cabin. He heard the noise level of the engines decrease, but never heard the level increase again. He did not recall seeing the ground before impact.

The second survivor was seated over the left wing. He stated that he could see the airborne radar and that the pilots were detouring around what he believed to be images of thunderstorms on the radar. There was light turbulence throughout the trip for the first hour. He recalled one period of turbulence, which he described as a roller coaster, "except you did not know when you were coming down or going back up. This happened four or five times in a row." This turbulence was followed by light rain which increased to heavy rain accompanied by lightning. The turbulence increased and continued for about 5 minutes. The survivor stated that suddenly the engine noise level diminished to almost nothing and he looked to the cockpit and saw four or five red lights illuminated on the instrument panel. About 15 seconds later, the engine noise level increased. He stated that previously the engines had been operating at a "high, powerful tone"; however, after they restarted they were at a low tone. He said ". . . I could tell it (the engines) was trying to build back up. It was trying to keep coming higher, but it wasn't very high, not at all." He also recalled activity by both pilots in the cockpit, continued heavy rain and lightning, and electrical discharges from the static wicks on the wings. He did not recall significant attitude changes of the aircraft, nor did he recall seeing the ground before impact.

No one on the ground saw the aircraft. Those individuals in the area of the crash site who heard the aircraft stated that its engine noise was brief and loud. One witness said he believed the engines were operating "at full throttle." He said the engine sounds ceased abruptly but he did not hear the sound of impact. The witness had been near the accident site in a tractor just before the aircraft crashed. He stated that the winds were about 100 mph and that there was heavy rain. He also reported a wind shift and limited visibility.

The aircraft crashed during daylight hours at an elevation of 1,140 ft and at latitude 41°21'42"N and longitude 96°20'30"W.

## 1.2 Injuries to Persons

| Injuries | Crew | Passengers | Others | Total |
|---|---|---|---|---|
| Fatal | 2 | 11* | 0 | 13 |
| Serious | 0 | 2 | 0 | 2 |
| Minor/None | 0 | 0 | 0 | 0 |
| Total | 2 | 13 | 0 | 15 |

*Includes two nonrevenue passengers.

## 1.3 Damage to Aircraft

The aircraft was destroyed.

## 1.4 Other Damage

There was damage to the corn crop in the field where the aircraft crashed.

## 1.5 Personnel Information

The two crewmembers on Flight 965 were qualified and certificated for the flight; they had received the training required by current regulations. (See appendix B.)

The crewmembers reported for duty at 1200. Each pilot had 13 hours 20 minutes of off-duty time since the previous work day. They had flown 7 hours 8 minutes on June 11, 1980. Several Air Wisconsin employees, including the flight manager, stated that the crew appeared well rested and alert. One first officer who had flown with the captain stated that he was cautious, but not fearful of flying in weather. He said the captain would deviate around thunderstorms by a wide margin and would avoid turbulence by operating at lower altitudes.

## 1.6 Aircraft Information

The aircraft, a Swearingen Model SA-226TC Metro, was certificated and maintained in accordance with applicable regulations. (See appendix C.)

The aircraft was equipped with two AiResearch TPE 331-34W-303G turbopropeller engines. The most recent hot-section inspection was accomplished on December 31, 1979, for the left engine, and on May 21, 1980, for the right engine. The aircraft was equipped with a RCA AVQ 47 X-band radar set. The aircraft was within center of gravity limits and was below the maximum allowable weight limit when it departed the Minneapolis/St. Paul International Airport. There were 1,400 lbs of jet A fuel on board Flight 965 when it departed Minneapolis.

## 1.7 Meteorological Information

Synoptic Situation

The 1600 National Weather Service (NWS) surface analysis showed a southerly flow of air in eastern Nebraska. A cold front extended from northeastern South Dakota southwestward to southwestern South Dakota. A low-pressure area was located in eastern Kansas with a surface trough extending southward into New Mexico. The 1400 NWS weather chart depicted ceilings of 3,000 ft. or more in eastern Nebraska.

Area Forecast

The area forecast issued by the NWS forecast office in Kansas City, Missouri, at 0740, valid from 0800 June 12 to 0200 June 13, was, in part, as follows:

> Nebraska. . .
> Thunderstorms imply possible severe or greater turbulence. . . severe icing and low-level wind shear . . .
> Significant clouds and weather. . .
>
> Nebraska. . .
> Southeastern quarter 3,000 feet scattered, ceiling 10,000 ft broken with north/south line thunderstorms, light rain showers diminishing to widely scattered by 1200. Elsewhere 5,000 to 10,000 ft scattered with widely scattered thunderstorms; light rain showers developing during the afternoon. Tops cumulonimbus 4 000 ft.
> Turbulence. . . occasional moderate below 8,000 ft eastern halves of Kansas and Nebraska. . . after 1000.

The flight precautions in the area forecast were amended by the NWS forecast office in Kansas City at 1035. The amended precautions were valid from 1035 on June 12 to 0200 on June 13. The following is the amended flight precaution pertinent to eastern Nebraska:

> Over eastern half Dakotas and eastern half Nebraska severe thunderstorm 4/ activity developing during the afternoon. See latest convective SIGMET.

Convective SIGMET's

A series of convective SIGMET's was issued on June 12, 1980, by the National Severe Storms Forecast Center, Kansas City, Missouri. A convective SIGMET is issued when one or more of the following conditions exist: (a) tornadoes; (b) lines of thunderstorms; (c) embedded thunderstorms of any intensity

4/ Wind gusts of 50 kns or greater or hail 3/4 inch or greater in diameter.

level; 5/ (d) areas of thunderstorms greater than, or equal to, intensity level 4; or (e) hail greater than 3/4 inch in diameter.

Convective SIGMET 38C, issued at 1155 (figure 2), stated:

> From 60 nautical miles west-northwest of Sioux City, Iowa, to 50 nautical miles southwest of Sioux City to 50 nautical miles north of Grand Island, Nebraska: Area thunderstorms moving from 220° at 20 kns. Maximum tops to 40,000 ft.

The forecast valid until 1355 stated:

> Developing area will continue moving northeast at 20 kns through 1355. Hail 3/4 inch, wind gusts to 50 kns possible.

Convective SIGMET 39C, issued at 1255. It stated:

> From 40 nautical miles west of Sioux City to 30 nautical miles northwest of Omaha, to 50 nautical miles northeast of Grand Island, area thunderstorms moving from 280° at 20 kns. Maximum tops to 40,000 ft.

The forecast valid until 1455 stated:

> Area will continue moving eastward 20 kns through 1455. Hail to 3/4 inch, wind gust to 50 kns possible.

Convective SIGMET 40 C, issued at 1355, stated:

> From 20 nautical miles southwest of Sioux City, Iowa, to Omaha to 40 nautical miles southwest of Omaha to 70 miles southwest of Sioux City. Area of thunderstorms moving from 280° at 20 kns, tops to 42,000 ft.

The forecast valid until 1555 stated:

> Area will continue moving eastward at 20 kns through 1555. Hail 3/4 inch, gusts to 50 kn possible.

5/

| Echo Intensity | | Rainfall Rate (in/hr) | |
|---|---|---|---|
| 1 | weak | .05-.2 (Light) | Light to moderate turbulence |
| 2 | moderate | .2-1.1 (Moderate) | is possible with lightning. |
| 3 | strong | 1.1-2.2 (Heavy) | Severe turbulence possible, lightning. |
| 4 | very strong | 2.2-4.5 (Very Heavy) | Severe turbulence likely, lightning. |
| 5 | intense | 4.5-7.1 (Intense) | Severe turbulence, lightning, organized wind gusts. Hail likely. |
| 6 | extreme | >7.1 (Extreme) | Severe turbulence, large hail, lightning, extensive wind gusts and turbulence. |

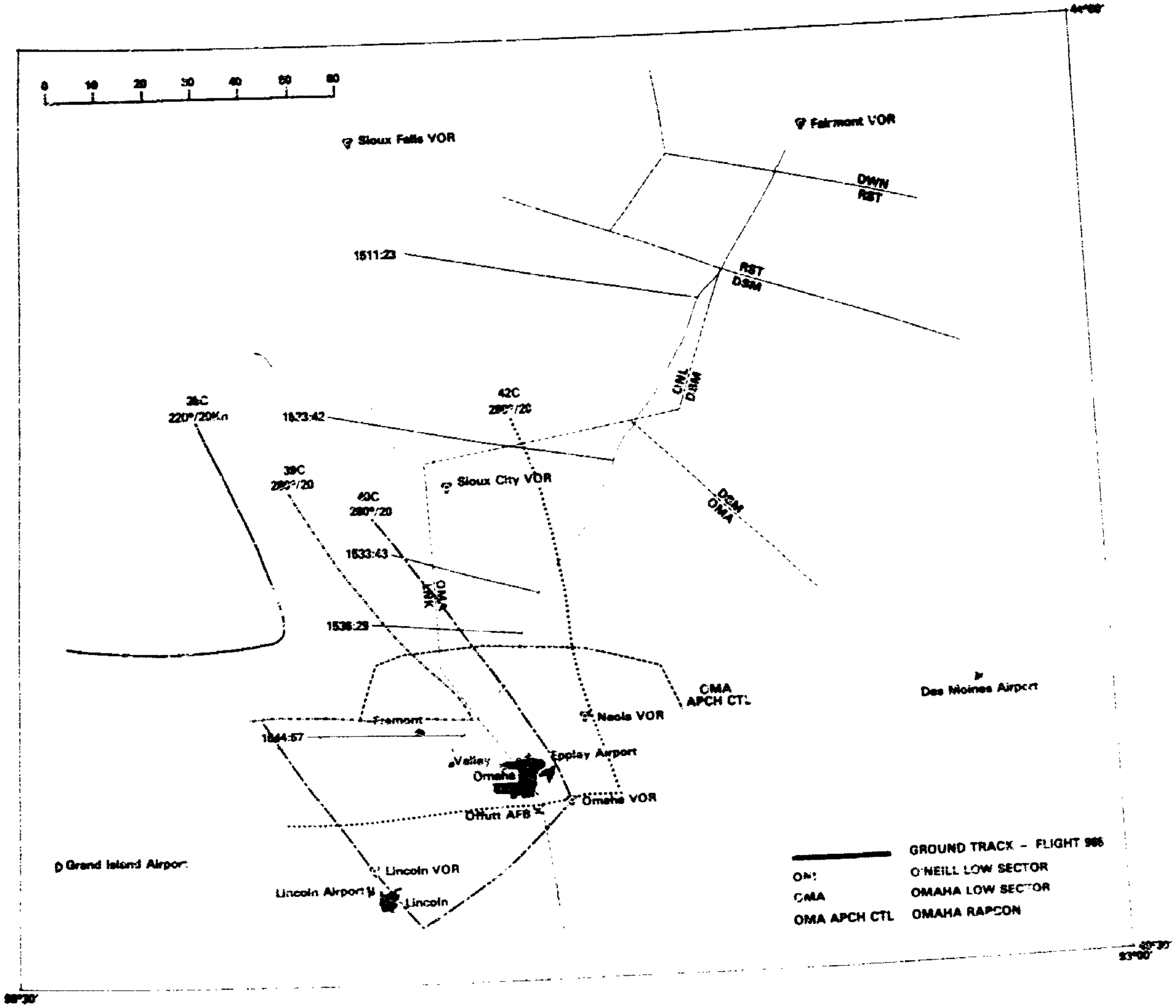


Figure 2.-- Location of convective SIGMET's.

Convective SIGMET 42C, issued at 1455, stated:

Twenty nautical miles northeast of Sioux City to 19 nautical miles east of Omaha to 50 nautical miles east-northeast of Grand Island. Area thunderstorms moving 280° at 20 kns, maximum tops 45,000 ft.

These convective SIGMET's were available at the Minneapolis ARTCC over teletype circuit service A. 6/ The convective SIGMET's were also received in the Air Wisconsin flight operations office in Appleton, Wisconsin, through service A, and they were available at the Air Wisconsin station at Minneapolis/St. Paul International Airport. Convective SIGMET's were received in the Omaha RAPCON on the Flight Data Entry and Printout System (FDEP) from the Minneapolis ARTCC. However, the controller stated that he did not receive any convective SIGMET's or severe weather warnings while he was controlling Flight 965 (from 1536 to 1546).

Actual Conditions

Surface weather observations were, in part, as follows for the following locations and times:

Omaha, Nebraska (Eppley Field)

1559--4,000 ft scattered, estimated ceiling 10,000 ft broken, 25,000 ft overcast, visibility 7 statute miles, altimeter setting 29.86 inHg., dark to the north, lightning cloud to ground west to north.

1628--Indefinite ceiling 100 ft, sky obscured, visibility 1/4 statute mile, thunderstorm, heavy rain showers, winds 260° at 19 knots gusting to 28 knots, altimeter setting 29.96 inHg., thunderstorm overhead moving northeast, frequent lightning cloud to cloud, cloud to ground, cloud to air, peak wind 260° at 28 knots at 1627.

Offutt Air Force Base

1555--Estimated ceiling 5,000 ft broken, 25,000 ft overcast, visibility 10 statute miles, temperature 80° F, dewpoint 61° F, wind 140° at 15 knots gusting to 26 knots, altimeter setting estimated at 29.86 inHg.

1641--Measured ceiling 600 ft broken, 1,400 ft overcast, visibility 1/2 statute mile, thunderstorm, heavy rain showers, winds 350° at 20 knots gusting to 41 knots, altimeter setting 29.89 inHg.

Weather Radar Observations

Weather radar observations taken at Grand Island, Nebraska, at 1530 and 1630 showed extreme weather echo's in the Omaha-Fremont area. Both observations noted that there had been "no change in intensity (of the echo's) over

6/ A teletypewriter system used primarily for collecting and diseminating aviation weather reports and forecasts.

the last hour." A Bow echo 7/ was also observed on the Grand Island radar. The Offutt Air Force Base weather detachment issued a radar report at 1530 which indicted "very strong echoes containing thunderstorms" in the same area.

A review of the radar film from the Grand Island, Nebraska, NWS weather radar showed an area of Video Integrator and Processor (VIP) level 6 weather echo intensity near the accident site at about 1547.

A weather radar overlay from the WSR-74C, 5-centimeter weather radar located at the NWS forecast office in Omaha, Nebraska, showed a VIP level 5 weather echo core located about 7 nautical miles north-northeast of Valley and a VIP level 5 echo 10 nautical miles northeast of Valley at 1545.

NWS weather radar summary charts showed an area of intense weather echoes in eastern Nebraska at 1335, 1435, 1535, and 1635. (Appendix E.)

Severe Thunderstorm Warnings for Local Omaha Area

Local weather warnings were issued by the NWS forecast office in Omaha at 1520 on June 12, 1980, and valid until 1620. The severe thunderstorm warning stated, "The NWS has issued a severe thunderstorm warning effective until 1620 for persons in southeast Dodge and Washington counties. Wind gusts of 70 mph were reported at Fremont, Nebraska, with a very heavy thunderstorm . . . . In addition, a flash flood warning remains in effect for Dodge County."

Warning of the 1520 severe thunderstorm was received in the Minneapolis ARTCC over the Rarep and Warning Coordination System (RAWARC). It was transmitted by the NWS forecast office in Omaha to local radio and television stations, but was not sent to the Omaha RAPCON since the storm did not threaten Douglas County, where the RAPCON and Eppley Airfield were located. At 1555, a severe thunderstorm with high winds and possible large hail was located in northwest Douglas County, and a severe thunderstorm warning was issued for Douglas County. At 1600, the NWS forecast office in Omaha transmitted that warning on the electrowriter to Omaha RAPCON and the flight service station at Eppley Airport.

Cooperative weather observers reported to the NWS rainfalls of 2 to 4 inches in the Omaha-Fremont area in 30 to 40 minutes during the afternoon of June 12, 1980. Winds in the area were measured as high as 70 kns, and some witnesses estimated 100 mph winds. There were numerous reports of trees and powerlines being down, and pea-size hail at Fremont, Nebraska.

The meteorologist in charge of the Omaha NWS forecast office stated that between 1500 and 1545 the line between Omaha and Fremont had 25 to 70 percent coverage of thunderstorms, and that some of the thunderstorms were of level 5 and 6 intensity. The lead forecaster at the Omaha NWS forecast office observed VIP level 5 thunderstorms on the WSR-74C radarscope in the Omaha

7/ A weather echo whose leading edge is convex.

