02/28/84 Scandinavian Airlines System

Official Accident Report Index Page

Report Number	NTSB/AAR-84/15
Access Number	PB84-910415
Report Title	Scandinavian Airlines System Flight 901 McDonnell Douglas CD-10-30 Norwegian Registry LN-RKB John F. Kennedy International Airport Jamaica, New York, February 28, 1984
Report Date	November 15, 1984
Organization Name	National Transportation Safety Board Bureau of Accident Investigation Washington, D.C. 20594
WUN	3894-A
Sponsor Name	NATIONAL TRANSPORTATION SAFETY BOARD Washington, D. C. 20594
Report Type	Aircraft Accident Report February 28, 1984
Distribution Status	This document is available to the public through the National Technical Information Service Springfield, Virginia 22161
Report Class	UNCLASSIFIED
Pg Class	UNCLASSIFIED
Pages	85
Keywords	Landing accident, autothrottle speed control system, crew overreliance, crew procedures, wind shear.

Facts of the Accident

Accident NTSB ID	84-15
Airline	Scandinavian Airlines System
Model aircraft	DC-10-30, Norwegian Registry LN-RKB, Serial No. 46871.219
Year shipped	1976
Aircraft manufacturer	McDonnell Douglas
Engine type	CF 6-50C
Engine manuafacturer	General Electric
Date	02/28/84
Time	2118
Location	John F. Kennedy International Airport, Jamaica, NY
Country	USA
Injuries	12
Fire during flight?	N
Fire on the ground?	Y-localized, small fire confined to wiring: self-extinguished almost immediately
Probable cause	Flightcrew's (a) disregard for prescribed procedures for monitoring and controlling of airspeed during the final stages of the approach, (b) decision to continue the landing rather than to execute a missed approach, and (c) overreliance on the autothrottle speed control system which had a history of recent malfunctions.
Contributing causes	Weather condition..TailwindAutopilot/flight director,auto throttle..ErraticAirspeed..Excessive..Copilot/second pilotObject..Approach light/navaid
Weather conditions	Ceiling 200 ft overcast, 3/4-mile visibility with light drizzle and fog; runway wet
Total crew size	14
Cockpit crew size	3
Cabin crew size	11
Passengers	163
Report ID	NTSB/AAR-84/15
Pages	85
Day or night?	Daylight
Flight number	901
Flight origin	Stockholm, Sweden
Flight destination	New York City, NY
Description	Following an approach to runway 4 right at New York's JFK International Airport, the airplane touched down

about 4,700 ft (1,440 meters) beyond the threshold of the 8,400-foot (2,560 meter) runway and could not be stopped on the runway. The airplane was steered to the right to avoid the approach light pier at the departure end of the runway and came to rest in Thurston Basin, a tidal waterway located about 600 ft from the departure end of runway 4R.

Synopsis

On February 28, 1984, Scandinavian Airlines System Flight 901, a McDonnell Douglas DC-10-30, was a regularly scheduled international passenger flight from Stockholm, Sweden, to New York City, New York, with an en route stop at Oslo, Norway. Following an approach to runway 4 right at New York's John F. Kennedy International Airport, the airplane touched down about 4,700 ft (1,440 meters) beyond the threshold of the 8,400-foot (2,560-meter) runway and could not be stopped on the runway. The airplane was steered to the right to avoid the approach light pier at the departure end of the runway and came to rest in Thurston Basin, a tidal waterway located about 600 ft from the departure end of runway 4R. The 163 passengers and 14 crewmembers evacuated the airplane safely, but a few received minor injuries. The nose and lower forward fuselage sections, wing engines, flaps, and leading edge devices were substantially damaged at impact.

The weather was ceiling 200 ft overcast, 3/4-mile visibility, with light drizzle and fog. The temperature was 47° F with the wind from 100° at 5 knots. The surface of the runway was wet, but there was no standing water.

The National Transportation Safety Board determines that the probable cause of this accident was the flightcrew's (a) disregard for prescribed procedures for monitoring and controlling of airspeed during the final stages of the approach, (b) decision to continue the landing rather than to execute a missed approach, and (c) overreliance on the autothrottle speed control system which had a history of recent malfunctions.

1. Factual Information

1.1 History of the Flight

On February 28, 1984, Scandinavian Airlines System (SAS) Flight 901, a McDonnell Douglas DC-10-30 of Norwegian Registry, was a regularly scheduled international passenger flight from Stockholm, Sweden, to New York City, New York, with an intermediate stop at Oslo, Norway.

Before leaving Oslo for New York at 1239 Greenwich Mean Time (GMT), 1 the flightcrew reviewed weather information for John F. Kennedy International Airport (JFK) which were pertinent to the Oslo - JFK segment of the flight. Because the weather conditions in New York for the scheduled arrival time of Flight 901 were forecast as marginal, with low ceiling, limited visibility, light rain and fog, additional fuel was placed on board at the captain's request. There were 202,826 pounds (92,000 kilograms) of fuel on board; the takeoff weight was 543,217 pounds (246,398 kilograms). Philadelphia International Airport was listed as the alternate airport. The Atlantic crossing was routine and without incident.