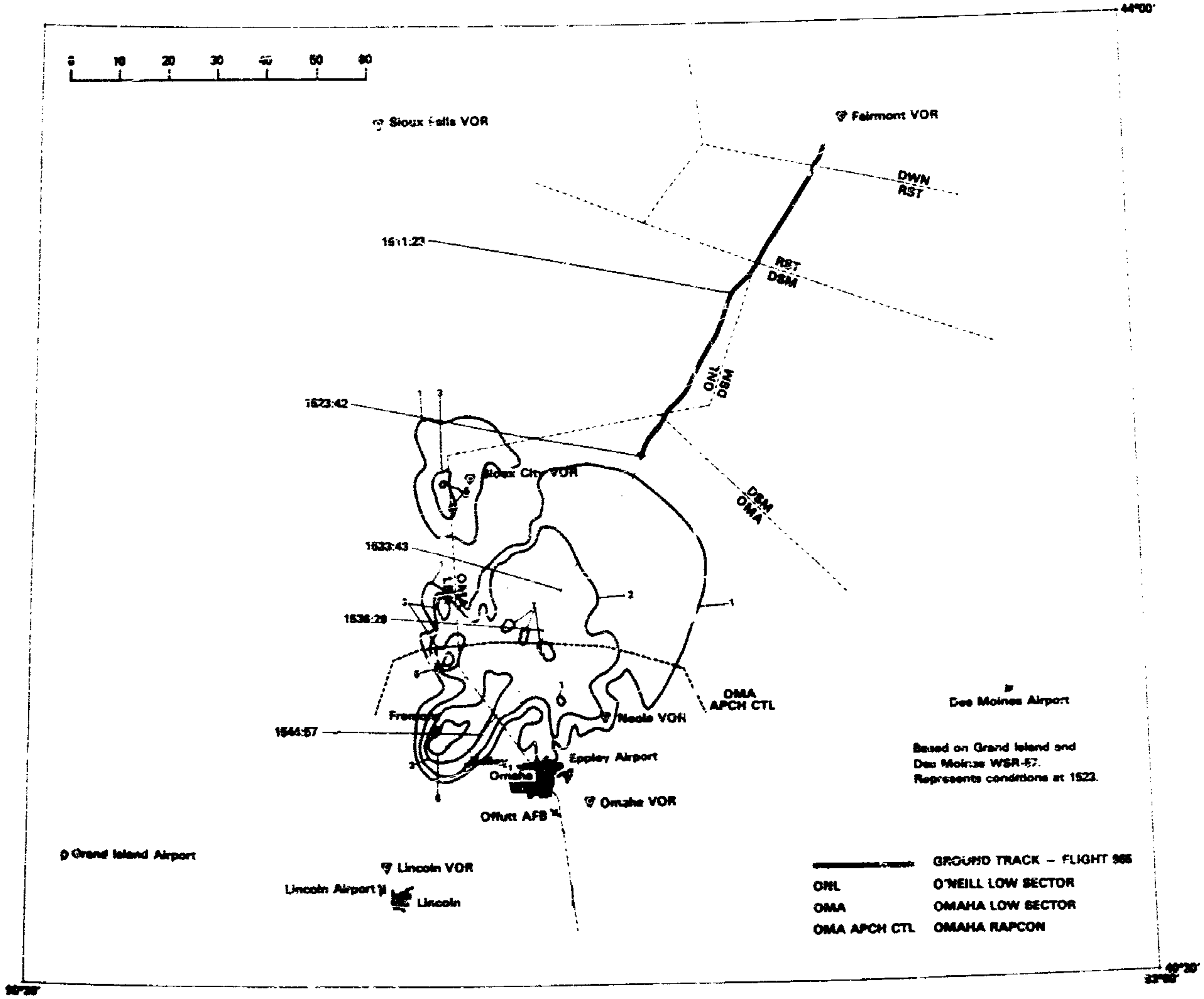


Figure 3.--Weather Echos--Flight Track

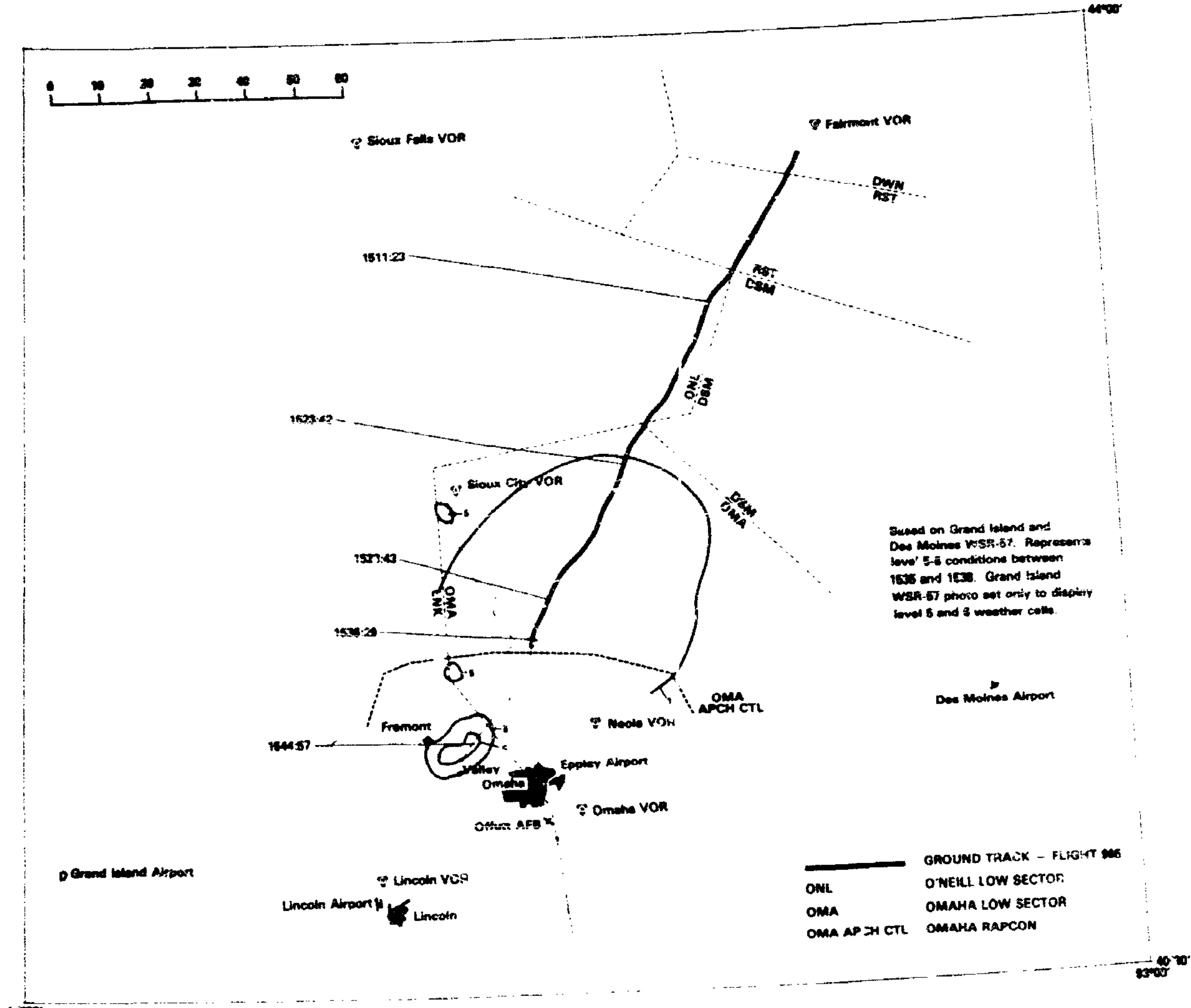


Figure 4.--Weather Echos-Flight Track Overlay

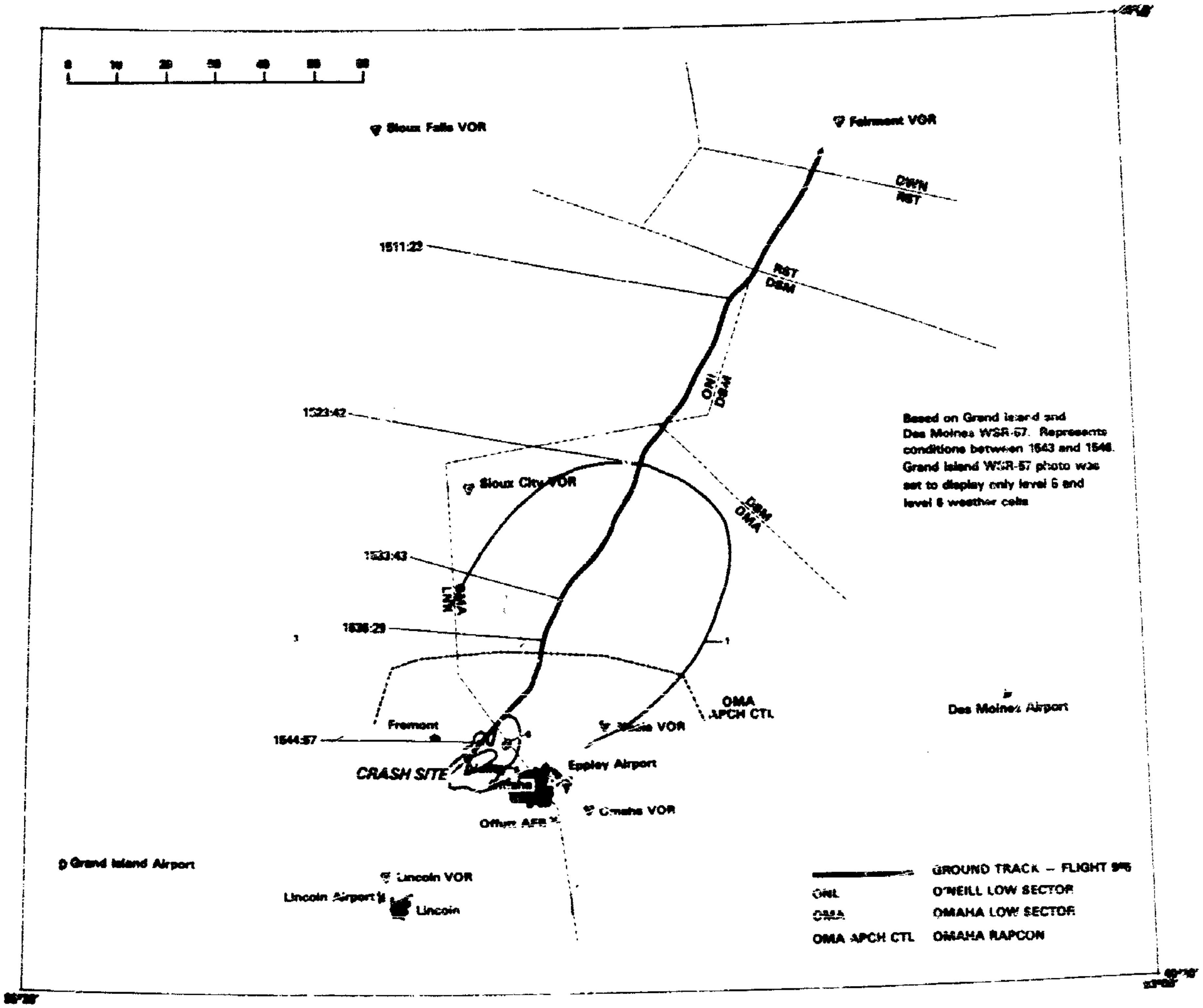


Figure 5.--Weather Echos-Flight Track Overlay

observed VIP level 5 thunderstorms on the WSR-74C radarscope in the Omaha office between 1500 and 1550. The weather radar overlay prepared at Omaha at 1545 showed two VIP level 5 weather echo cores. One was located about 7 miles north-northeast of Valley and the other about 10 miles northeast of Valley. The lead forecaster observed that when the storm entered northwest Douglas County "it built rapidly southwestward."

## Minneapolis ARTCC Center Weather Service Unit

The Center Weather Service Unit (CWSU) at the Minneapolis ARTCC was staffed with two NWS meteorologists on June 12, 1980. CWSU meteorologists provide support through meteorological consultation and advice concerning actual or forecast adverse weather conditions which affect air traffic or aircraft safety over any portion of the ARTCC area. The CWSU weather brief, valid from 1400 on June 12 to 0200 June 13 was, in part:

### General Minneapolis Center Weather

> Lines of thunderstorms and moderate rain showers extend through central Minnesota, western Iowa, and eastern Nebraska and will move east into Wisconsin, northern Michigan, and Iowa with tops to 40,000 ft. Thunderstorms are diminishing slightly in intensity as they move east at 20 to 25 knots.
>
> Broken lines of thunderstorms with moderate rain showers will again develop over eastern Dakotas, eastern Nebraska, and western Minnesota near sunset. These thunderstorms with moderate rain showers will move east over the area with some cells becoming severe.

## Weather Briefing - Flight 965

The flightcrew reported to the Air Wisconsin flight operations center at 1200 and received a weather briefing from the duty dispatcher. The dispatcher told them that there were thunderstorms in Nebraska and that they were forecast for Lincoln and Grand Island. He recalled that there were no SIGMET's in effect. The crew then reviewed hourly sequence reports, terminal forecasts, area forecasts, winds aloft charts, severe weather reports, radar report displays, visual displays of fronts and weather systems, the 12- and 24-hour prognosis charts, satellite maps, and surface analyses. Convective SIGMET 39C was probably available during the stop at Minneapolis/St. Paul International Airport between 1405 and 1420. Convective SIGMET 40C may have been available at Minneapolis between 1405 and 1420. There was no evidence that the crew received convective SIGMET's 39C or 40C from Air Wisconsin or from ATC sources, or by their own initiative from other agencies. There was no evidence that the crew received convective SIGMET 42C from any source while enroute. The 1200 sequence report for Lincoln, Nebraska, was as follows:

> 1149: 80 scattered 120 scattered, visibility 15 miles temperature 81° F, wind 180°/17, 29.94 inHg.

Air Wisconsin obtained weather information over the American Airlines DECS System. Convective SIGMET's were usually obtained over this system immediately after they are issued by the National Severe Storms Forecast Center in Kansas City. The system was available for weather callup at the Air Wisconsin station in Minneapolis.

Convective SIGMET 40C was disseminated at the Minneapolis ARTCC at 1438. Convective SIGMET 42C was received in the Minneapolis ARTCC at 1459. It was placed in the center's flow control area in-box and was not retransmitted to the sector controllers for 43 minutes.

A terminal forecast for Lincoln, Nebraska, for the period 1000 June 12 through 1000 June 13 was found at the scene of the accident. It read:

> 15Z (1000 cdt) June 12 to 15Z (1000 cdt) June 13, 1980, ceiling 5,000 ft broken clouds, wind 170°/14 knots, chance of ceiling 3,000 ft overcast thunderstorms, moderate rain showers, wind gusting to 45 knots. 19Z (1400 cdt) 5,000 feet scattered clouds, wind 170°/16 knots gusting to 26 kns, slight chance ceiling 5,000 ft overcast, thunderstorms, moderate rain showers, wind gusting to 45 knots. 06Z (0100 cdt) 10,000 ft scattered clouds, wind 170°/12 knots. 09Z (0400 cdt) VFR (visual flight rules).

Downburst

A downburst is a strong downdraft that can occur in a thunderstorm, inducing an outward burst of damaging winds on or near the ground. Horizontal wind speeds on the ground are greater than 40 miles per hour. The most frequent dimensions of downbursts may be characterized by a path length of 1 to 10 miles and a width of 1 to 3 miles.

The ground damage pattern in the immediate vicinity of the accident site exhibited characteristics of a downburst. The damage pattern included broken trees, downed powerlines, and other wind damage.

## 1.8 Aids to Navigation

Not applicable.

## 1.9 Communications

There were no known communications difficulties.

**1.10 Aerodrome and Ground Facilities**

Not applicable.

**1.11 Flight Recorders**

The aircraft was not equipped, nor was it required to be equipped, with flight recorders.

**1.12 Wreckage and Impact Information**

The aircraft struck the level, muddy field in a slight nosedown, right wing-down attitude, on a magnetic heading of 235°. The aircraft bounced and again hit the ground 288 ft beyond the initial impact point. The aircraft continued for 1,022 ft before the fuselage came to rest inverted and on a heading of about 55°.

The empennage separated from the fuselage about 665 ft beyond the initial point of impact, and both engines and wings were found between 900 ft and 1,150 ft from the initial impact point. The propeller assemblies had separated from the powerplants, which had separated from the wings. (See appendix D.)

The fuselage nose structure from fuselage station (FS) 60 forward had separated from the fuselage. The forward right side of the fuselage, from the windshield to the aft bulkhead of the coat closet, was crushed. The fuselage structure remained relatively intact, although the fuselage skin was torn and crushed on the right side. The cabin floor was deformed only in the forward cabin area.

The left aft cargo door remained intact and closed. However, the bottom of the door was torn severely. The main cabin door on the left side of the fuselage had been cut open and removed during rescue operations.

The right wing had separated from the fuselage. The wing leading edge was crushed from the nacelle outboard for 15 ft. The end of the wing section leading edge was crushed severely. The left wing had separated from the aircraft. The leading edge, beginning at a point 8 ft inboard of the wing outboard closure rib, was bent upward. The upper and lower wing skin in the outboard area was torn and buckled severely. The ailerons and flaps were recovered along the wreckage path and exhibited only impact damage. All control surfaces of the empennage were recovered; they exhibited no preimpact damage. The leading edges of the right and left horizontal stabilizer were bent down. The tip of the vertical stabilizer was bent to the left, while the tip of the rudder and the rudder trailing edge were crushed and bent to the right. The right main landing gear and nose gear assemblies separated from the aircraft. The left main landing gear assembly was retracted within the left nacelle wheelwell.

Both cockpit control columns and the crossover tube had separated from the aircraft structure and were partially outside the aircraft. Control cables for the ailerons, elevators, rudder, and control surface trim failed in tension. There was no preimpact damage noted. The static wicks were all attached and in good condition. The electrical, hydraulic, navigation, fuel, and communications systems were examined; no preimpact damage was discovered.

The left engine was detached from the nacelle and the wing. The engine-mounting frame was torn from the nacelle and still attached to the engine mounts. The engine-mount pads were intact and several spindles were bent. All engine-driven accessories, except the starter generator, were attached to their respective mount pads. All engine accessory-to-airframe cables, wiring, tubing, and linkages had separated. The linkage rod connections to the fuel control, propeller pitch control, and propeller governor were intact and attached to their respective drive arms.

The feathering valve was found in the actuated position in its mounting adapter adjacent to the propeller pitch control pad. The valve was bent and the clevis was pulled from the valve housing. The propeller pitch control arm was found in the 80° position and could not be moved. The manual fuel control valve was found in the 20° position and the arm could be rotated. The fuel-flow divider and associated fuel lines were attached to their respective compressor housing mounting flange and were undamaged. The fuel shutoff valve and lines were attached to the compressor housing. The fuel purge system and components were found intact on a fractured piece of engine mount.

The right engine was detached from the wing and nacelle assembly. The engine-mounting frame was torn from the nacelle and was still attached to the engine mounts. All engine-driven accessories, except the starter generator, were found attached to their respective mount pads. All engine accessory-to-airframe cables, wires, tubing, and linkage had separated. The linkage rod end connections to the fuel control, propeller pitch control, and propeller governor were intact and attached to their respective drive arms. The feathering valve was found in the actuated position in its gearbox mounting adapter. The valve was held stationary by the bent linkage assembly. The propeller pitch control arm was found in the 95° position and the arm moved freely. The fuel control manual fuel valve was found in the 100° position and would not rotate.

The fuel-flow divider and associated fuel lines were attached to their respective housings. The fuel-flow transmitter was found to be fractured in its locating line. The fuel filter bypass indicator was in the bypass position, or opposite its normal position.

The right propeller had separated from the engine shaft and was recovered 318 ft from the initial point of impact and 15 ft to the right of the wreckage path. The dome assembly had separated at the hub and the dome was recovered in a crater about 2 ft deep, the impression made by the right-hand engine and nacelle. The moveable piston had been fractured into small pieces, five of which were recovered with the dome assembly or directly adjacent to, but in front of, the nacelle impression.

The left propeller had separated from the engine shaft, and the blade and hub assembly was recovered about 436 ft from the point of initial impact and about 155 ft left of the wreckage path. The left and right propeller blades were bent, twisted, and distorted; the leading edge blades of both propellers were damaged slightly.

## 1.13 Medical and Pathological Information

Postmortem examinations of the flightcrew and passengers were conducted to determine extent of injuries. Toxicological examinations of the flightcrew were negative, and no ethyl alcohol was present.

Both flightcrew members died of extensive impact trauma caused by multiple fractures and internal injuries. Gross anatomical examination of the 11 passengers indicated that 5 received multiple bilateral rib fractures, 5 received spinal fractures, 8 received lower limb fractures, and several received skull fractures. Abdominal bruises were present on eight of the passengers.

Of the surviving passengers, one received fractures of the left leg and arm and a dislocated hip; the other had a dislocated hip, facial lacerations, and internal injuries.

## 1.14 Fire

There was no fire.

## 1.15 Survival Aspects

The accident was not survivable for the flightcrew because the occupiable space in the cockpit was intruded when the right side of the fuselage was crushed. The captain's seat separated from the fuselage, and the inboard and outboard sides of the seatpan frame separated from the attachment to the seatback. The first officer's seat was found outside of the aircraft, with the cockpit floor still attached to the seat pedestal. Both flightcrew restraint systems functioned properly.

The accident was partially survivable for the passengers since the fuselage remained essentially intact. The cabin floor showed little signs of deformation or displacement except in the area of the first row of seats. Despite the integrity of the cabin area, all of the 13 occupied passenger seats separated from their attachments during the impact sequence, leading to the fatal and nonfatal fracture injuries to the passengers.

The Swearingen SA-226 Metro seats are not constructed to Technical Standard Order (TSO) specifications, but rather to meet the airworthiness requirements of 14 CFR 23.785. During certification testing, there was some deformation in the seat channels, but there were no seat failures and the seats were removed easily, folded, and reinstalled.

The Swearingen Metro passenger and crew seats were designed to withstand the ultimate inertia loads (i.e., limit or design loads multiplied by a factor of safety, usually 1.5) specified in 14 CFR 23.561, which are 9g's forward, 3g's downward, and 1.5g's sideward. In fact, in the forward direction the Metro passenger seat was designed to withstand a static load of 13.5g's. The Metro seat was tested to the uniaxial compliance static load test requirements of 14 CFR 23.785 (f), using Technical Standard Order (TSO)-C39a and National Aircraft Standard (NAS)-809 which is referenced in TSO-C39a.

In addition, 14 CFR 23.785(*f*)(3) provides a factor of safety in all seat-to-structure attachments by requiring an increased load-carrying capability of 33 percent over the seat ultimate inertia loads. This factor of safety, however, does not apply to the attachment of the safety belt to the seat or airframe structure.

The passenger seats were designed to permit easy conversion of the cabin to a cargo configuration. The seats were attached to the fuselage wall with quick-disconnect pins and to the floor cargo tiedown pans with quick-disconnect fittings attached to the two inboard legs. The two spring-loaded quick-disconnect pins passed through fore and aft seat channels, which were riveted to the air conditioning duct wall. (Seven rivets were placed forward and five rivets aft.) Flanges were welded to the seatpan frame. The two quick-disconnect seat leg fittings also were spring loaded and were designed with a series of moveable clamps which, when the fitting was locked in place, surrounded a stud fitting recessed in the floorpan and locked beneath the stud fitting head. Seatbelts were attached to the duct wall outboard and to the seat structure inboard. The inboard legs on these seats also were hinged at the seatpan frame. This feature provided for the stowing of the seat against the fuselage wall.

The passenger seats were damaged primarily by the separation of the forward and aft seat channels from the duct wall assembly; many of the rivets pulled through the wall in the process. Other common failures included (1) seat legs separated from seatpan frames; (2) seat channel flanges failed or pinhole areas of flanges tore out or became elongated; (3) quick-disconnect fitting separated from the seat leg or the floorpan fitting; and (4) shaft of floorpan button separated from the floorpan fitting.

These crash survivors could not attempt an evacuation of the aircraft because of their injuries, but in any event egress was blocked. The survivors had to be removed through the tail of the aircraft after removing the rear pressure bulkhead. Later, the main cabin door was cut open to remove the other victims. Both survivors and a passenger who died shortly afterward were removed from the wreckage when the first fire and police department units responded starting at 1620.

The crash/fire/rescue response was initiated at 1552:19 when Offutt Air Force Base notified Douglas County Communications Center of the possibility of a crash. The Douglas County Sheriff's Department, the Valley Police Department, the Valley Volunteer Fire Department, and the Waterloo and Elkhorn rescue units responded. The first sheriff department units were dispatched at 1555. The location of the accident was reported by a resident about 1615. A medical evacuation helicopter arrived at the accident site at 1701. In addition, a mobile intensive care unit was dispatched from a local hospital.

## 1.16 Tests and Research

### 1.16.1 Engine and Propeller Inspection

The Safety Board disassembled the engines and inspected them. The internal inspections did not reveal any preimpact malfunctions or damage which would have caused the engines to cease operation.

Engine accessories were inspected and tested. No malfunctions were noted in the fuel-flow dividers, igniter boxes, propeller governors, propeller pitch controls, fuel controllers, and the speed switches. The fuel pump and the start pressure regulator for the left engine were inspected and tested; no irregularities were found. These engine accessories on the right engine could not be tested because of impact damage.

The dome assemblies and the propeller blades had been damaged extensively during the impact; however, no preimpact malfunctions were noted.

Blade L1 on the left propeller was bent aft about 45° at midspan, with the outboard 1/3 of the blade bent aft and twisted about 90° from the normal position. There was evidence of blade rotation in the clamp about 90° toward the low-pitch position. Blade L2 was bent 90° toward the face of the blade. The bend was located at the 1/3 blade span position. From the 1/3 blade span position to the tip the blade was bent, twisted, and curled toward the low pitch. Evidence indicated that the blade had rotated about 180° in the clamp. Blade L3 was bent aft about 90° starting about midspan. The tip was curled slightly toward low pitch. The blade slipped in the hub clamp toward the low-pitch position.

It was not possible to determine the impact angle of any of the left propeller blades. However, an examination of the inside diameter of the movable piston of the dome and piston assembly disclosed three distinctive circumferential impressions and longitudinal scoring. The manufacturer's representative stated that similar markings on other pistons have been interpreted as representative of the blade angle and to have been caused by something interferring with normal blade rotation. When measured from the rear face of the piston, the blade angles were (1)3 9/32 in. or 51°, (2)2 29/32 in. or 39°, and (3)1 29/32 in. or 7°.

Blade R1 on the right propeller had been bent rearward at two locations. The first bend, located about 15 in. from the hub, was about 15°. The second bend was about 20°. The blade tip was curled slightly toward low pitch, and the blade had rotated in the clamps about 90° toward the low-pitch position. Blade R2 was bent aft about 45° at the 2/3 blade span position and the tip was curled slightly toward the low-pitch position. The blade rotated slightly in the clamp toward the low-pitch position. Blade R3 had a uniform 45° bend to the aft position and was 90° toward the low-pitch position. The blade was rotated in the clamp about 40° toward the low-pitch position.

The ball carriers for blade R1 had broken in two places. An examination of the dome and piston assembly indicated a 71° blade angle at impact; blade R3 revealed a blade impact angle of about 34°.

### 1.16.2 Water Ingestion Tests

Water ingestion certification tests on the TPE-331 engine were accomplished on January 30, 1969, and on February 11, 1969, in accordance with FAR Part 33.19, Advisory Circular No. AC 33-1A, dated June 19, 1968, and AiResearch Data Sheet DS-3927, dated May 15, 1968. A review of the test report showed that the test engine successfully passed the water ingestion test when subjected to water flow into the engine inlet simulating maximum rainfall in quantities of up to about 4 percent of the engine airflow weight with the engine operating at cruise and takeoff power levels.

After the accident, a test was conducted to determine the effect of rainfall above 4 percent water-air ratio with the engine operating at cruise and takeoff power levels. The test engine was as similar as possible to the engines on Flight 965. A nacelle was not installed around the engine. A water injection manifold was used to spray water directly into the engine inlet. No attempt was made during the test to compensate for airflow interruption caused by turbulence, wind gusts, or pilot inputs. With the engine operating at cruise power, water was injected into the engine until it ceased operation. Operation ceased when water quantities reached a 9.46 percent of the engine airflow. This figure was more than twice the maximum certification level. Attempts were made to restart the engines, but restart was not possible with the water quantity at 9.46 percent. The engines did start several times when the water quantities were reduced to a water-air ratio of 5.45 percent. Liquid water content levels equivalent to 9.46 percent and 5.45 percent water-air ratio may be expected from a VIP level-5 thunderstorm. 8/

According to the manufacturer, there has been only one other incident of a dual engine power loss in the history of the TPE-331 engine. The incident occurred when the aircraft penetrated a thunderstorm while flying at 13,000 ft. The pilot reported moderate to severe turbulence, heavy hail, and torrential rain. The engines were restarted when the aircraft reached 2,600 ft. The postflight inspection did not reveal any engine damage.

## 1.17 Additional Information

### 1.17.1 Air Wisconsin, Inc., Operating Procedures

In accordance with 14 CFR 121, Subpart U, "Dispatching and Flight Release Rules," Air Wisconsin, Inc., maintained complete dispatching services for the aircraft it operated under 14 CFR 121. Dispatching was accomplished by licensed dispatchers who supervised the Air Wisconsin flight control. The Air Wisconsin Flight Operations Manual specifies the following for 14 CFR 121 operations:

8/ Brown, E.N. and Braham, R.R., Jr. 1963: Precipitation Particle Measurement in Cumulus Congestus. J. Atmos Sci. volumn 20: 23-28

Flight Control is a simplified semidispatch system which is the controlling agency for all Air Wisconsin flight operations (maintenance test, maintenance ferry, and training flights excluded).

Flight Control has the authority to cause and direct the following:

a. Flight cancellations and additions
b. Flight delay (beyond the 10 minutes local discretionary delay allowed)
c. Flight rerouting/rescheduling
d. Overflights
e. Aircraft changes
f. Alternate station irregular operations
g. Crew changes or rescheduling in connection with the above or personal crew problems
h. Flight locating
i. Fuel load limitations (maximum and minimum)
j. Restriction or suspension of operations

Flight control was established for the primary purpose of coordinating and expediting all aircraft movements over Air Wisconsin's system. Flight control monitored aircraft loads, (freight and passenger) weather, and traffic conditions in order to make the most effective use of the available aircraft at any given time. The Director of Flight Operations also stated that flight control had the responsibility to provide the service A weather information to other Air Wisconsin stations.

The Swearingen Metro is a small aircraft which seats 30 passengers or less and carries a payload of 7,500 lbs. or less. As a result, Air Wisconsin operated the Metro under the regulations of 14 CFR 135, "Air Taxi Operators and Commercial Operations," 14 CFR 135 does not require flight dispatch services. Nevertheless, Air Wisconsin provided a flight-following service to Metro flights through flight control. The same personnel provide meteorological data and the same facilities were available as were available to 14 CFR 121 operations. However, the company left to the Metro captains the responsibility for securing weather and flight data, flight planning, fuel and load planning, and routing decisions beyond the established routes.

In practice, the airline provided the means for Metro flightcrews to obtain up-to-the-minute weather information. At the Appleton, Wisconsin, flight control office, weather was received on teletype service A. The flight controller posted the forecasts and hourly sequences at designated places on the walls of the office. SIGMET's and AIRMET's 9/were posted at a designated location. At on line

9/ AIRMET--Inflight weather advisories which are of operational interest to all aircraft and potentially hazardous to aircraft having limited capability because of lack of equipment, instrumentation, or pilot qualifications.

stations, cathode ray tubes and high speed printers, which were tied into the American Airlines weather distribution system, were provided for crew use in obtaining up-to-date weather information, including SIGMET's. In addition, crews could obtain weather from FAA flight service stations, from ATC facilities, and from the company radio if within range. Air Wisconsin station personnel were not required by company procedure to have weather updates available for Metro crews; the crew was responsible for securing the data. The Director of Flight Operations stated that Air Wisconsin intends in the near future to extend all 14 CFR 121 dispatching services to all Air Wisconsin flights.

The Air Wisconsin Flight Operations Manual requires the following for flight in the vicinity of thunderstorms:

> "When a flight encounters thunderstorm conditions, the area should be detoured if possible. When early evasive action is not practicable, the following suggested minimum clearance distances apply:
>
> a. Avoid areas where sharp changes in rainfall intensity occur by at least five miles at 10,000 feet or below. (Use a 20 NM to 30 NM Range setting on the aircraft radar.)
>
> b. This distance must be increased at the higher altitudes; rule of thumb being about 10-15 miles at middle altitudes (15,000-20,000 feet) and 20 miles at the higher levels above 20,000 feet due to possible tilted storm cells. Echoes which are changing shape, size, or intensity rapidly or echoes which have prominent scallops, hooks, or fingers should also be avoided by the same suggested mileage as shown above.
>
> A minimum distance through thunderstorm areas should be the minimum distances indicated in the preceding paragraph.
>
> a. Weak echoes or areas of weak rainfall gradient may be flown through or adjacent to if judgment dictates this to be the most desirable procedure.
>
> b. When using the recommended ranges for circumnavigating storm cells, a higher range should be monitored at frequent intervals to determine the total extent of the storm areas as well as watching for additional developments."

### 1.17.2 Engine Restart Procedure

The aircraft flight manual provided procedures for an inflight engine restart and for the use of continuous ignition on takeoff and initial climb. There was no procedure calling for placing the ignition in the override position for flight through heavy precipitation. The following procedures for use of ignition are excerpted from the aircraft flight manual:

<u>Normal:</u> Ignition is only supplied to the engine during the automatic start cycle, between 10 percent and 50 percent RPM. This mode is provided for ground use during normal operations. The selector is left in the "Norm" position when not in use for other than normal situations.

<u>Continuous:</u> Ignition is supplied to the engine continuously as long as the main landing gear squat switches are in the ground position. This mode is provided for use during takeoff or landing on wet or slush-covered runways when ingestion is possible.

<u>Override:</u> Ignition is supplied to the engine continuously, regardless of landing gear switch position. This mode is provided for use in the event of inadvertent icing encounters during flight.

The manual cautions that excessive operation of the system in the continuous or override mode will reduce ignition plug life. The duty cycles were 1 minute on - 1 minute off, or 2 minutes on - 2 minutes off, then if required, 2 minutes on - 23 minutes off, or 5 minutes on - 55 minutes off.

The Air Wisconsin Metro Initial Response Emergency Checklist prescribes the following procedures for an emergency inflight engine restart:

EMERGENCY AIRSTART PROCEDURE

1. Power Lever 1 INCH FORWARD OF FLIGHT IDLE
2. Stop and Feather Control IN
3. Fuel Shutoff Switch OPEN
4. Boost Pump ON
5. Start Button (BELOW 50% RPM) DEPRESS & HOLD

IF ENGINE FAILS TO START, REFER TO COMPLETE AIRSTART PROCEDURE ON PAGE III-5 OF METRO EMERGENCY CHECKLIST

Testimony by Air Research personnel was that it would take about 8 seconds for the engine to spool down to 50 percent rpm. However, the restart procedure could be begun sooner if the captain selected the override mode for ignition. However, an AiResearch spokesman stated that, once the engines spooled down to 50 percent, they would require about 6 seconds to develop power again.

### 1.17.3 Aircraft Weather Radar

The aircraft was equipped with a RCA AVQ-47 weather radar set. The system operated on X-band frequency 3.2 centimeter wavelength. The system could display targets at two range selections -- 20 mi and 80 mi. The system was designed to display weather in two modes -- normal and contour. In the normal mode, precipitation is displayed as luminescent areas on the dark background of the cockpit radarscope. In the contour mode, the system displays storm cells by blanking out that portion of the storm trace which indicates heavy rains and attendant turbulence. The contour mode gives positive identification of storm cells by making them appear as black holes in the bright display of the storm boundary trace. The pilot has the capability to tilt the antenna up or down 12° from the horizontal.

At the Safety Board's public hearing on this accident, the manager, Advanced Avionics Systems for RCA, gave testimony regarding the AVQ-47 radar set. He stated that the AVQ-47 radar was designed to give information about thunderstorms to crews so that they can avoid them rather than maneuver through them. He also stated that a major limitation of X-band radar is its higher attenuation rate in precipitation when compared to radars operating at lower frequencies or on longer wavelengths. Attenuation is the loss of radar signal as the signal travels through precipitation. The precipitation diffuses the signal and reduces the receiver's ability to detect the signal return. The amount of signal dissipation is directly proportional to the rate of rainfall. The witness stated that if the AVQ-47 radar is located in an area of rainfall equivalent to 1 inch per hour, or a level-2 intensity rainfall, the radar would not detect a stronger level cell beyond the rainfall area. However, if rainfall remains constant, as an aircraft approaches the stronger cell the attenuation would decrease and the stronger cell would be detectable. If the amount of precipitation increased above a level-2 rate, the attenuation would be greater.

Using data based on NWS WSR 57 radar pictures of the convective activity near the accident site, the RCA spokesman indicated that if the aircraft was in level-2 precipitation northwest of Omaha, the level-5 cell near Fremont would not be detectable until the aircraft came close to the larger storm. He testified that in this case, Flight 965 could have detected the storm almost 15 miles from the level-5 cell. However, the radar system on Flight 965 would not have been able to contour the storm until the aircraft was within 9 miles. He stated that the radar system's ability to detect and contour the level-5 cell would have been less if rainfall intensity exceeded the moderate rate.

The theoretical effects of attenuation by rainfall and water vapor between the radar antenna and the target have been calculated to be quite high for X-band radar as compared to radar operating at lower frequencies and longer wavelengths. 10/ Additionally, empirical evidence 11/ confirms that radio magnetic waves of the X-band frequency are significantly more susceptible to attenuation by rainfall than are the waves of longer length and lower frequency. According to Medhurst there were indications that the measured amounts of attenuation substantially exceeded the theoretical amounts, and he believed that further measurements were needed to clarify the discrepancies.

10/ Skolnik, Merrill L.: Radar Handbook, Chapter 24, McGraw-Hill Book Company, New York, 1970.
11/ Medhurst, R.G.: Rainfall Attenuation of Centimetre Waves: Comparison of Theory and Measurement, IEEE Transactions, Vol AP-13, pp. 550-564, July 1965.