At 2005, Flight 901 arrived in the vicinity of the Kennebunk VORTAC 2 and SAS operations at JFK requested ARINC 3 to advise the flight that runway 4R was being used currently for approaches and landings at JFK and that no inbound delays were expected. ARINC also was requested to advise Flight 901 of the latest JFK and Philadelphia weather. The 2000 weather observations for JFK were transmitted to Flight 901 at 2028.

About 2040, Flight 901 called the SAS dispatcher at JFK to advise him that the estimated arrival time was 2105 and to confirm receipt of previous messages from ARINC. The flight was also advised at this time of the latest weather which had been received on the Aviation Weather Display System (AWDS) at 2039. The weather given at that time was: measured 300 ft broken, 600 ft overcast, visibility 1.5 miles in light rain and fog, wind 090° at 8 knots, altimeter 29.15 inches. The dispatcher heard Flight 901 make its initial radio contact with JFK approach control and noted that the flight had the most current ATIS information. Information Whiskey was most current and was as follows:

Information whiskey, two zero five one Greenwich measured ceiling three hundred overcast, visibility one light drizzle, fog temperature four five, dew point four four, wind zero eight zero at four, altimeter two niner one four, approach in use ILS four right, departure runway four left, notice to airman, important information sigmet alpha one four is valid, -- from moderate to occasional severe turbulence between one seven thousand and flight level three eight zero, New York center weather at five three is valid with strong low level wind shear potential, for further information, contact New York flight service station, in the interest of noise abatement, Runway 4R preferential use runway, advise you have whiskey.

The systems operator5 had prepared the landing data card and had entered the data contained in ATIS information "uniform" on it. The flightcrew stated that they were aware that ATIS information "uniform" and "whiskey" mentioned potential low level wind shear.

On arrival in the New York area, the crew found the weather better than expected. Because it was his route segment to fly, the first officer performed the landing/approach briefing for a category I instrument landing system (ILS)6 approach to runway 4R. During the approach, both autothrottles were engaged. The No. 2 "auto pilot engaged" switch was selected to the command position. The ILS switch on the directional control panel was armed for capture and approach with the control wheel steering (CWS) mode to be used for the landing. The captain and first officer agreed to use 35° of flaps rather than 50° because of the possibility of encountering wind shear.

During the initial approach, however, the runway visual range (RVR)7 for runway 4R went below category I landing minimums. According to the captain, because the airplane and crew were both qualified for category II landing minimums, he informed the crew that he would make a category II8 approach. He recalled setting his radio altimeter to category II minimums and believed the first officer did the same. Shortly thereafter, however, the RVR increased, and the captain instructed the cockpit crew to "go back to normal." Postaccident examination of the cockpit showed that the radio altimeter bugs9 were set at 115, the decision height for a category II approach.

The systems operator calculated a landing weight of 172 metric tons (378,400 pounds), entered the weight on the landing data card, and gave it to the captain and first officer who then obtained precalculated V_A and V_{TH}10 speeds of 154 and 149 knots, respectively, based on a landing weight of 175 metric tons (385,000 pounds) and 35° flaps from an SAS DC-10 performance chart.(See figure 1.)

None of the three flightcrew members could recall precisely the airspeed associated with the initial and final approach or landing segments. The captain did recall seeing an airspeed of 180 knots or slightly lower on his airspeed indicator at some point during the initial approach. He also recalled dialing 168 knots into the autothrottle speed select window but did not recall whether he obtained the speed he selected. Neither the captain nor the first officer recalled selecting a lower speed. During the postaccident examination of the cockpit, the autothrottle speed selected was found to be 168 knots.

SAS DC-10

LANDING		175 t
FL	<300	≥300
V_{HOLD}	237	247
V_P	Clean ... 237	PULLUP
	0 204	V_2 22 .. 146
	15 176	$V_{Fl\ up}$ ... 165
	22 168	$V_{Sl\ in}$ ... 203
V_A	35 154	V_{Clean} .. 214
FLAP	35	50
V_A	154	149
V_{TH}	149	144

Figure 1.--SAS DC-10 Performance Chart.

During the approach, the crew switched to the performance page on the command display unit (CDU). At about 1,000 ft radio altitude, the captain recalled a tailwind component of about 20 knots displayed on the CDU. The first officer believed he observed winds out of the west - southwest at 23 knots between 2,000 ft and 1,500 ft on the approach. The systems operator could not observe either the wind direction or speed display on the CDU because of his seat position. The flightcrew stated that the autopilot kept the airplane on the localizer and glideslope and that the approach was smooth. They detected no wind shear or significant precipitation.