As a result, of its investigation of the crash of Southern Airways, Inc., DC-9-31, N1335U, at New Hope, Georgia, on April 4, 1977, the Safety Board issued the following safety recommendation:

> "Initiate research to determine the attenuating effects of various levels of precipitation and icing on airborne radomes of both x- and c- band radar, and disseminate to the aviation community any data derived concerning the limitations of airborne radar in precipitation. (Class II, Priority Action) (A-78-1)

The FAA responsed, "We do not have evidence of serious problems caused by the accumulation of ice and water on radomes. The attenuation effects of ice and water are well known. We do not believe that research is necessary. To ensure that air carrier training programs are satisfactory in this area, we will request that each principal operations inspector check the training program of his assigned carrier to ensure that all pilots are being given information on the limitations of airborne weather radar with special emphasis on the attenuation effects of precipitation." However, the FAA stated it did plan to measure the effect of water on the radome of aircraft in flight. The Safety Board considers FAA's response unacceptable. We believe that the effect of water on the radome of the aircraft as referenced in Recommendation A-78-1 and the effect of intervening precipitation as evidenced in this accident have a serious affect on airborne radar, and the the subject warrants research and inclusion in aviation training programs for pilots.

### 1.17.4 Center Weather Service Unit

CWSU's were established in air route traffic control centers to provide meteorological information to ensure safe and efficient flow of air traffic. The CWSU's attempt to accomplish this objective by identifying weather phenomena which represent a potential hazard to safe aircraft operation and advising the appropriate ATC facilities of such conditions. The Minneapolis ARTCC CWSU was responsible to provide weather information to supervisory personnel at the Omaha RAPCON, as well as at hub airports in the Minneapolis ARTCC area.

The CWSU at Minneapolis ARTCC was established in March 1980 and staffed by three NWS meteorologists who provide support on weekdays and part of Sunday. The unit was not staffed on Saturday. The CWSU is located in the Minneapolis ARTCC near the flow control desk and is equipped to receive and display service A reports, surface analyses, radar summaries, and all other standard sources of meteorological information. Reports which were received in the center on service A, including SIGMETs, were first received in a separate area of the center. Some service A data were brought to the flow control desk and then provided to the CWSU by the flow control/weather coordinator. Convective SIGMET's were delivered to the CWSU in the same manner, except that the convective SIGMET from service A was first condensed and disseminated to sector controllers and other ATC locations through the FDEP by the flow controller/weather coordinator. The CWSU would receive a copy of the condensed SIGMET.

The CWSU received information on thunderstorms from several radar or radar-derived sources. However, none of the sources provided what CWSU meteorologists and ATC personnel considered timely data. Radar summaries were received from facsimile machines every 2 hours, or time permitting, slightly more frequently. (See appendix E.) Radar summaries were compiled from radar data from NWS radar units which depicted general locations of weather echoes and intensity levels. A second source of radar data was satellite photos which were received every 30 minutes. These photos depict storm locations but cannot be used independently to determine intensity levels. A third source of radar data was the Weather Bureau Radar Remote (WBRR), which provides a continuous radar scan from NWS radar units in the system. However, CWSU personnel stated that the radar presentation of the WBRR was not adequate to determine storm intensity. In addition, the Grand Island NWS radar unit was not in the WBRR system, thus there was no means to determine accurate weather echo intensity and location by WBRR for eastern Nebraska. However, coded weather radar reports from the Grand Island, Nebraska, WSR 57 radar unit were available over the teletype hourly. The reports provided the general location and intensity of weather echoes within 125 miles of the radar. Finally, the CWSU meteorologist could use an ATC plan view display (PVD) to view precipitation returns. However, the PVD is configured for air traffic control purposes and cannot be used to determine specific weather data. It was designed to filter out much of the visible evidence of precipitation so that clutter would not interfere with ATC activities. Nonradar sources of information concerning thunderstorms were available on a timely basis -- service A and other warning systems -- but they did not provide the up-to-the-minute radar-derived data that CWSU and ATC personnel required. CWSU meteorologists and ATC personnel stated that effective CWSU support required the capability for up-to-the-minute radar information which would allow the instant determination of the location and intensity of thunderstorms. "Real time" weather data could be made available through NWS weather radar color remote displays which portray weather cell intensity in color for instant detection by ARTCC personnel. CWSU meteorologists also stated that a service A system was needed in the CWSU work area and that a capability should exist to depict thunderstorm intensities on ATC PVD radarscopes.

CWSU procedures require that written weather briefings be prepared at least three times daily and that one verbal briefing be given. In the Minneapolis Center, briefings were given to the supervisory personnel--assistant facility chiefs, weather coordinator/flow controllers, and the team supervisors -- and to sector controllers when they were available. During the shifts, weather updates were given to supervisory personnel responsible to insure that the information reached the sector controllers. Written briefings were recorded for use by personnel at other FAA facilities.

CWSU meteorologists were responsible to record telephone weather briefings three times daily. The controllers had direct access to telephone briefings from individual sector positions.

CWSU meteorologists issued center weather advisories (CWA) as follows:

a. As an update/supplement to the NWS convective SIGMET program.

b. When the CWSU meteorologist believes that observed or forecast conditions meet SIGMET/AIRMET criteria, coordination will be made with the aviation forecaster, Chicago or Kansas City Weather Service Forecast Office, or National Severe Storm Forecast Center at Kansas City. If the aviation forecaster concurs, a CWA will be issued by the SIGMET/AIRMET.

c. If the CWSU meteorologist believes that a CWA is required and time is of the essence to ensure the safe flow of traffic, the CWA may be issued before a coordination call is made to the appropriate NWS facility.

CWSU meteorologists stated that sector controllers would stop by the CWSU work area to receive spot weather updates and to study the meteorological information that was posted. While controllers observed that the CWSU was helpful, they also noted that, at times, the posted information and the telephone briefings were not up-to-date.

A CWSU meteorologist conducted a weather briefing about 1330 on June 12, 1980. The appropriate supervisors and oncoming controllers were present. The meteorologist who conducted the briefing had issued CWA's that morning which advised of "level 6 severe thunderstorms from 25 northwest of Omaha to 20 west of Pawnee." He stated that in the 1330 briefing he mentioned that "there were, at present time, significant thunderstorms in eastern Nebraska, I believe, extending up over south-central Minnesota and the eastern portions of Iowa and that these systems would, later in the afternoon and evening, build in intensity and area of coverage." He stated that he did not issue additional CWA's since the existing convective SIGMETs, which were being updated hourly, covered the situation adequately.

The second meteorologist briefed supervisory personnel that the eastern Nebraska area would have scattered to broken thunderstorm coverage which would represent up to 50 percent coverage in the thunderstorm areas. He also stated that as additional data became available on the severity of the thunderstorms, he briefed the supervisory personnel on the situation. He recalled telling a flow controller/weather coordinator, about 1500 that in eastern Nebraska there were level-4 and level-5 storms and possibly a level-6. He located the storm area on the PVD in the flow control area and showed the flow controller/weather coordinator the 1400 and 1430 satellite pictures. He stated that before and after that briefing he brought weather information to the supervisors "and discussed the traffic flow and weather parameters at that time." He stated that in addition to discussing the weather situation with the flow controller/weather coordinator, he passed much of the same information and pictures to the area supervisors.

Neither CWSU meteorologist transmitted any information to supervisory personnel at the Omaha RAPCON. They stated that the convective SIGMET's were adequate to cover the existing meteorological condition.

### 1.17.5 Air Traffic Control Procedures

The following were excerpted from FAA Operating Manuals and Orders:

FAA Air Traffic Control Handbook (7110.65B):

Section 2. Weather Information

Paragraph 40. Familiarization

Become familiar with pertinent weather information when coming on duty and stay aware of current weather information needed to perform air traffic control duties.

41. SIGMET Alert

a. Broadcast a SIGMET alert once on all frequencies, except emergency frequencies, when any part of the area described in the SIGMET is within 150 miles of the airspace under your jurisdiction. The broadcast is not required if aircraft on your frequency/s will not be affected by the weather addressed in the SIGMET.

Note 1: The message should be brief but contain enough information to alert pilots of significant weather conditions along their route of flight and to enable them to decide whether they should contact an FSS for more detailed SIGMET information.

Weather and Chaff Services

50. a. Issue pertinent information on observed/reported weather or chaff areas. Provide radar navigational guidance and/or approve deviations around weather or chaff areas when requested by the pilot. Do not use the word "turbulence" in describing radar-derived weather.

b. In areas of significant weather, plan ahead and be prepared to suggest, upon pilot request, the use of alternative routes/altitudes.

50b. NOTE.--Weather significant to the safety of aircraft includes such conditions as tornadoes, lines of thunderstorms, embedded thunderstorms, large hail, wind shear, moderate to extreme turbulence (including CAT), and moderate to severe icing.

FAA Facility Operation and Administrative Handbook (7210.3E):

Paragraph 820. Handling of SIGMET's and Pilot Reports

ARTCC chiefs shall designate a weather coordinator (WC) to serve as the focal point for the collection and dissemination of pertinent weather conditions. The WC shall:

a. To extent possible, not be assigned any other operational or administrative duties which would interfere with weather coodination duties.

b. Receive all requests for PIREP's/SIGMET's and other pertinent weather generated by FSS, other ATC facilities, airline dispatchers, preflight pilots, airport managers, the NWS, military base operations offices, etc.

* * * * *

c. Review SIGMET's to determine required distribution. Disseminate SIGMET information in accordance with the following:

1) Disseminate pertinent information from the SIGMET to terminal ATC facilities and ARTCC sectors when their airspace is within the SIGMET area.

2) Disseminate sufficient SIGMET information to facilitate broadcast of the SIGMET alert message to ARTCC sectors and terminal ATC facilities within 150 miles of the SIGMET area.

Minneapolis ARTCC Order ZMP 7900.7, dated March 7, 1980, established guidelines for the operation of the CWSU. It stated that the CWSU "staffing consists of the NWS meteorologists and weather coordinators. The responsibilities of the CWSU is to function as a team, detect, screen and disseminate aviation weather information to ATC personnel." The weather coordinator was responsible, for distribution of PIREP's and SIGMET's to the meteorologist on duty, to sectors, and to other facilities. The area supervisor was responsible to insure that all area personnel were briefed on current and forecast weather conditions and to consult with the meteorologist regarding development of significant weather systems. Finally, he was to keep the weather coordinator and meteorologist informed of significant weather affecting operations in his area.

Statements

There were two flow controllers/weather coordinators on duty during the afternoon of June 12. The combined duties were to adjust the flow of air traffic to ensure the most effective utilization of airspace and to gather and disseminate weather information through the Center. One flow controller/weather coordinator stated that the CWSU meteorologist told him there was convective activity up to level 6 intensity in the Fremont area but that he did nothing with that information because he assumed that the team supervisor would brief the sector controllers. He believed, therefore, that he was relieved of his weather coordination duties for that particular situation. He stated that since there was significant convective activity in the Fremont area, he was occupied with flow control duties in the high-altitude sectors -- 24,000 ft and above. He did not concern himself with flow control at the low sectors, since "its very difficult to do anything, actually, in flow control for low altitudes due to the fact of the difference of type of traffic that goes on." He further stated that the low sector situation was more a responsibility of the team supervisor. However, he did not discuss the low sector traffic situation with the team supervisor "since there was nothing that I could do for them."

The second flow controller/weather coordinator stated that he was aware of convective activity in the Fremont area from convective SIGMET 40C and from looking at the radar scope in the flow control area. He also stated that the CWSU meteorologist briefed him on the convective activity in eastern Nebraska, but that he was not aware of the severity of the convective activity. He stated that his attention was directed to the flow control duties within an area in the Minneapolis high-altitude sectors, which was being affected by convective activity, and that he did not consider the effect of the convective activity on the low-altitude traffic near Omaha. He believed that the responsibility for the assessment of the impact of weather on that area was the team supervisor's.

The second flow controller/weather coordinator had transmitted convective SIGMET 40C on the FDEP at 1438. Convective SIGMET 42C was received at the flow control desk about 1459, but was not transmitted until 1542. He did not recall why he did not transmit it for 43 minutes. He also stated that when he did transmit the SIGMET he did not include the forecast portion because there was no requirement to do so. The forecast portion stated, "Wind gusts to 55 kns, hail 3/4 inch."

There were two team supervisors on duty during the early afternoon of June 12, 1980. They came on duty at 1200 and 1530 and were responsible only for low sector controllers. The supervisor who came on duty at 1530 was aware of the weather in the Omaha area and that it could possibly be severe. However, he assumed that, since the supervisor he was relieving was aware of the weather, the controllers also were aware of it. He stated that while the supervisor is responsible to insure that the controllers have up-to-date weather information, he did not know why the controllers who handled Flight 965 were uninformed on the severity of the weather around Fremont. He also stated that the flow of traffic through a sector is each individual controller's responsibility. He would not, as supervisor, direct that air traffic be routed around an area which was being affected on a long-term basis by severe weather.

The supervisor signed in for duty at 1200 on June 12, 1980. He was briefed at 1330 by the CWSU meteorologist and again at 1520 by another supervisor. He was aware of possible severe thunderstorms in the Fremont area. He stated that he was not aware of the intensity levels of the storms. He also stated that he assumed the controllers on duty already knew the up-to-date weather. He would have briefed the controllers on any weather information he received directly from the CWSU meteorologists or the flow controller/weather coordinator. He believed he had the authority to reroute traffic around unfavorable weather conditions but he would only do so in conjunction with the flow coordinator.

The assistant chief of the Minneapolis ARTCC stated that, if the area supervisors had been aware of the existing and potential convective activity west of Omaha, they should have informed the sector controllers of the conditions. Otherwise he was satisfied that the CWSU did provide adequate weather data to the ARTCC. He did state that he would like to have a better "real time" radar capability.

Flight Service Station (FSS)

The Lincoln FSS inflight specialist stated that he did not transmit convective SIGMET 42C over the Lincoln VOR because he was occupied with higher priority duties. Between 1500 and 1545 he briefed pilots, plotted radar reports, communicated with pilots, and performed other duties. The chief of the Omaha FSS stated that convective SIGMET 42C was not broadcast over any VOR's in his area. He did not know why, but assumed it was because of higher priority duties. Convective SIGMET 42C was received in the Omaha FSS at 1504. It was broadcast by a recording on the outer compass locator of the Omaha instrument landing system (ILS).

The following procedures were extracted from FAA Flight Services Handbook (7110.10E) Paragraph 8:

8. Priority Duties

During peak activity periods, duties may occasionally conflict. Under these circumstances, personnel must use good judgment and, in general, be guided by the following order of duty priorities:

a. Emergency or urgent actions when life or property is in immediate danger.

b. Actions required by indications of navaid malfunctioning.

c. Services to airborne aircraft.

d. TWEB and PATWAS (except those recording changes required by subparagraph e).

e. "Aviation Inflight Weather Advisory, Convective SIGMET (WST), SIGMET (WS), AIRMET (WA), Alert Weather Watch (WW). Actions required for scheduled, unscheduled and TWEB broadcast."

f. Weather observations and PIREPs (includes dissemination)

g. Preflight pilot briefings.

h. Unscheduled broadcasts (except those broadcasts required by subparagraph e.)

i. Teletypewriter duties.

j. Alaska - Scheduled broadcasts (except those broadcasts required by subparagraph e.)

Paragraph 261A of 7110.10E requires that Convective SIGMETs be broadcast over VORs within their areas immediately upon receipt and then each 15 minutes on the quarter hour.

## 1.18 Useful or Effective Investigation Techniques

Commercial television stations in the Omaha area were canvassed to determine if recorded weather radar data were available for the time period of the accident. One station, which owned a WR 100-2/77 meteorological radar unit, videotaped weather echo returns near Fremont during the period before and after the accident. The radar unit was calibrated to depict the six NWS weather echo intensities in color.

The videotape provided a method to develop a nautical mile range scale based on the polar coordinates of the radar antenna and the weather map overlays for Fremont, Nebraska, and Sioux City, Iowa. The distance and true bearings were determined by the National Oceanic and Atmospheric Administration from the polar coordinates of the points. The location of Flight 965's flight track was determined from polar coordinates derived from the Minneapolis ARTCC RDP D-log data.

The correlation of the data indicated that at 1512 Flight 965 was about 46 miles from the eastern edge of the level-1 precipitation area shown on the video tape. The northeast/southwest extent of the precipitation area was about 70 miles and covered the area from Fremont to about 15 miles east-northeast of Sioux City, Iowa. The eastern edge of the precipitation area remained fairly stationary up until Flight 965 entered it. A level 5 weather cell was located about 40 miles ahead of Flight 965 when it entered level-2 precipitation.

## 2. ANALYSIS

The pilots were certificated properly and were qualified for the flight. They had had the off-duty time required by regulation. There was no evidence that physiological factors might have affected the flightcrew's performance.

The aircraft was certificated, equipped, and maintained in accordance with regulations and approved procedures. There was no evidence of a failure of the aircraft's flight controls, systems, structure, or powerplants before the aircraft entered heavy precipitation. Although the aircraft reportedly experienced a dual power loss or flameout after the heavy precipitation was encountered, there was no preimpact damage to the powerplants, systems, or flight controls.

### Flight Into Severe Meteorological Conditions and Engine Flameout

Based on the radar summary charts prepared by the NWS between 1235 and 1635, the weather radar observations from the NWS WSR 57 radar at Grand Island for 1530 and 1630, and the weather radar overlay from the Omaha NWS radar at 1545, there is no doubt that Flight 965 encountered a thunderstorm of VIP level 5 or greater intensity, and that the aircraft had encountered the storm before the 1545:02 transmission that it had "lost both engines." The testimony of the surviving passengers and the 1544:10 transmission indicating moderate to severe turbulence provide additional evidence that Flight 965 had encountered severe weather conditions.

Once Flight 965 encountered the storm cell, it was subjected to intense or extreme precipitation and severe turbulence. Strong horizontal wind gusts of 35 meters per second (70 kns) and severe wind shears also were likely present. The aircraft remained in the VIP level 5 or greater thunderstorm area through ground impact. Since the ceiling and visibility at the accident site was less than 100 ft, with the sky obscured and 1/4 mile visibility, the flightcrew had almost no visual warning of the impact with the ground.

The wind damage pattern on the ground near the accident site and the Bow echo observed on the Grand Island radar photographs indicate a downburst. The downburst probably produced horizontal wind gusts near the surface of 35 meters per second from the north with strong downward vertical velocities.

The magnitude of the downward vertical velocities could not be measured. However, research indicates 12/ that the magnitude of downdrafts can be determined by calculating the surface divergence and then solving for the vertical velocity. The divergence near the center of the downburst is computed from $\frac{2\,Vr}{R}$, where Vr is the radial velocity averaged over the entire azimuth from the center of the downburst in meters per second and R is the range from the center of the downburst in meters. The horizontal surface winds were measured by anemometers near the accident site at 35 meters per second (81 mph) and were

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12/ Fujita, Theodore T., May 1978: Manual on Downburst Identification for Project Nimrod, SMRP Research paper No. 156, 104 pp.

estimated as high as 100 mph by other observers. Therefore, Vr is assumed to be 35 meters per second. The exact center of the downdraft could not be determined. However, by postulating the downdraft center as being at distances of 3,000 meters, 2,000 meters, or 1,000 meters from the aircraft, downdrafts as great as 1,400 fpm, 2,100 fpm, and 4,100 fpm respectively were calculated for 900 ft above ground level. The downdraft velocities would be higher if the actual winds approached 100 mph at the surface.

From 1543:34 to 1544:57, Flight 965 descended 2,200 ft, or almost 1,600 fpm. From 1544:57 until 1545:19, when the Omaha RAPCON controller observed the altitude of Flight 965 about 1,900 ft, the rate increased to about 4,900 fpm. When Flight 965's crew reported a dual power loss at 1545:02, the aircraft probably was being subjected to a downburst which may have reached 4,100 fpm or greater, in addition to the precipitation and the turbulence. The loss of thrust at this critical moment for at least 14 seconds and the failure of the engines to recover full thrust probably made the accident inevitable.

The Safety Board concludes that the dual loss of power (or the complete flameout of both engines, which was reported by the crew at 1545:02) was the result of ingestion of massive quantities of water through the engine inlets. In addition, strong horizontal wind gusts and vertical downdrafts could have affected the engine operation by disrupting the airflow through the engine inlets. The Safety Board was not able to determine if pilot actions affected the engine operation. Based on the probable water levels which are present in VIP level 5 or greater thunderstorms, the Safety Board concludes that Flight 965's engines ingested water flows which were at least 9.6 percent of air-flow weight. That figure was at least 2.4 times greater than the certification requirement for the engine and 2.3 times greater than the ingested water flow demonstrated during the certification process. The Safety Board believes that the certification standards are adequate to ensure the safe operation of the AiResearch TPE 331-3UW-303G engine in the full range of normal or emergency conditions. However, it is not realistic to expect an engine or an airframe to be designed to sustain the extreme forces and conditions which were encountered in this severe thunderstorm.

The engine and propeller examinations revealed that both engines were operating at low power at impact. Evidence of low-power indicate that a crewmember reduced the power just before impact, or most likely, the engines had not recovered full takeoff power. The level of water ingested could have allowed the engine be restarted, but did not permit a normal spool-up to takeoff power. The latter event is more likely since one surviving passenger recalled that both engines were restarted, but never regained the level of power that he recalled was present during cruise flight.

## Preflight Preparation, ATC Handling, and En Route Operations

Air Wisconsin's flight operations procedures stated clearly that flight in or near thunderstorms was to be avoided. However, since Flight 965 clearly encountered a VIP level 5 or greater thunderstorm near Fremont, Nebraska, the

Safety Board sought to determine why a professional crew flew into such severe weather and what effect their preflight preparation and en route activities had on the severe weather encounter.

The flightcrew accomplished all the preflight activities required by 14 CFR 135 and by company procedures. Convective SIGMET 38C and terminal forecasts were available to the flightcrew. In fact, the Air Wisconsin flight control and supervising dispatchers provided the crew with information similar to that a 14 CFR 121 crew would receive. Based on the meteorological information available from flight control and from statements by Air Wisconsin personnel, the Safety Board concludes that the flightcrew had received an adequate briefing and were aware of the forecast of thunderstorms in the eastern Nebraska area.

When Flight 965 arrived at Minneapolis/St. Paul International Airport, the crew had the option of again checking the weather and SIGMET's. By that time, convective SIGMET's 39C and possibly 40C were available. Since there is no indication that the Air Wisconsin weather facilities were used by the crew in the 18-minute stopover, nor that any FAA en route facilities were queried by Flight 965, the Safety Board concludes that the crew did not try to acquire the information. The Safety Board also concludes that based on the forecast of thunderstorm activity near their destination and the visible evidence of thunderstorms along the route, a prudent flightcrew would have sought additional weather information as their flight progressed. Since there is evidence that the crew of Flight 965 asked for no additional information, or assistance from ATC sources, and had received only the PIREP from another Air Wisconsin flightcrew, it seems likely that the crew of Flight 965 placed significant reliance on that PIREP. However, it is evident that, while Flight 965 was flying from Minneapolis toward Lincoln, the weather was not dissipating; it was, in fact, intensifying. The Safety Board believes that this accident illustrates the hazard associated with reliance on any single source for information about potentially severe convective weather activity. Just as significant, the accident underscores the changing nature of thunderstorms, and the importance of up-to-date information on the safety of flight near areas of convective activity.

Although Air Wisconsin dispatchers at Flight Control received the hourly convective SIGMET's, no Federal regulation or company policy existed to require that the information be passed to crews by flight control. Furthermore, there was no regulation or company requirement which caused station personnel to prepare updated weather documentation for incoming flights. While the Safety Board recognizes that 14 CFR 135 places total responsibility for weather information with the captain, it believes that, station personnel should be encouraged to prepare weather documents for incoming crews and that weather packages should be given to flight crew. In addition, available SIGMET's should be posted in a designated area for pilot briefing purposes. The Safety Board believes this service is particularly important when short ground time is scheduled, and that in the case of Flight 965, it would have served to forewarn the crew of developing weather conditions, since additional convective SIGMET's would have been available to the crew. The Safety Board believes that the conflict between the earlier pilot report and convective SIGMET's 39C and 40C would have been significant information to the crew.

While en route, convective SIGMET 42C was issued by the NWS and was received in the Minneapolis ARTCC. Since it was not given to the controllers of Flight 965 by supervisors and, therefore, was not broadcast to Flight 965, the ATC system failed to provide an important element of the flightcrew's data base. However, it was available to the crew from flight service stations. In addition, since the sector controllers were not informed of the convective SIGMET by their supervisors, they were not prompted to ask for PIREP's or to make in-house inquiries to ATC supervisors who were aware of the severity of the thunderstorm cells. Had the O'Neill low sector controller known of the severity of the thunderstorms, when he informed Flight 965 of a "large area of weather" which lay across the route of flight, he could have told the crew that the large area of weather contained severe thunderstorms. Additionally, at 1514:19, when the O'Neill and Omaha low sector controllers discussed Flight 965's decision "to try to go through it," had either controller known of the VIP level 6 thunderstorm, he could have passed along this critical information to the crew of Flight 965. Finally, had the Omaha RAPCON controller been aware of convective SIGMET 42C and of VIP level 6 thunderstorms in his sector, the comment at 1534:05 about a "pretty good size" cell would have been given significantly more emphasis and explanation. Instead, the controller made no reference to any cell activity when Flight 965 was handed off to Omaha RAPCON at 1536:25.

The Safety Board believes that the installation of a NWS weather radar color remote display at the Minneapolis CSWU would have aided the meteorologists and ATC supervisors in assessing the impact of the severe meteorological conditions. In addition, if the NWS weather radar color remote display had been correlated with sector controller's radar displays, controllers would have had first hand knowledge of the weather situation. The Safety Board is aware of the program of the FAA to introduce weather radar color remote displays to CWSU's and to correlate the displays to the controller's radar presentation. We urge the FAA to expedite the completion of these programs.

The failure of the Omaha and Lincoln FSS to broadcast convective SIGMET 42C on the VOR's prevented the flightcrew from receiving important weather information from the ATC system. The Safety Board has cited the failure of the ATC system to provide a timely flow of meteorological information in several accidents and incidents. Specifically, the Safety Board had been critical of the processing of SIGMET's and AIRMET's, and of the failure of the ATC system to provide critical information to sector controllers. The facts of this accident indicate that despite the efforts of the FAA to implement new and existing procedures and to establish facilities such as the CWSU, there still remains a need for more effective coordination efforts to insure that the procedures are implemented uniformly throughout the ATC system.

Despite the failures of the ATC system to provide adequate advisories, the flightcrew retained the responsibility to conduct the flight safely and had adequate means and information to do so. The flightcrew had received preflight weather information which indicated VFR conditions with scattered clouds and good visibilities except in thunderstorms. As Flight 965 approached the Omaha-Fremont area the visible thunderstorm cells, lightning and precipitation, and the lowering ceiling should have prompted the crew to request vectors around the area or to inquire about the conditions ahead. In addition to the SIGMET information available during the flight's stop at Minneapolis and the inflight observations the captain had the airborne radar to assist him in circumnavigating significant weather echoes as they were encountered. The ATC transcript indicates that the captain had considerable confidence in the airborne radar to accomplish this function. However, an analysis of the meteorological situation from a point about 50 miles northeast of the accident site revealed that there was a strong likelihood that the capabilities of the radar set were degraded by precipitation. (The meteorological environment that Flight 965 encountered before the accident was estimated from Grand Island and Des Moines weather radar data (figure 3). These data were assumed to represent the radar reflectivity patterns encountered by Flight 965.). The Safety Board believes that when the moderate precipitation was encountered, the crew should have anticipated the developing thunderstorm activity. Flight 965 encountered light and then moderate precipitation more than 32 miles northeast of the accident site, which, when coupled with lightning, should have prompted the crew to seek additional assistance from the ATC system or from Air Wisconsin flight control.

At 1537, while 32 miles from the accident site, Flight 965 reported moderate precipitation. Analysis of Grand Island weather radar data supports the fact that the aircraft was in an area of moderate precipitation (VIP level 2) at that time. These data also indicate that the precipitation area ahead of the aircraft increased in intensity continuously to the accident site. In the contour mode, the AVQ-47 will indicate a contour when the weather echo reflectivity is about the threshold value of a VIP level 3 weather echo. At 1537, the leading edge of a VIP level 3 weather echo was about 14 miles ahead of the aircraft and a level 5 or 6 intensity weather echo was farther ahead of the aircraft. Because Flight 965 was in an area of moderate VIP level 2 precipitation, significant 2-way attenuation of radar energy would have occurred. Consequently, at 32 miles from the accident site, the flightcrew would not have been able to detect any VIP level 3, 4, 5, or 6 intensity thunderstorm.

As the aircraft proceeded southwest, a contour should have been evident on the radarscope as Flight 965 approached the leading edge of the VIP level 3 weather echo area. However, precipitation-induced attenuation probably prevented the display of a contour on the radarscope until Flight 965 was within about 1 mile of the area. At that point, the area of contour actually depicted on the radarscope would have been small.

Once the aircraft entered the area of VIP level 3 weather echo, it is not likely that a contour was being displayed on the radarscope from that point forward to impact. Therefore, the pilot had no way of knowing the intensity of weather echoes ahead by using his weather radar. Additionally, the detection capability of the weather radar would have been reduced to less than 9 miles once the aircraft entered the area of VIP level 3 weather echoes. As a result, as the aircraft proceeded southwestward, the weather ahead of the aircraft displayed as a bright area on the radarscope would have diminished in horizontal extent. This could have lead the crew to believe that they were about to leave the area of precipitation when in fact they were heading into the most severe portions.

Surviving passengers reported two distinct encounters with increasing precipitation and turbulence just before the loss of both engines. Although it is not possible to associate either encounter with a particular cell, based on passenger statements and recorded weather data, it is reasonable to conclude that, by 1544:10 when the crew reported moderate to severe turbulence, Flight 965 had penetrated a VIP level 5 or 6 thunderstorm. In view of the severe turbulence, wind, and precipitation associated with a VIP level 5 or 6 thunderstorm, at that point, the flightcrew had no option other than to attempt to maintain attitude and fly through the cell.

After the Southern Airways DC-9 accident, the Safety Board stressed the fact that flightcrews must know the uses and limitations of airborne weather radar. In that report the Safety Board stated:

> "Scientific studies show that the X-band frequency radar is comparatively susceptible to attenuation by water vapor and precipitation. This may be particularly true when precipitation covers the antenna radome. If a pilot fails to consider this limitation, he may misinterpret the display in the process, which is a significant reason why airborne radar should not be used as a storm penetration aid. For maximum effectiveness, interpretation of X-band radar displays should be accomplished when the aircraft is in areas free of water vapor or precipitation."

The circumstances of this accident again prove that airborne radar has significant limitations and that flightcrews must be aware of those limitations. Three important lessons must be learned from this accident. First, airborne weather radar cannot and should not be used to penetrate severe weather. Secondly, existing airborne weather radar cannot be relied upon exclusively for severe weather detection and avoidance in all circumstances. Third, when atmospheric conditions exist which would limit the capabilities of airborne weather radar, the flightcrew must seek additional assistance from ATC and company sources. The Safety Board believes that air carrier training programs must reflect renewed emphasis on educating pilots on these limitations of airborne weather radar.

### 2.1.3 Air Traffic Control Procedures

The details of the ATC involvement in the accident indicate that adequate personnel, procedures, and units were available to provide satisfactory ATC services to Flight 965. The establishment of the CWSU and the institution of flow controller/weather coordinator procedures to channel meteorological data to sector controllers and to the approach controller at Omaha RAPCON were well documented in FAA Order ZMP 7900.7 and in the Minneapolis CWSU Duty Manual. Therefore, in theory and in practice, FAA and the NWS had the means to provide to Flight 965 meteorological information in the form of convective SIGMET 42C, and more significantly, virtually real-time information concerning VIP level 5 or greater thunderstorms near Fremont. Furthermore, Flight 965 could have been advised of the meteorological conditions in time to have requested alternate routing to Lincoln.

The Safety Board is concerned with the deficiencies in the Minneapolis ARTCC performance in this accident, since many of the shortcomings had been discovered in the investigation of the April 4, 1977, Southern Airways DC9-31 accident in New Hope, Georgia, and were the subject of several Safety Board safety recommendations. In response to these safety recommendations, the FAA specifically instituted adequate procedures which could have prevented similar weather-involved accidents. However, the ineffective manner in which the procedures were implemented by the Minneapolis ARTCC undermines the credibility of the new FAA procedures.

Clearly, the critical meteorological information was available in the Minneapolis ARTCC in time to affect Flight 965's decisionmaking. The CWSU meteorologists provided a steady flow of weather updates to Minneapolis ARTCC team supervisors and flow controller/weather coordinators. Despite the assertion by CWSU meteorologists and ATC personnel that the CWSU lacked a satisfactory source of real-time weather information, the Safety Board concludes that, in this instance, the CWSU meteorologists had sufficient and credible data to alert supervisory personnel of the existing hazardous meteorological conditions and that CWSU personnel, in fact, provided adequate briefings of Minneapolis ARTCC personnel.

The severity of the thunderstorms near Fremont was the subject of weather briefings and updates between 1330 and 1545 in the Minneapolis ARTCC. The two team supervisors and the two flow controller/weather coordinators responsible for the supervision of the sector controllers and for dissemination of weather data had received the information. However, each stated that he did not inform any sector controller of the severe weather conditions nor did he know why the information was not given to the controllers. Three of the individuals assumed that the information was provided to the controllers by on-duty controllers and earlier supervisors. None of the four took any action to determine how the severe weather information was affecting air traffic in the Fremont area or if the sector controllers were aware of the most recent updates--after 1500--on the severity of the cells. The Safety Board concludes, therefore, that the sector controllers involved with Flight 965 did not receive critical meteorological briefing updates because the team supervisors and the flow controller/weather coordinators failed to perform the duties specified in FAA Order ZMP 7900.7 with regard to dissemination of weather data. The Safety Board is concerned particularly that, in this instance, the breakdown in the system resulted from a failure to use facilities and procedures already in place rather than from a lack of facilities or procedures.

The Omaha RAPCON controller was not alerted to the severity of the thunderstorms because convective SIGMET 42C was not transmitted to his position by the Minneapolis ARTCC flow controller/weather coordinator until 1542 and because the CWSU meteorologists did not inform Omaha RAPCON supervisors of the convective developments in the Fremont area. FAA Order 7210.38 requires that weather information be disseminated to the Omaha RAPCON, and one meteorologist testified that he would have passed on information of thunderstorms with moderate or greater levels of turbulence. Although he did brief Minneapolis

ARTCC supervisors on a continuous basis regarding the convective activity near Fremont, he did not provide the same service to the Omaha RAPCON supervisors. He stated that he believed the convective SIGMET's covered the meteorological situation adequately.

In addition to its concern about the failure of the system to communicate weather data to the controllers and thus to pilots, the Safety Board is also concerned by three other aspects of the ATC system. First, while the fundamental purpose of the ATC system is to separate aircraft from other aircraft, the Safety Board believes that the FAA should analyze and evaluate the technical and operational feasibility of requiring that the ATC system provide separation between aircraft and hazardous meteorological conditions. The critical element however, is equipment to locate and display severe meteorological intelligence in a timely manner. The Safety Board believes that technology can be developed to provide data on hazardous meteorological conditions to the ATC system on a real-time basis. Therefore, we urge the FAA to expedite programs which are involved with this technology. Once the ATC system has the capability to receive real-time weather intelligence, the question should be considered of expanding the purpose of the ATC system to include the active separation of aircraft from hazardous weather conditions.

Second, apparently the responsibilities of the two weather coordinators, who were also assigned the duties as flow controllers were not clearly defined. Neither individual believed he had significant responsibility for aircraft in the low-altitude sectors. In fact, both flow controller/weather coordinators were preoccupied with high-altitude traffic which was being disrupted by convective activity; one of those areas was the Omaha high-altitude sector. One flow controller/weather coordinator stated that he had not given any thought to the impact of the meteorological conditions on low-sector traffic near Omaha. At the same time, both team supervisors had only a vague idea regarding the relationship of the team supervisor, flow controller/weather coordinator, and low-sector traffic. Testimony of the supervisory personnel indicated that, while it was more in the purview of the team supervisor to insure that low-sector traffic was not disrupted by meteorological conditions, both team supervisors would expect controller/weather coordinators to assist. The lack of clearly defined supervisory responsibility was an important factor since the attention of any team supervisor or flow controller/weather coordinator to the specific situation near Omaha and Fremont would have insured that the sector controllers were informed of the existing severe meteorological conditions. Conceivably, proper supervisory coordination would have resulted in the rerouting of traffic around the Fremont-Omaha area. The Safety Board believes, therefore, that the specific responsibilities of team supervisors and flow controller/weather coordinators must be examined and more clearly defined to provide adequate information to sector controllers.

Third, although there were two flow controller/weather coordinators on duty, actually, only one was performing as a weather coordinator. This individual testified that he did not receive the training required to perform some of the duties of weather coordinator, nor was he able to "collect, evaluate, and screen weather intelligence to determine its operational pertinence." This individual was also responsible for receiving and retransmitting the various convective SIGMET's. Convective SIGMET 40C was not disseminated to the required sectors and facilities until 38 minutes after it was received, and convective SIGMET 42C was not disseminated until 43 minutes after it was received. These events, coupled with the lack of dissemination of other meteorological information, support the Safety Board's conclusion that the weather coordinator duties were not performed satisfactorily and that at least one weather coordinator was not fully aware of his duties.