The captain stated that everything seemed stabilized until just before making visual contact with the runway environment at about 100 ft above minimums (300 ft). At this point, he noted that the airspeed was "high" and called out to the first officer "speed high." Shortly after this callout, the captain said that he considered going around, but he decided not to. He said his decision was influenced by his confidence in his copilot, the deteriorating weather conditions, and anticipated delays for a second approach.

Once over the runway, the flightcrew recalled that the airplane floated for some distance after the initial landing flare. The systems operator said that he made the required 50-, 40-, 30-, and 20-ft callouts from reference to the left radio altimeter. He called out 20 ft three times. Thereafter, the captain told the first officer to "put it down."

The captain believed that a normal touchdown was made at least one-third of the way down the runway; the first officer described it as gentle and believed that the airplane landed halfway down the runway; the systems operator described the touchdown as harder-than-normal and believed it to have been made within three-eights to halfway down the runway. Performance calculations based on digital flight data recorder and aircraft integrated data system (AIDS) information show that the initial touchdown point was about 4,700 ft (1,433 meters) beyond the threshold of runway 4R, or about

3,700 ft (1,128 meters) from the runway's end. None of the flightcrew could see the end of the runway at the point of touchdown.

The captain said that he told the first officer to use all three thrust reversers11 and full braking. He recalled seeing the amber transition lights of the three thrust reversers. The first officer believed that he deployed the three reversers "right away" and that maximum reverse was used until just before going off the end of the overrun, at which point he selected reverse idle; he said that his application of brakes was initially light to moderate. As the airplane continued down the runway centerline, he began increased braking. The captain said that he also applied brakes when he first saw the end of the runway. He believed that he first saw the end of the runway between taxiway F and A. He said that when he the applied brakes, the pedals went down farther. According to the flightcrew, braking was not as effective as they had anticipated. In their opinion, this may have been due to water on the runway. It was not until just before impact that the flightcrew realized the airplane could not be stopped on the runway overrun.

Once near the overrun, the captain used nose wheel steering to direct the airplane to the right in order to avoid colliding head on with the approach light structure located at the end of the overrun area. After leaving the overrun area, the airplane came to an abrupt stop with the cockpit in the water.

The forward section of the airplane fuselage came to rest in Thurston Basin, a tidal waterway about 600 ft (182.88 meters) from the runway 4R departure end. The airplane was damaged substantially.(See figure 2.) The captain immediately began to execute the memory items of the "On-Ground Emergency Check List." However, neither he nor the systems operator could move the engine fire selectors or fuel cutoff levers to their full off positions.

The captain switched on emergency power, took the public address (PA) handset, and shouted words to the effect: "This is an emergency, evacuate the airplane without delay." He did not hear any side tone in the PA handset, indicating that the handset was inoperable. He then used the radio communication microphone in an attempt to alert JFK tower; this microphone was also dead. When he prepared to activate the evacuation signal, he found that it was already on. He recalled hearing the signal as did the other cockpit crewmembers. The flightcrew remained in the cockpit for about 1 minute after the airplane came to a stop. The JFK Port Authority of New York and New Jersey emergency crews received initial notification of the accident from the tower at 2119 and responded immediately.

The captain said that when he entered the cabin from the cockpit, it was almost completely evacuated. With the aid of the systems operator, he assisted a passenger out of the airplane through the right side emergency overwing exit. He then reentered the cabin and asked the flight attendants if they knew if anyone was still on board. They said, "it is only we." Afterward, he told the flight attendants to leave the airplane. He then left the airplane through the rearmost exit on the right side where a ladder had been placed over the deflated slide. The captain was the last person to leave the airplane.

The accident occurred at 2118:41 during daylight hours at 40°38' north latitude and 73°46' west longitude.

1.2 Injuries to Persons

Injuries	Cockpit	Crew Cabin	Passengers	Other	Total
Fatal	0	0	0	0	0
Serious	0	0	1[12]	0	1
Minor	2	1	8	0	11
None	1	10	154	0	165
Total	3	11	163	0	177

[12] A female passenger with a cardiac condition was hospitalized for over 48 hours for observation which required classification of "serious injury" in accordance with 49 CFR 830.2 definitions.

1.3 Damage to Aircraft

The airplane was damaged substantially.

1.4 Other Damage

The approach light structure for runway 22R was damaged substantially from contact with the left wing.