The O'Neill and Omaha low-sector controllers performed their ATC advisory responsibilities in a satisfactory manner, considering the information available. Each controller passed to Flight 965 all the information that was at hand, and none of the data indicated the presence of severe thunderstorm cells near Omaha. Although the Omaha RAPCON controller had received no additional information from ATC services, he did receive information from other pilots in the 2 minutes before he took control of Flight 965. The transmissions, which concerned a "good size cell" and deviations around the Fremont area, could have provided an indication of the nature of the weather. It is not possible to determine what effect that information would have had on the crew of Flight 965. The Safety Board does believe, however, the controllers would have informed Flight 965 of the severe nature of the thunderstorms near Fremont if that information was presented to them. Also, we believe the crew would have requested a change of route.

The severe thunderstorm warning issued at 1520 by the NWS was not transmitted to the Omaha RAPCON because it did not include Douglas County. Although it cannot be determined what effect this information would have had on the accident, this warning would have provided the Omaha RAPCON controller with an indicator of the intensity of thunderstorms he was observing within his airspace. The Safety Board believes that all weather warnings issued by the NWS Office in Omaha should be transmitted to the Omaha RAPCON. In addition, selected weather radar reports should also be transmitted when it is determined the severe weather will affect the flow of air traffic.

Crashworthiness

The seat deformation and separation patterns indicate that the primary decelerative forces were to the front right of the fuselage and slightly downward. In the cockpit and the forward cabin area, there were high vertical decelerative g forces. There were high longitudinal decelerative g forces in the main cabin, since all occupied seats sustained damage without severe floor disruption. The g forces probably exceeded the ultimate inertia loads to which the seats were designed and tested.

The design and compliance criteria do not require combined loading to be considered or accounted for in the design or static testing of passenger or crew seats. The present criteria obviously are unrealistic as almost every crash impact will have at least two components to the resultant crash force. In fact, dynamic tests have indicated that the loads transmitted to the seat can be greater than the peak loads at the floor due to "dynamic overshoot," which is the amplification of the floor load due primarily to the elongation of the restraint system induced by the reaction of seat occupants to the decelerative forces. 13/ The load amplification can range from 1.1 to 2 times the floor level load, depending on the elasticity of the seat and the restraint system. Therefore, it is logical that the passenger seat separations occurred when the uniaxial loads transmitted to the seat exceeded 18g's (13.5g X 1.33) forward, 4g's downward (3g X 1.33), or 2 g's sideward (1.5g X 1.33). However, the seats could have failed as a result of a combined load that was of lower magnitude.

The Safety Board has been concerned about the crash safety standards in 14 CFR 23, "Airworthiness Standards, Normal, Utility and Acrobatic Category Airplanes" In 1970, the Safety Board recommended dynamic testing of aircraft seats and the raising of the "minor crash landing" inertia forces of 14 CFR 23.561. (CY-70-42). The letter to the FAA Administrator, also stated, "In the light of the aforementioned crash safety research data, we think that the existing crash safety standards in FAR Part 23 do not encourage practical applications of existent state of the art."

On June 2, 1975, the Safety Board issued safety recommendation A-75-51. The Safety Board stated:

> "The Safety Board also questions the adequacy of 14 CFR 23 certification criteria for static testing of seats and restraint devices. The seat attachments in this case, which had been certificated under 14 CFR 23, were not adequate and had to be redesigned. The Safety Board, therefore, reiterates its belief that crashworthiness standards for small aircraft should include dynamic testing of aircraft seats as a part of the certification requirements. The Safety Board further believes that the mechanism which caused the "quick disconnect" seats to fail would have been identified in the certification process if realistic dynamic tests had been made."

The Safety Board recommended:

> Amend 14 CFR 23.785(f) to require dynamic testing of seats to insure more realistic protection of occupants from serious injury in a minor crash. (A-75-51.)

The FAA responded that it has "considered for some time the feasibility of changing the current structural design regulations in order to improve conditions pertinent to the protection of occupants of small airplanes in survivable crash conditions. The current design regulations, based on static inertia loads, may be amended to include dynamic loads." Completion of the FAA program in this area was scheduled for the mid-1980's.

13/ "Crash Survival Design Guide," USAAMRDL TR 71-22, revised October, 1971.

While the Safety Board is encouraged by the FAA's intentions to consider an upgrade of Part 23 standards, an urgent, immediate need exists to expedite the ongoing efforts and to improve the crash safety standards in 14 CFR 23.

The Safety Board has urged the FAA to accelerate its crashworthiness program and to develop a realistic definition of the crash environment. The Safety Board believes that sufficient data exist to establish the relationship between static design loads and actual dynamic conditions, and we urge the FAA to continue the existing crashworthiness programs on an expedited and priority basis.

The accident was survivable for the passengers since the cabin remained virtually intact and the occupant acceleration environment, although relatively high, was within the limits of human tolerances. The failures of the seats and of the occupant restraints were the survivability elements which resulted in the fatalities and injuries to the passengers. The avoidable deaths of these passengers underscore the urgency of the need for improvements in aircraft crashworthiness standards. The accident was not survivable for the flightcrew, since the cockpit area was destroyed during the impact sequence.

Passenger injuries probably were inflicted throughout the crash sequence, as the seat and restraint systems tiedown chain was weakened and damaged by each succeeding impact. In the final stages of the crash sequence, the occupied seats were torn from the attach points which allowed the occupants to be thrown about the cabin. This is evident by the proximity of the passengers to their seats, and by their distribution throughout the cabin rather than just in the front area of the fuselage. Most of the serious and fatal injuries resulted from the secondary impacts that were sustained after the passengers were thrown against the aircraft structure and cabin interior furnishings. The abdominal bruises on all passengers and serious internal injuries suffered by the two survivors attest to the relatively high acceleration environment.

The access to the accident was hampered severly by the remote site and by the mud conditions in the fields and roads near the site. The mud made movement to the accident site almost impossible for all rescue vehicles except farm tractors. The only postcrash hazard at the accident site was the potential inability of rescue personnel to obtain immediate access to the injured passengers inside the aircraft. The main entry door was jammed and two of the three emergency window exits remained closed. None of the window exits could be opened from the outside. Access to the cabin would have been blocked completely if the left emergency exit window had not popped open during the impact sequence. Fire was not a factor in the accident; however, in accidents involving fire where passengers may be incapacitated by impact trauma, smoke, or otherwise unable to get out the capability of rescue personnel to quickly and efficiently enter the aircraft to fight cabin fires and assist in passenger egress is paramount.

The Safety Board recommended on May 1, 1979, that the FAA "amend 14 CFR 135.169 by incorporating the general provisions of 14 CFR 121.310(g)(1), (2) and (3) with regard to exit conspicuity and operability on air taxi aircraft with a capacity of 10 or more passengers." (A-79-14). The Safety Board also recommended that the FAA "amend 14 CFR 135 appendix A (paragraph 32) by incorporating the general provisions of 14 CFR 25.811(f)(1), (2) and (3) with regard to exit conspicuity and operability." (A-79-15)

The recommendations were made because many of the larger Part 23 aircraft had emergency exits which were not identified easily from the outside, and had no operating instructions for rescue personnel. The Safety Board believes that the air taxi/commuter type aircraft should have highly visible external markings, on emergency exits and that emergency exits be operable from the outside for rescue purposes.

## 3. CONCLUSIONS

### 3.1 Findings

1. The flightcrew was properly certificated and qualified.

2. The aircraft was properly certificated and maintained according to approved procedures.

3. The flight was conducted properly in accordance with 14 CFR 135 and in accordance with Air Wisconsin operational specifications and procedures.

4. Air Wisconsin flight control provided all the required preflight and meteorological information before Flight 965 departed Appleton.

5. The flightcrew was aware that thunderstorms were forecast for eastern Nebraska.

6. The flightcrew did not update its weather information during the stop at Minneapolis, but did receive a pilot report that the thunderstorms on the route to Lincoln were dissipating.

7. The flightcrew did not receive convective SIGMET 40C or 42C from any ATC facility.

8. The flightcrew did not attempt to update the weather en route to Lincoln from ATC facilities, and convective SIGMET 42C was not on transcribed VOR broadcasts.

9. Adequate indications existed to alert the flightcrew of the development of thunderstorms in eastern Nebraska.

10. The flightcrew had sufficient time to request a deviation after it had indications that thunderstorms had developed along the route of flight.

11. The aircraft was operated continuously in level 2 or greater precipitation from about 50 miles northeast of the accident site.

12. The airborne weather radar operated properly; however, precipitation-induced attenuation severely limited its usefulness.

13. The radar did not display any contours of weather echoes along the flightpath on the airborne radar until Flight 965 was within 1 mile of the VIP level 3 weather cell.

14. The captain attempted to avoid the more intense turbulence by descending to 3,000 ft.

15. A dual power loss or flame out occurred when the engines were subjected to an injected water flow which was more than two times the certification standard.

16. Once the power was lost, the accident was inevitable.

17. Flight 965 entered a VIP level 5 or greater thunderstorm and remained in the cell until ground impact.

18. After encountering the severe thunderstorm, Flight 965 was subjected to intense or extreme precipitation, severe turbulence, strong horizontal wind gusts, and severe wind shear.

19. Flight 965 encountered a downburst just before impact which resulted in downward vertical velocities of about 4,100 fpm.

20. The severity of the thunderstorms in the Fremont area was known to the local population in Omaha/Fremont, to the NWS forecast office in Omaha, to the CWSU meteorologist, and to certain ATC supervisory personnel in the Minneapolis ARTCC.

21. The O'Neill and Omaha low-sector controllers and the Omaha RAPCON controllers were not aware of the severe weather in the Fremont area.

22. The Minneapolis ATC/CWSU procedures for the dissemination of weather information would have been adequate if they had been adhered to by ATC supervisory personnel.

23. The CWSU meteorologist should have briefed Omaha RAPCON supervisory personnel on the convective activity near Fremont.

24. Convective SIGMET 42C was not disseminated in time to be of use to the appropriate sector controllers and to the crew of Flight 965.

25. The flow controllers failed to evaluate the impact of the severe weather on low-altitude traffic.

26. The flow controller-team supervisor relationship and responsibilities were not understood by individual supervisors.

27. Weather coordinator duties were not performed satisfactorily.

28. One weather coordinator was not qualified for the position.

29. The team supervisors failed to insure that the sector controllers were aware of current weather conditions, and they did not assess the impact of the convective activity on the air traffic near Fremont.

30. The ARTCC at Minneapolis did not have the capability to receive adequate real-time weather echo information.

31. Air traffic controllers do not have the responsibility to separate aircraft from hazardous weather conditions unless requested by the pilot.

32. All of the occupied passenger seats separated from the airframe.

33. The static seat test requirements of the Federal regulations are not representative of dynamic loads generated in accidents because the actual loads on the seat can be significantly higher than those on the airframe because of factors involving dynamic overshoot.

34. The flightcrews fatal injuries were a result of blunt impact trauma associated with the collapse and destruction of the cockpit area and subsequent secondary impact with surrounding structure.

35. Passenger fatal and serious injuries resulted from impacting the seats and fuselage internal structure surrounding them because of seat failures and failures of the restraint system.

36. The accident would have been survivable to more passengers if the seats had remained in place.

37. Emergency exit windows on the Swearingen Metro could not be opened from the outside.

## 3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of the accident was the flightcrew's continued flight into an area of severe thunderstorms, and the resultant precipitation induced flameout or loss of power of both engines at an altitude from which recovery could not be made.

Contributing to the cause of the accident was the failure of the flightcrew to utilize all available sources of weather information and the failure of the air traffic control system to disseminate critical weather information to the air traffic controllers and to the crew of Flight 965, the failure of air traffic control supervisory personnel to accomplish key job functions, and the failure of Center Weather Service Unit meteorologists to disseminate critical weather information to the Omaha Radar Approach Control Facility supervisors. Also contributing was the precipitation induced X-band radar attenuation which limited the ability of airborne weather radar to detect the extent and intensity of the weather disturbances.

## 4. RECOMMENDATIONS

The Safety Board has issued several safety recommendations relating to aviation weather subsystems and real-time display of weather phenomena. The FAA has made significant progress in that area. However, the Safety Board continues to reiterate the need for real time weather data for the ATC system users and urges the FAA to continue to expedite the current programs.

On September 28, 1977, the Safety Board forwarded the following recommendation to the FAA:

> "Transmit SIGMET's more frequently on navaids so that pilots can receive more timely information about hazardous weather. (Class II, Priority Action) (A-77-65)"

On November 28, 1977, the FAA responsed:

> "To enhance the broadcast program as an immediate measure, in May 1977, a revision to the priority of duties for FSS specialists was issued. This revision elevated notification actions to other Air Traffic facilities by the FSS and in FSS broadcasts of SIGMETs and AIRMETs. Required notifications now are only ranked after emergency actions and NAVAID malfunctioning requirements. Broadcast of SIGMETs and AIRMETs now are ranked only below services to airborne aircraft (other than above actions). This provided for dissemination of vital information to pilots and controllers in a more timely and effective manner."

In addition, the Safety Board has been concerned with the flow of real time weather data to sector controllers at en route and terminal facilities. On April 18, 1974, the Safety Board issued the following recommendations:

> "Develop and install air traffic control radar capable of locating severe weather and displaying convective turbulence. This radar should be used to vector aircraft around severe weather. (A-74-13)

"Implement, in cooperation with the National Weather Service, a system to relay severe thunderstorm and tornado warning bulletins expeditiously to inbound and outbound flights when such bulletins include the terminal area (A-74-14)."

With regard to this recommendation, on January 28, 1980, the Chairman, on behalf of the National Transportation Safety Board, addressed a letter to the FAA Administrator which stated, in part:

"The assignment of meteorologists to the ARTCC's should result in improved dissemination of weather information. At the present time, however, information on the location and severity of convective storms is not consistently reaching the individual sector controllers or other ATC facilities. Direct video weather radar displays in the centers might solve this problem. However, at the present time they are installed at only one ARTCC, and experience with the system has been insufficient to fully evaluate its capabilities.

Although A-74-14 applies to terminal areas, the procedural changes listed in your letter apply equally to en route flight. On June 21, 1979, about 60 miles southwest of Salina, Kansas, TWA Flight 1, an L1011, was attempting to navigate between thunderstorm cells when it encountered damaging hail. None of the convective SIGMETs in effect at the time covered the local environment, and the pilot was not informed of the intensity of the cells in the area. Evidence indicates that the sector controller did not have such information. The pilot stated that had he known the severity of the thunderstorms he would not have flown close to them.

It is evident from the above cases that timely and sufficient severe weather information may not be provided to controllers and pilots in sufficient time to avoid encounter with potentially hazardous thunderstorms. We, therefore, request that the FAA reevaluate the effectiveness of the Center Weather Service Units and assure us further that appropriate action is being taken to expeditiously disseminate severe weather information."

As a result of this investigation, the Safety Board reiterates the following recommendations:

Amend 14 CFR 23.785(f) to require dynamic testing of seats to insure more realistic protection of occupants from serious injury in a minor crash. (Class III, Longer-Term Action) (A-75-51)

Expedite the development and implementation of an aviation weather subsystem for both en route and terminal area environments, which is capable of providing a real-time display of either precipitation or turbulence, or both, and which includes a multiple-intensity classification scheme. Transmit this information to pilots either via the controller as a safety advisory or via an electronic data link. (Class II, Priority Action) (A-77-63)

Formulate rules and procedures for the timely dissemination by air traffic controllers of all available severe weather information to inbound and outbound flightcrews in the terminal area. (Class II, Priority Action) (A-77-68)

Initiate research to determine the attenuating effects of various levels of precipitation and icing on airborne radomes of both x- and c-band radar, and disseminate to the aviation community any data derived concerning the limitations of airborne radar in precipitation. (Class II, Priority Action) (A-78-1)

As a result of this accident, the Safety Board issued the following recommendations on November 19, 1980:

Expedite the delivery of NWS weather radar color remote displays to all Air Route Traffic Control Centers' Center Weather Service Units. (Class I, Urgent Action) (A-80-115)

Schedule the planned testing of NWS weather radar color remote displays at the Cleveland Air Route Traffic Control Center to encompass the next season of frequent convective meteorological activity. (Class II, Priority Action) (A-80-116)

Expedite the development of appropriate graphic mapping techniques for correlation of the NWS weather radar color remote display and the air traffic controller's radar display presentation. (Class II, Priority Action) (A-80-117)

Expedite the development of an integrated weather radar/air traffic control radar single video display system capable of providing multiple weather echo intensity discrimination without derogation of air traffic control radar intelligence. (Class II, Priority Action) (A-80-118)

Require air route traffic control centers to make maximum use of the existing National Weather Service radar sites as inputs to the color remote displays at their facilities. (Class II, Priority Action) (A-80-119)

Also as a result of this investigation, the Safety Board issued the following recommendations to the Federal Aviation Administration:

Undertake an experimental program to analyze and evaluate the technical and operational feasibility of requiring that air traffic control provide separation between aircraft and severe meteorological conditions when the nature and location of the meteorological condition can be determined. (Class III, Longer Term Action) (A-80-132)

Review the relationship and duties of ARTCC team supervisors to flow controllers/weather coordinators to insure that the nature of each job function is understood and accomplished. (Class III, Longer Term Action) (A-80-133)

Require that the subject accident report be reviewed by air traffic control specialists and supervisors. (Class III, Longer Term Action) (A-80-134)

Require that flow controllers and supervisory personnel assess the potential effects of hazardous weather on low altitude en route traffic and use the evaluation to adjust air traffic flow as necessary. (Class II, Priority Action) (A-80-135)

Require that the effect of precipitation induced attenuation on X-band airborne weather radar be incorporated into airline training programs and that airborne weather radar manufactures include attenuation data in radar operators handbooks. (Class II, Priority Action) (A-80-136)

Amend 14 CFR 23.807, Emergency Exits, to require all emergency exits on Part 23 air taxi and commuter aircraft with a capacity of 10 or more passenger seats manufactured after a specified date to be installed so that each can be opened from outside the aircraft. (Class III, Longer Term Action) (A-80-137)

Evaluate procedures which govern the transmission of SIGMET's on navaids to determine what additional steps are necessary to provide timely dissemination and take necessary corrective measures to insure that they are issued according to the procedures. (Class II, Priority Action) (A-80-138)

The National Transportation Safety Board recommends that the National Weather Service:

Develop specific criteria for Center Weather Service Units which would govern the issuance of center weather advisories to update or supplement convective SIGMET's. (Class II, Priority Action) - (A-80-139)

Require that all severe weather warnings and significant weather radar observations issued by a National Weather Service office expected to affect the airspace of an air traffic control approach control facility be transmitted by that office to the facility by the most expeditious means available. (Class II, Priority Action) (A-80-140)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JAMES B. KING
Chairman

/s/ ELWOOD T. DRIVER
Vice Chairman

/s/ FRANCIS H. McADAMS
Member

/s/ PATRICIA A. GOLDMAN
Member

/s/ G. H. PATRICK BURSLEY
Member

December 9, 1980

# APPENDIX A

## INVESTIGATION AND HEARING

### 1. Investigation

The National Transportation Safety Board was notified of the accident about 1745 e.d.t., on June 12, 1980, and immediately dispatched an investigative team to the scene. Investigative groups were established for operation/witnesses, air traffic control, weather, powerplants, systems, structures, human factors and maintenance records.

Parties to the investigation were the Federal Aviation Administration, Air Wisconsin, Inc., Swearingen Aviation, Garrett AiResearch Manufacturing, the Union of Professional Airmen, and the International Association of Machinists and Aerospace Workers.

### 2. Public Hearing

A 3-day public hearing was held in Omaha, Nebraska, beginning on September 16, 1980. Parties represented at the hearing were the Federal Aviation Administration, Air Wisconsin, Inc., Swearingen Aviation, Garrett AiResearch Manufacturing Company, the Union of Professional Airmen, the Professional Air Traffic Controllers Organization, and the National Weather Service.

## APPENDIX B

## PERSONNEL INFORMATION

### Captain Peter A. Grab

Captain Grab, 37, was employed by Air Wisconsin, Inc., on October 3, 1972. He held Airline Transport Pilot Certificate No. 2089271 with an aircraft multiengine land rating and commercial privileges in airplane single engine land. His first-class medical certificate was issue on February 12, 1980. He was required to wear glasses for near vision while exercising the privileges of this certificate.

Captain Grab had accumulated about 8,391 flight hours of which about 6,000 hours were in the Swearingen SA 226-TC type aircraft. Of the time in type, he had 4,727 hours as second-in-command. He had 1,273 hours in single engine aircraft and 8,100 in multiengine aircraft. He had accumulated 995 hours actual instrument time.

Captain Grab had flown 7 hours and 56 minutes in the last 24 hours before this flight. In the last 90 days, he had flown a total of 177:27 pilot-in-command time and 1 hour and 11 minutes dual on a proficiency check.

His last proficiency check was completed on May 28, 1980. During recurrent training severe thunderstorm/windshear techniques were discussed.

### First Officer Nicholas Gallmeister

First Officer Gallmeister, 28, was employed by Air Wisconsin, Inc., on March 11, 1980. He held Airline Transport Pilot Certificate No. 378584208 with an airplane multiengine land rating, and commercial privileges for airplane engine land. His first-class medical certificate, issued October 23, 1979, had reverted to a second-class certficate once the six month time period had elapsed. However, it remained a valid certificate. The medical certificate contained no limitations.

Mr. Gallmeister had accumulated a total of 4,063 flight hours of which 143 hours were as second-in-command. Of the total time, 2,280 hours were in single engine and 1,783 hours were in multiengine aircraft. He had accumulated 431 hours of actual instrument time.

His initial pilot ground training with Air Wisconsin was completed on March 19, 1980. His second-in-command flight check was accomplished on March 26, 1980. His last recurrent ground training was on May 13, 1980. Among other items taught was the severe thunderstorm/windshear penentration program.

In the 24 hours preceding the flight, Mr. Gallmeister flew 7 hours and 56 minutes. In the last 90 days, he flew 142 hours and 32 minutes of which 8 hours and 5 minutes was flight training.

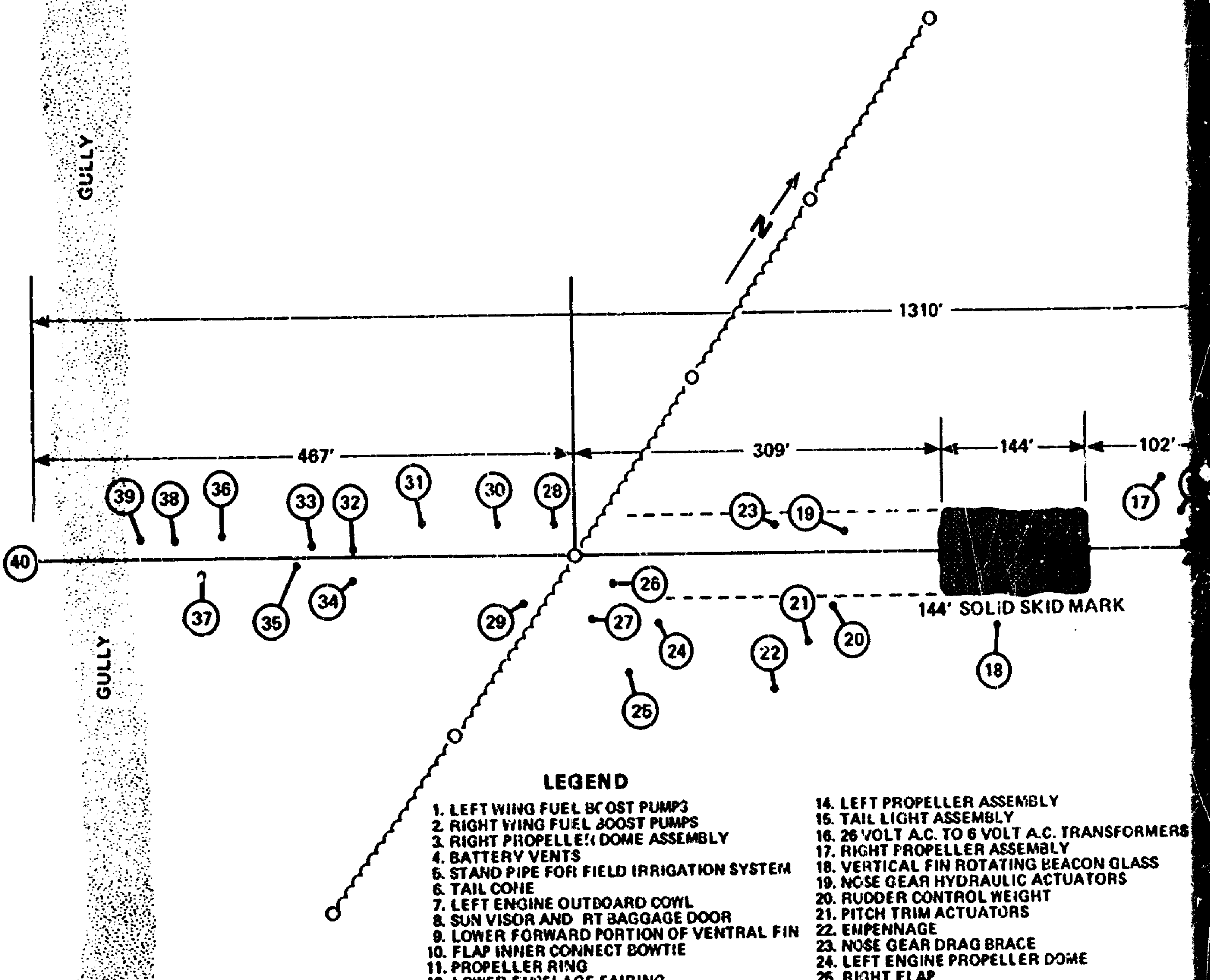
## APPENDIX C

## AIRCRAFT INFORMATION

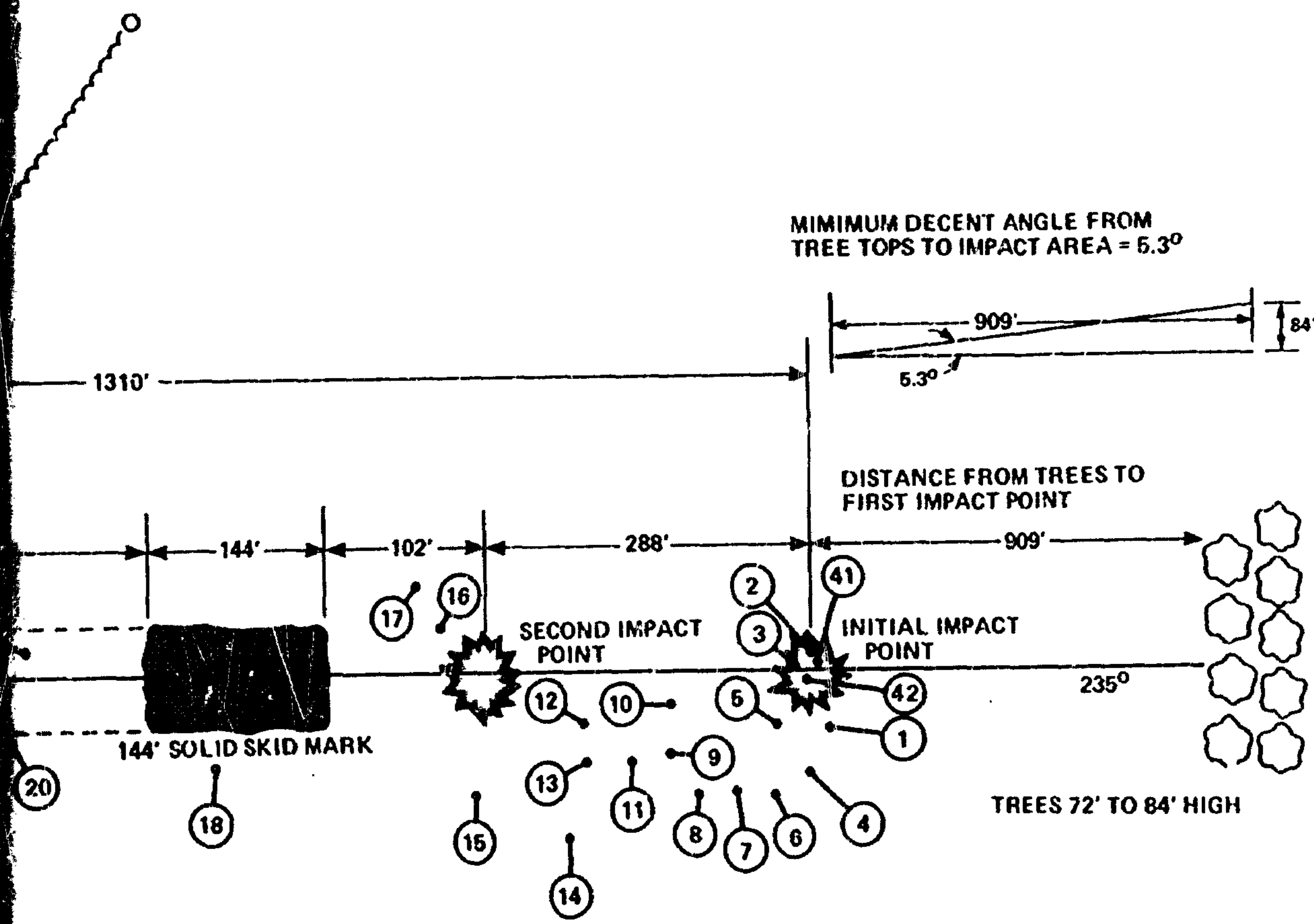
Swearinger SA-226-TC Metro, N650S, was manufactured in November 1976. As of June 10, 1980, the aircraft had a total time of about 8,055 hours. The continous maintenance program for the aircraft had 8 inspections. All 8 phases were completed between April 10, 1980, and June 6, 1980.

N650S was equipped with AiResearch TPE 331-3VW-3036 engines and Hartzell Model HCB-3TN-56 propellers. Information pertaining to the powerplant is as follows:

| | Left Engine | Left Propeller | Right Engine | Right Propeller |
|---|---|---|---|---|
| Serial No. | P-033656 | Hub-BV-3196 | P-05007C | Hub-BV-2069 |
| Total time/TSO | 5299:18 | 2194:40 | 2680:29 | 2042:36 |
| Date of Manufacture | Nov. 1977 | 03-13-77 | Nov. 1969 | 02-02-74 |



GULLY
GULLY
N
1310'
467'
309'
144'
102'
144' SOLID SKID MARK
LEGEND
1. LEFT WING FUEL BC OST PUMPS
2. RIGHT WING FUEL BOOST PUMPS
3. RIGHT PROPELLE.'I DOME ASSEMBLY
4. BATTERY VENTS
5. STAND PIPE FOR FIELD IRRIGATION SYSTEM
6. TAIL CONE
7. LEFT ENGINE OUTBOARD COWL
8. SUN VISOR AND RT BAGGAGE DOOR
9. LOWER FORWARD PORTION OF VENTRAL FIN
10. FLAP INNER CONNECT BOWTIE
11. PROPELLER RING
12. LOWER FUSELAGE FAIRING
13. GENERATOR COOLING DUCT HOUSING
14. LEFT PROPELLER ASSEMBLY
15. TAIL LIGHT ASSEMBLY
16. 26 VOLT A.C. TO 6 VOLT A.C. TRANSFORMERS
17. RIGHT PROPELLER ASSEMBLY
18. VERTICAL FIN ROTATING BEACON GLASS
19. NOSE GEAR HYDRAULIC ACTUATORS
20. RUDDER CONTROL WEIGHT
21. PITCH TRIM ACTUATORS
22. EMPENNAGE
23. NOSE GEAR DRAG BRACE
24. LEFT ENGINE PROPELLER DOME
26. RIGHT FLAP
26. NOSE GEAR STRUT




LEFT PROPELLER ASSEMBLY
TAIL LIGHT ASSEMBLY
26 VOLT A.C. TO 6 VOLT A.C. TRANSFORMERS
RIGHT PROPELLER ASSEMBLY
VERTICAL FIN ROTATING BEACON GLASS
NOSE GEAR HYDRAULIC ACTUATORS
RUDDER CONTROL WEIGHT
PITCH TRIM ACTUATORS
EMPENNAGE
NOSE GEAR DRAG BRACE
LEFT ENGINE PROPELLER DOME
RIGHT FLAP
NOSE GEAR STRUT

27. LEFT WING TIP/ONE OIL COOLER
28. OIL COOLER
29. NOSE SECTION FORWARD PRESSURE VESSEL
30. OXYGEN BOTTLE
31. RIGHT BATTERY CASE
32. LEFT ENGINE
33. AIR CYCLE MACHINE
34. RIGHT MAIN GEAR
35. LEFT WING/PARTIAL NACELLE / MAIN GEAR
36. RIGHT ENGINE
37. RIGHT WING (INVERTED)
38. COPILOT SEAT
39. RIGHT INBOARD KEELSON / INBOARD WING
40. FUSELAGE (INVERTED)
41. SAS MAST
42. RIGHT AND LEFT PITOT TUBES