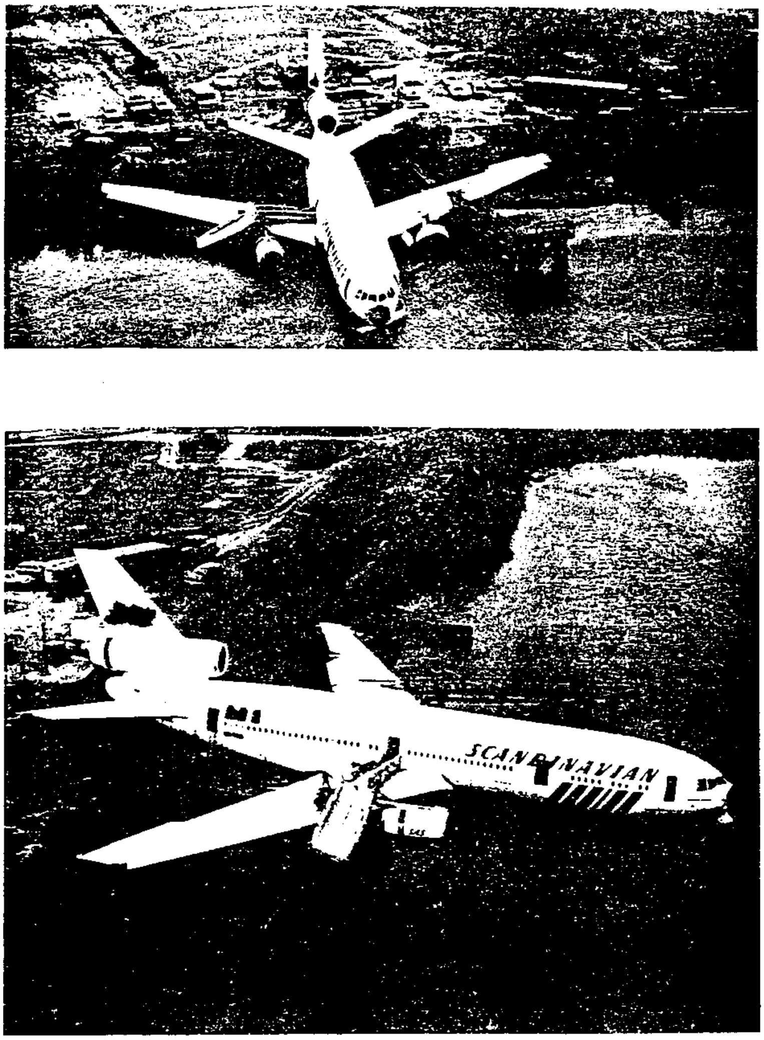

Figure 2.--Flight 901 gt rest in Thurston Basin.

1.5 Personnel Information

The flightcrew was qualified for the flight in accordance with regulations of the Norwegian, Swedish, and Danish Civil Aviation Authorities and the Federal Aviation Administration and had received the required training. The flightcrew members indicated that they were not fatigued before the accident and that they had had the required rest periods before the flight. (See appendix B.)

1.6 Aircraft Information

The airplane, a McDonnell Douglas DC-10-30, Norwegian Registry LN-RKB, was operated by SAS of Denmark, Norway, and Sweden. The airplane had been maintained in accordance with applicable regulations. At the time of the accident, the airplane autothrottle speed control and related systems had a history of intermittent malfunctions as follows: Because a previously reported mechanical irregularity with the autothrottle speed command system, SAS Maintenance in Copenhagen changed the autothrottle speed command computer on January 18, 1984. No specific reference was made as to which computer or if both computers were changed. On February 25, 1984, LN-RKB operating as Flight 901 from Copenhagen, Denmark, to Gottenburg, Sweden, experienced an autothrottle problem wherein the autothrottles, with both systems on, would not throttle back in the speed mode. The autothrottle speed system kept the speed 30 knots high. On the same day during an approach into JFK, the autothrottle system on LN-RKB, kept the speed 20 to 30 knots too high with either one or both of the systems on. At times, the throttles moved back and forth +/- 1 cm. The crew commented that the autothrottle speed was not reliable on descent, but was reliable during takeoff, climb, and cruise. On February 26, 1984, the autothrottle control panel on LN-RKB was replaced by SAS Maintenance in Stockholm.

On February 26, the crew of LN-RKB, on a flight from JFK to Stockholm, reported that the No. 1 stall warning system was unserviceable during the preflight. After interchange of the No. 1 and No. 2 stall warning computers, a ground check found that both systems operated normally; however, after liftoff from JFK, both speed flags appeared once. During slat retraction, the stall warning came on with autoslat extension. The crew reported that the stall warning cycled on and off with autoslats extended. A circuit breaker was pulled to silence the warning and to make retraction of the slats possible. The circuit breaker was reset during cruise and no further abnormalities with the stall warning system were noted for the remainder of the flight. On February 26, SAS Maintenance replaced the No. 1 angle of attack sensor to correct the cause of the last four discrepancies.

On February 27, the crew of LN-RKB, on a flight from JFK to Stockholm, reported that either one or both autothrottles kept a speed 20 knots above that which had been selected for the approach. On February 27, the crew of LN-RKB, on a flight from Stockholm to Oslo and Oslo to JFK, noted the same problem with the autothrottle system.

The airplane, operated as Flight 902, returned to Stockholm via Oslo on February 28. SAS Maintenance in Stockholm replaced the No. 2 autothrottle speed control computer. This was the last recorded entry in the airplane log that addressed the autothrottle speed control system. The airplane had accumulated about 34,941 hours in service since new.

The airplane's calculated gross weight at landing was 385,000 pounds (175 metric tons). The airplane was powered by three CF-6-50-C high bypass ratio turbofan engines. A review of the inspection records for the airplane and engines and the airplane's logbook for the last 90 days preceding the accident disclosed no significant deferred maintenance items. (See appendix C.)

1.7 Meteorological Information

The 2100 National Weather Service (NWS) surface analysis prepared by the National Meteorological Center in Camp Springs, Maryland, showed a low pressure area (985 millibars) located in central Pennsylvania, with a weak occluded front extending east from the low across Long Island. The 0000 NWS surface analysis showed the low pressure area (982 millibars) in northeastern Pennsylvania, with the occluded front extending eastward into Connecticut.

The following was determined from surface weather observations from JFK, Farmingdale, New York, Islip, New York, and Westhampton Beach, New York:

About 2100 the surface occluded front was north of Westhampton Beach and south of Islip, Farmingdale, and JFK. At 2125, the front was still south of JFK and the surface wind at JFK was 100° at 6 knots. At 2142, the front was due north of JFK and the surface wind had changed to 180° at 5 knots. At 2150, the front was north of Farmingdale and Islip. From the 2100 NWS surface analysis, it was determined that surface winds were from a southerly direction south of the front and an easterly direction north of the front. From the 2100 and 0000 NWS surface analysis, it was determined that the occluded front was moving north about 20 knots. Since the occluded front was moving north about 20 knots and assuming that the front passed JFK around 2142, it was determined that the surface front was about 8 nmi south of JFK at the time of the accident. Based on the AIDS static air temperature data, Flight 901 penetrated the top of the frontal zone below 1,000 ft above ground level.

The terminal forecast for JFK issued by the NWS Forecast Office in New York City at 1440 was as follows.

> 1500 to 2100: 500 ft scattered, ceiling 1,000 ft overcast, visibility --2 miles, light rain, fog, wind--090° at 20 knots gusting to 35 knots, low-level wind shear, occasional ceiling 500 ft overcast, visibility--3/4 miles, moderate rain, fog, chance of a thunderstorm, moderate rainshowers.
>
> 2100 to 0200: 400 ft scattered, ceiling 800 ft overcast, visibility--3 miles, light rain showers, fog, wind--150° at 20 knots gusting to 35 knots, low-level wind shear, occasional ceiling 400 ft overcast, visibility--3/4 mile, fog, chance of indefinite ceiling 200 ft sky obscured, visibility 1/4 mile, fog.

According to the surface weather observation for JFK, the amount of rainfall measured by the NWS at JFK from 1745 to 2352 was 0.23 inch. From 1915 to 2240, light drizzle was reported at the airport. Review of the NWS rain gauge record for JFK indicated that from 2000 to 2130 less than .05 inch of rain was recorded. The rain gauge is located on top of the International Arrivals Building.

Review of the record for the NWS wind gust recorder for JFK indicated that at 2113 the wind speed was 6 knots, at 2118 the wind speed was 5 knots, and at 2123 the wind speed was 6 knots. The highest wind speed recorded from 2113 to 2123 was 6 knots.

Winds Aloft

NWS upper wind readings from Atlantic City, New Jersey, (about 75 nmi south of JFK) about 2300 were as follows:

Altitude (ft above sea level)	Wind Direction (° true)	Wind Speed (knots)
973	222	30
1,825	231	36
2,685	233	44
3,580	226	48
4,439	219	45
5,268	211	44
6,078	205	46
6,869	205	47
7,710	204	49
8,649	201	47
9,512	202	43

The Brookhaven National Laboratory, Brookhaven, Long Island, New York, located about 45 nmi east of JFK has an instrumented meteorological tower. Wind direction/data from this tower provided by this facility for 2100 to 2120 and wind speed data for 2110 are as follows:

Altitude (ft above sea level)	Wind Direction (° true)	Wind Speed (knots)
117	180 to 210	2
370	180 to 210	8

Surface weather observations for JFK made by the NWS were as follows:

1951 Record Special - Measured ceiling 800 ft broken, 1,200 ft overcast, visibility 2 miles, light drizzle, fog, temperature 45° F, dewpoint 44° F, wind 060° at 15 knots, altimeter setting--29.16 inHg.

2018 Special - Measured ceiling 400 ft broken, 800 ft overcast, visibility 2 miles, light drizzle fog, wind 080° at 10 knots, altimeter setting--29.15 inHg.

2039 Special - Measured ceiling 300 ft broken, 600 ft overcast, visibility 1 1/2 miles light drizzle, fog, wind 090° at 08 knots, altimeter setting--29.15 inHg.