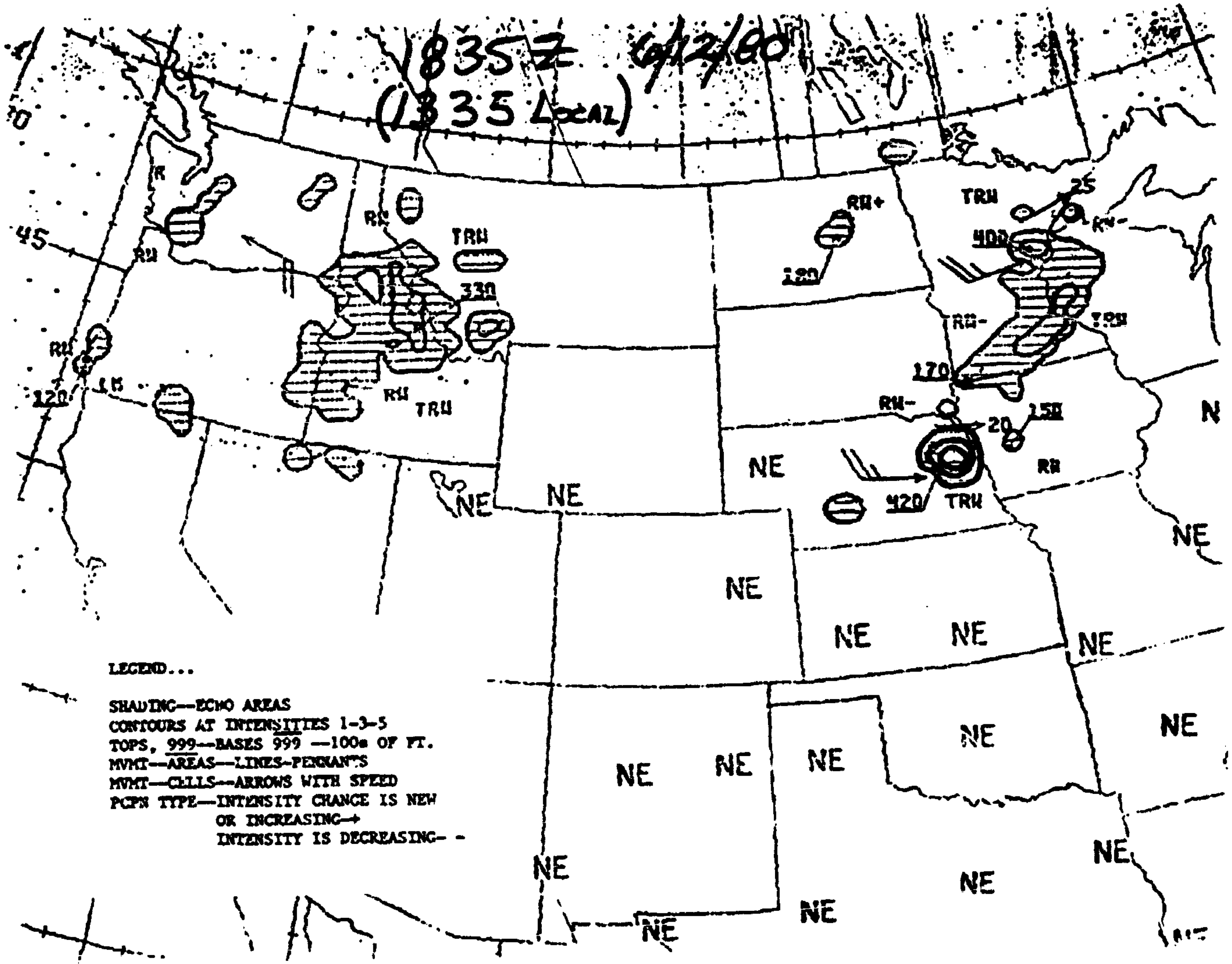
# APPENDIX D

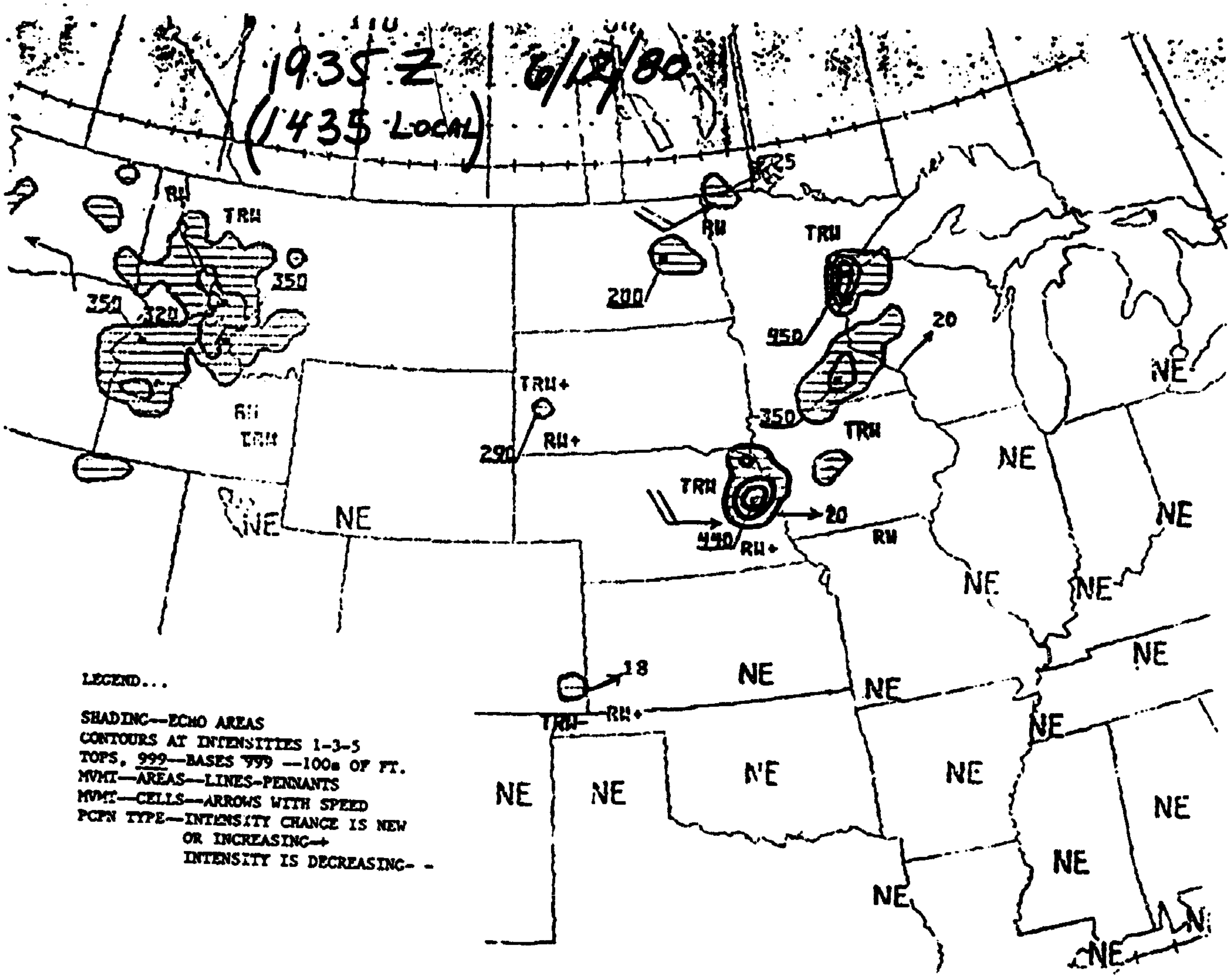
**Wreckage Distribution Chart**

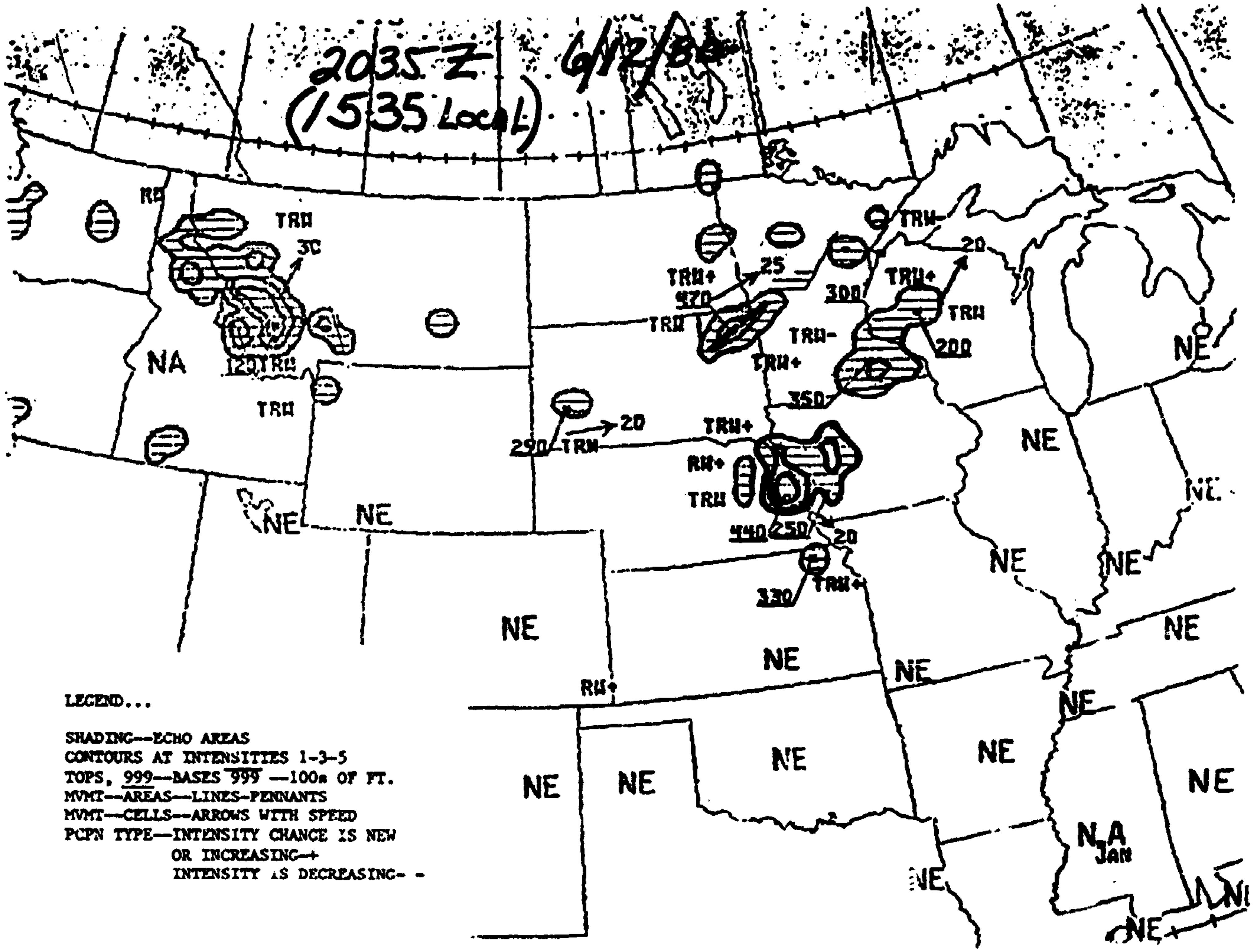
**Air Wisconsin Swearingen Model SA–226TC, N650S**

## APPENDIX B

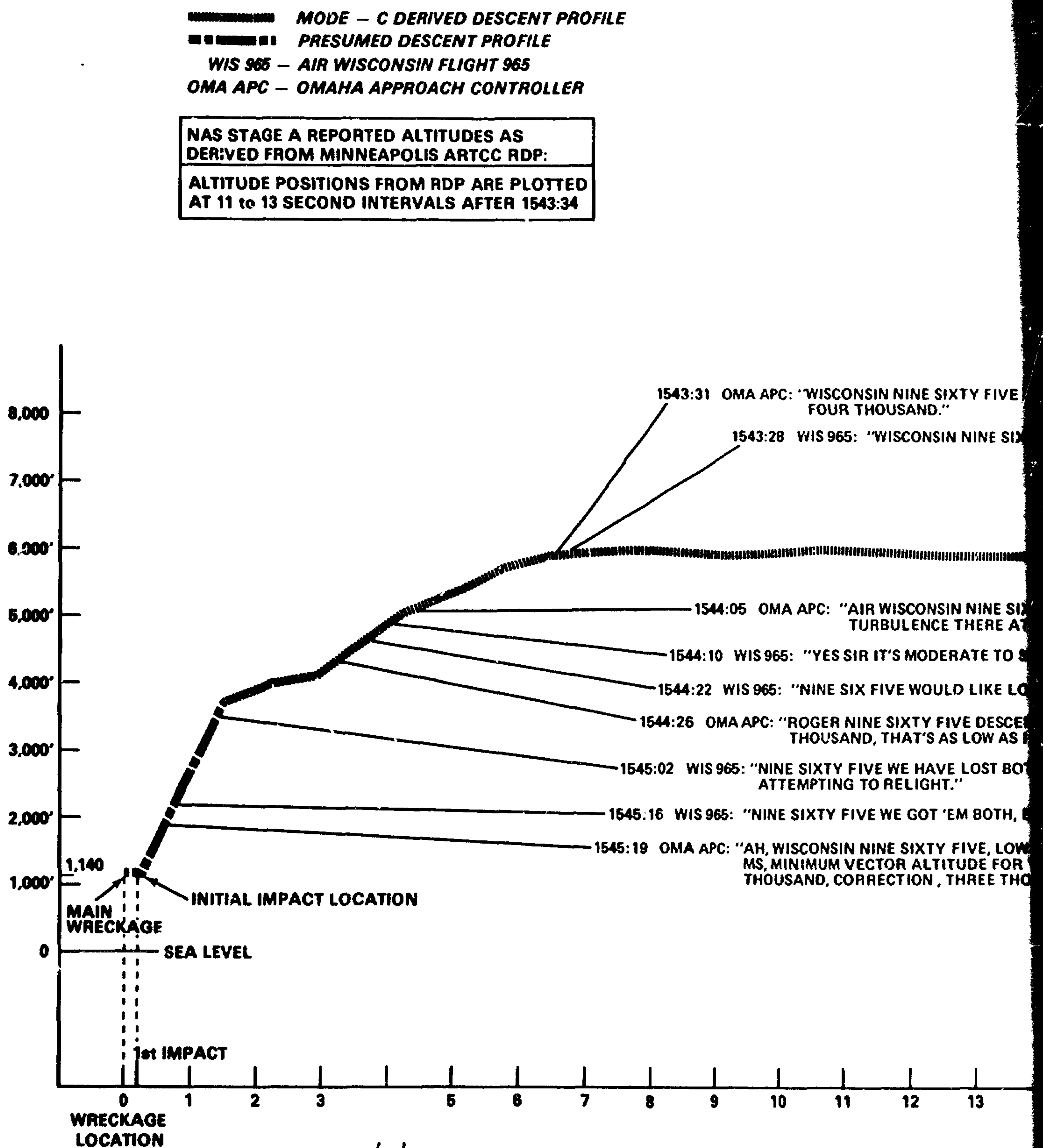
## RADAR SUMMARY CHART



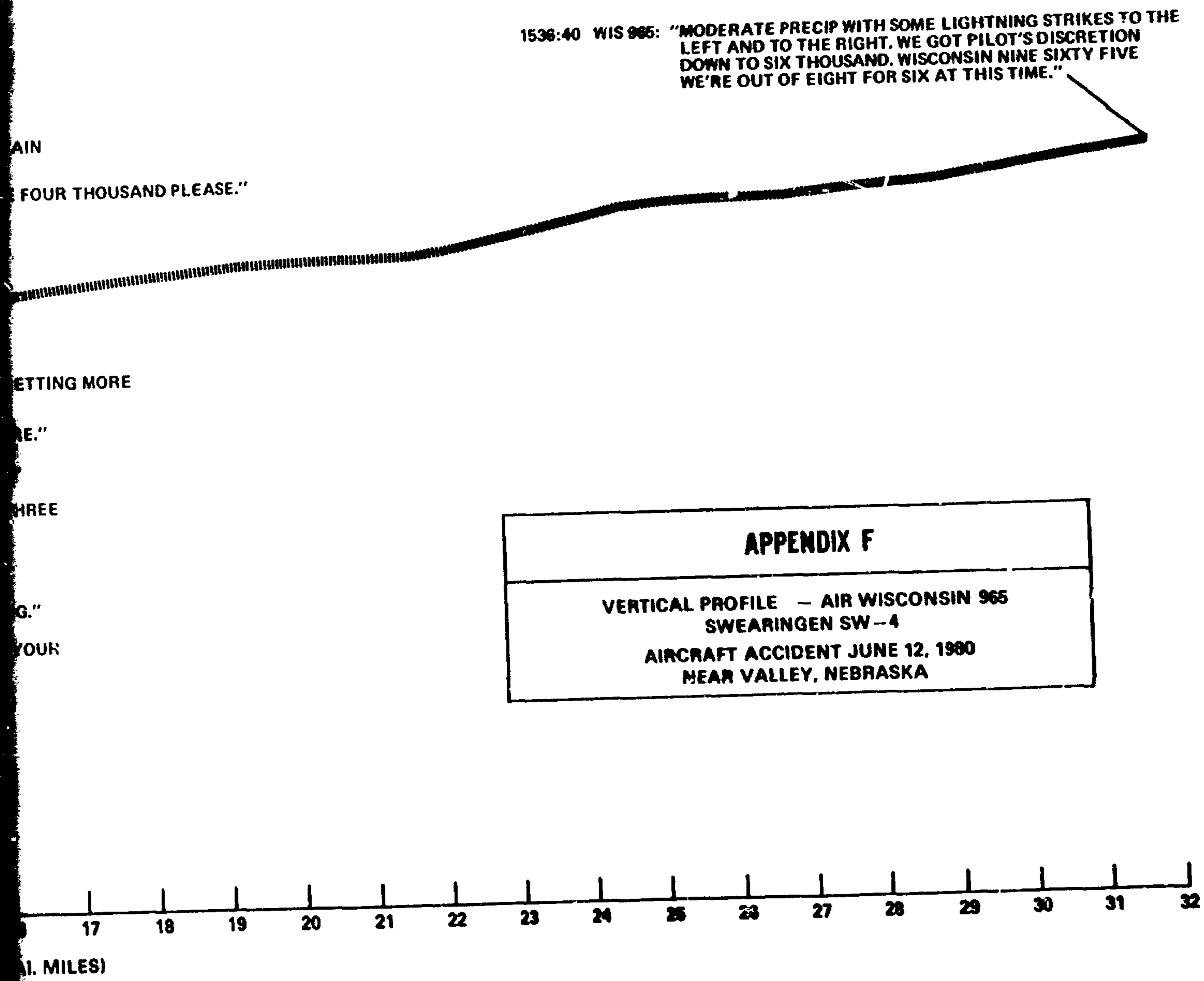

1935 Z 6/12/80
(1435 LOCAL)
TRW
RW
350
320
TRW+
RW+
290
200
950
TRW-
RW+
18
20
25
440
NE
LEGEND...
SHADING--ECHO AREAS
CONTOURS AT INTENSITIES 1-3-5
TOPS, 999--BASES 999 --100s OF FT.
MVMT--AREAS--LINES-PENNANTS
MVMT--CELLS--ARROWS WITH SPEED
PCPN TYPE--INTENSITY CHANGE IS NEW
OR INCREASING+
INTENSITY IS DECREASING- -


2035Z 6/12/86
(1535 Local)
TRW
TRW+
TRW-
RW+
NA
NE
LEGEND...
SHADING--ECHO AREAS
CONTOURS AT INTENSITIES 1-3-5
TOPS, 999--BASES 999 --100s OF FT.
MVMT--AREAS--LINES-PENNANTS
MVMT--CELLS--ARROWS WITH SPEED
PCPN TYPE--INTENSITY CHANGE IS NEW
OR INCREASING-+
INTENSITY IS DECREASING- -

APPENDIX E



MODE – C DERIVED DESCENT PROFILE
PRESUMED DESCENT PROFILE
WIS 965 – AIR WISCONSIN FLIGHT 965
OMA APC – OMAHA APPROACH CONTROLLER
NAS STAGE A REPORTED ALTITUDES AS DERIVED FROM MINNEAPOLIS ARTCC RDP:
ALTITUDE POSITIONS FROM RDP ARE PLOTTED AT 11 to 13 SECOND INTERVALS AFTER 1543:34
1543:31 OMA APC: "WISCONSIN NINE SIXTY FIVE
FOUR THOUSAND."
1543:28 WIS 965: "WISCONSIN NINE SI
1544:05 OMA APC: "AIR WISCONSIN NINE SI
TURBULENCE THERE A
1544:10 WIS 965: "YES SIR IT'S MODERATE TO
1544:22 WIS 965: "NINE SIX FIVE WOULD LIKE LO
1544:26 OMA APC: "ROGER NINE SIXTY FIVE DESCE
THOUSAND, THAT'S AS LOW AS
1545:02 WIS 965: "NINE SIXTY FIVE WE HAVE LOST BO
ATTEMPTING TO RELIGHT."
1545:16 WIS 965: "NINE SIXTY FIVE WE GOT 'EM BOTH,
1545:19 OMA APC: "AH, WISCONSIN NINE SIXTY FIVE, LOW
MS, MINIMUM VECTOR ALTITUDE FOR
THOUSAND, CORRECTION, THREE THO
8,000
7,000'
6,000'
5,000'
4,000'
3,000'
2,000'
1,000'
0
1,140
MAIN WRECKAGE
INITIAL IMPACT LOCATION
SEA LEVEL
1st IMPACT
0 1 2 3 5 6 7 8 9 10 11 12 13
WRECKAGE LOCATION




## APPENDIX F

VERTICAL PROFILE — AIR WISCONSIN 965
SWEARINGEN SW-4

AIRCRAFT ACCIDENT JUNE 12, 1980
NEAR VALLEY, NEBRASKA