2051 Record Special - measured ceiling 300 ft overcast, visibility--1 mile, light drizzle, fog, temperature--45° F, dewpoint--44° F, wind--060° at 6 knots; altimeter setting--29.15 inHg., runway 4R visual range greater than 6,000 ft.

2109 Special - Measured ceiling 200 ft overcast, visibility--3/4 miles, light drizzle, fog, wind--100° at 7 knots;

altimeter setting--29.15 inHg.

2121 Local - Measured ceiling 200 ft overcast, visibility--3/4 mile, light drizzle, fog, temperature--47° F; dewpoint--46° F; wind--100° at 5 knots; altimeter setting--29.15 inHg., aircraft mishap, runway 4R visual range--2,400 ft variable to 2,600 ft.

Information pertinent to the area of the accident contained in the NWS area forecast, issued on February 28 at 1740 and valid until February 29, 0600, was:

· Flight precautions for [instrument flight rules] IFR, icing and turbulence.

· Occasional moderate mixed icing in clouds and in precipitation below 12,000 to 14,000 ft.

· Severe turbulence across the forecast area. (See SIGMET Alfa series for high level turbulence and SIGMET Charlie series for low level turbulence.)

· Low level wind shear potential across the entire forecast area due to strong cyclonic circulation associated with a West Virginia low pressure center.

· Occasional moderate turbulence below 17,000 ft due to wind shear.... Strong low-and mid-level winds.

· Occasional moderate turbulence between 17,000 to 38,000 ft due to wind shear aloft and jetstream.

· Ceilings occasionally below 1,000 ft overcast, visibilities occasionally below 3 miles, light rain, light snow, fog with intermittent light freezing rain, light freezing drizzle, light ice pellets.

· Isolated light rainshowers, thunderstorm, light rainshowers until 2300.

SIGMET Charlie 9 was issued by the National Aviation Weather Advisory Unit in Kansas City, Missouri, at 1815 and was valid until 2215. The area covered included JFK and indicated moderate occasional severe turbulence below 10,000 ft because of wind shear and strong low-level winds.

SIGMET Alfa 15 was issued by the National Aviation Weather Advisory Unit in Kansas City at 2050 and was valid until 0050. The area covered included JFK and indicated moderate to occasional severe turbulence between 17,000 to 38,000 ft because of wind shear aloft and jetstream.

A Center Weather Advisory was also issued by a New York ARTCC Weather Service Unit meteorologist at 1900 valid until 2100. The advisory advised of strong low-level wind shear potential within the New York Center area, northeast of a Slate Run (SLT)/Atlantic City (ACY) line, especially from Elmira through New York City, Long Island, and Connecticut.

At 1100, high wind warning was issued for all metropolitan New York airports by the NWS forecast office in New York City. The warning was valid until 0000. The warning called for winds east-southeast 15 to 25 knots with gusts 35 to 40 knots. The high wind warning was transmitted to the JFK Weather Service Office on AWDS, and the warning was transmitted to the tower by the Weather Service Office at JFK on the AWDS at 1140.

The AIDS recorder installed on board SAS Flight 901 recorded parameters during the approach to JFK, including wind direction and wind speed. Wind data recorded were as follows:

Radio Altitude (ft above the surface)	Wind Direction (° true)	Wind Speed (knots)
2,000	226	33
1,500	235	32
1,400	230	26
1,300	228	25
1,200	229	24

1,100	233	21
1,021	233	19
908	231	15
819	212	12
704	202	13
592	195	13
498	185	13
405	166	10
307	161	11
212	144	8
101	137	7
53	143	5
30	124	6
20	131	8
12	126	2
3	136	6

Wind components relative to a track of 40° magnetic were derived from AIDS data as follows:

Approximate Height (ft above the surface)	Computed Wind Speed (knots) (tailwind)
2,000	31.4
1,500	28.5
1,021	17.2
819	12.0
714	13.9
619	13.7
524	11.0
423	9.5

325	6.1
231	3.9
138	2.3
40	1.7
16	1.0
8	.1
3	1.9

1.8 Aids to Navigation

ILS approach procedures (categories I, II, and IIIA) serve runway 4R at JFK. The procedure is begun at an altitude of 3,000 ft, and a distance of 15.5 miles, distance measuring equipment (DME), from the departure end of runway 4R. The altitude profile positions the airplane at 1,500 ft at 6 miles DME from the departure end or 4.4 miles from the approach end of the runway on an inbound heading of 43° magnetic. Class-D category airplanes (such as the DC-10) require 200-ft ceilings and 1/2-mile visibility. The missed approach point is 0.4 mile from the approach end of the runway. The touchdown zone altitude is 12 ft m.s.l. The Airport/Facility Directory in effect at the time of the accident indicated that "temporary localizer needle aberrations may be experienced on ILS approaches to runway 4R or 22L due to heavy jet aircraft in vicinity."

1.9 Communications

There were no communications problems identified.

1.10 Aerodrome Information

John F. Kennedy International Airport in Jamacia, New York, is certificated by the Federal Aviation Administration under 14 CFR 139. Its runways are at an elevation of 12 ft m.s.l. The landing surfaces include four main runways: 13R/31L which is 14,572 ft long and 150 ft wide, 13L/31R which is 10,001 ft long and 150 ft wide; 4L/22R which is 11,351 ft long and 150 ft wide; and 4R/22L which is 8,400 ft long and 150 ft wide. Runway 4R is grooved and equipped with high intensity runway edge lights, centerline lights, a high intensity approach lighting system with sequenced flashing lights (category II configuration), and touchdown zone lights. The runway edge lights are white until the last 2,000 ft of the landing runway, which is marked by aviation yellow lights. The runway centerline lights also are white until the last 3,000 ft of runway, at which point the lights are alternating white and red. The centerline lights change to all red 1,000 ft from the runway end. The runway edge lights, the centerline lights, and touchdown zone lights for runway 4R were all set to their brightest illumination at the time of the accident. The approach light structures are not frangible.

There are no runway distance markers installed. The airport is also equipped with a low-level wind shear alert system (LLWAS) which was operational on the day of the accident.

Runway surface friction tests were conducted under Safety Board direction during both wet and dry runway conditions using the Saab and Mu Meter friction test units. Friction readings derived from both test units were well above the minimum acceptable value. (See appendix E.)

1.11 Flight Recorders

The airplane was equipped with a Sundstrand Data Control Model 573 digital flight data recorder (DFDR), serial No. 2891. The tape was in good condition and was examined at the National Transportation Safety Board's laboratory in Washington, D.C.

The airplane was also equipped with an aircraft integrated data system. Since the Safety Board's laboratory has no AIDS readout equipment, the readout of these data was accomplished at the facilities of SAS in Copenhagen, Denmark; Sundstrand Data Control, Redmond, Washington; and McDonnell Douglas Corporation, Long Beach, California.

Following the accident, Lufthansa, German airlines examined the flight recorders from one of its DC-10 and one of its Boeing 747 aircraft which landed before Flight 901 and provided the Safety Board with comparative performance data.

The airplane was also equipped with a Sundstrand Data Control Model AV-577B cockpit voice recorder (CVR), serial No. 7043. The tape was in good condition. Interpreters listened to the tape and translated it into English. The SAS Flight 901 flightcrew reviewed the transcript with the Cockpit Voice Recorder Group for accuracy and made corrections and/or additions as necessary. The CVR tape began with the normal approach briefing. The transcript began with the reception of ATIS information "whiskey." (See appendix F.)

1.12 Wreckage and Impact Information

The airplane came to rest about 35 ft to the right of the extended runway centerline on a 12° slope leading down to Thurston Basin. At high tide, the shorelines of Thurston Basin begins about 60 ft beyond the 500-ft runway overrun area. The basin is a shallow, mud-based estuary with its bottom about 10 to 15 ft below runway level, and it is subject to tidal changes. The nose of the airplane was about 160 ft beyond the end of the runway overrun area. The airplane's heading was 55° magnetic at impact. The leading edge of the airplane's left wing was partially embedded in a wooden pier structure which supported the approach lighting system.

The aft portion of the fuselage remained generally intact. There was major damage at the lower nose area, to the radome, and to the forward pressure bulkhead at fuselage station (FS) 275. The nose landing gear structure had collapsed under the fuselage. The drag braces were fractured and had separated from their attachment fittings. The interior of the forward fuselage area was deformed and exhibited fractures at the flight deck and galley floor locations. Several floor beams below the galley floor were fractured and twisted.

The wings, leading edge slats, and flaps sustained moderate damage from impact with the wooden pier structure. The leading edge slats were extended fully and the trailing edge flaps were extended to the 40° position.

The No. 1 engine pylon structure was buckled and twisted; the No. 2 and 3 engine pylons exhibited no major structural damage. The No. 1 and No. 3 engines sustained major impact and salt water damage. The No. 2 engine sustained no impact damage. All three fan and turbine thrust reversers were in the fully deployed (reverse thrust) positions.

All three engines and APU fire extinguishers were intact; examination of their discharge cartridges disclosed that none had been electrically activated or that any of the extinguishing units had been discharged. Systems components relative to the autothrottle speed control were examined and functionally tested.

Both Mach/airspeed indicators were found to be free of defects. The captain's attitude direction indicator had evidence of water contamination and corrosion. The copilot's unit was clean. Both indicators were tested for the slow/fast function and were found to function normally. The thrust rating computer had been contaminated by water and sand and was corroded. The computer was cleaned in a freon bath and tested. The computer failed to operate, and no further testing could be accomplished.

The duplex throttle servo also had been contaminated by water and was corroded. When tested, both drive motors were seized. Further testing resulted in the freeing of drive motor No. 2, which functioned normally and produced the proper torque output. The gear train moved freely. All coils to the drive motors and tachometers tested normal. Both autothrottle speed control computers had been contaminated by water and sand and were corroded. Both computers were cleaned in a freon bath and tested. Computers No. 1 and No. 2 exhibited multiple failures. All failed areas were examined closely. Four of the failures of computer No. 1 were in the areas of speed mode operation. When repeating the tests in this area, the failures could not be duplicated. Failures in computer No. 2 were so numerous that the computer would not function normally. Both computers were tested further, but results were inconclusive.

The left and right angle of attack sensors exhibited some light internal corrosion. The pickup was replaced in the left angle of attack sensor and tested. The left angle of attack sensor then functioned normally. The probe on the right angle of attack sensor had been bent during the accident and could not be tested.

Examination of the proximity electronic unit disclosed internal contamination and corrosion from salt water immersion; after cleaning, the unit passed all functional tests except for the left main landing gear "down" function.

The two digital air data computers exhibited internal contamination, corrosion, and impact damage to the circuit boards. The damage to the circuit boards prevented a functional testing of the computers. The flap position transmitters disclosed no internal damage and performed normally during functional testing.

The cockpit was damaged by impact. The glareshield and instrument panel were displaced aft and down several inches. All flight deck crew seats were intact and undamaged except for the second observer's jumpseat which was loosely attached to the cockpit floor. That seat was similar in design to the free-standing jumpseat used by flight attendants; the unit has a fold-down seat pan and an integral four-point restraint system. The observer seat was flush against the cockpit/cabin bulkhead and mounted to the floor with four bolts. The front attachments were intact. However, the two aft bolts were found loose but in place. Microscopic inspection disclosed that the threads on both bolts were stripped; the nuts to these bolts were not recovered.

The cabin was deformed only in the floor and ceiling area around doors 1L and 1R between the forward three galleys and the two lavatories. Additional damage was noted just aft of forward lavatories A and B. The airplane flooring in these areas was disrupted and displaced upward, exposing the supporting structure. The ceiling panels in the area were disrupted by the displaced galley units. Additionally, the vertical panel near door 1R, which covered the door mode selecter and control levers, was buckled and split in the area of these controls.

The cockpit/cabin bulkhead, at the junction of the floor and the left side of the cockpit door, was displaced upward 2 1/2 inches and forward about 1 inch. The upper piano hinge of the cockpit door was pulled away from the door edge. The right side of the cockpit/cabin bulkhead was displaced downward about 5 inches at the cockpit door frame.

The left galley unit, aft of the cockpit/cabin bulkhead, was tilted inboard about 2 inches at the top. The galley unit also was tilted aft. At the cockpit floor, the galley unit was displaced forward and upward about 2 inches and in contact with the observer's jumpseat. The center galley unit, G3, was displaced upward and was tilted aft. The floor and the forward bottom edge of the galley unit were displaced upward about 7 inches. All galley equipment remained stowed. However, the storage doors of the G3 galley unit were bowed out about 1 inch. The aft door lock had disengaged, but the interlocking right door lock kept the galley doors closed.

The remainder of the cabin interior structure aft of row 1 generally was undamaged. All of the overhead panels and stowage bins were intact. No sidewall or floor disruption was evident aft of the first row of seats.

The airplane was equipped with slide/rafts. The 1L door was found open and the slide/raft was deployed and inflated; the 1R door was found closed. The mode selector lever was in the manual position, and there was extensive damage to the forward panel covering the door handles. The 2L door was open and the slide/raft had been detached at the girt. The detached slide/raft was inflated and found floating near the approach light pier. Door 2R also was found open and the slide/raft had been detached at the girt. The slide/raft was found inflated and floating in the basin near the shore. Both slide/rafts from doors 2L and 2R were used as rafts. However, neither slide/raft had been converted from a slide to a raft configuration.

The 3L door was closed, and the mode selector lever was in the manual position. When the selector level was placed in the emergency position and the control level pulled, the door retracted and the ramp and slide/raft deployed and inflated. The 3R door was open. The ramp and slide/raft had deployed and were inflated.

The aft left door, 4L, was open, and the mode selector lever was in the emergency position. The slide/raft had deployed and was partially resting on the ground with the half ties intact and had not been inflated. Six-foot-tall marsh grass, up to 1/4 inch in diameter, was underneath and around this slide/raft and the slide/raft at the 4R door. The slide/raft was inflated by pulling the manual inflation handle. The aft right door, 4R, also was open; the mode selector lever was in the emergency position. The slide/raft had deployed but was not inflated. The cylinder was discharged and the manual inflation handle was in place. The slide/raft was stretched out on the ground. The examination of the slide/raft at door 4R disclosed that the supplemental restraints, known as quarter ties, located on the inside of both upper side chambers, were attached. The half tie and the orange frangible link had separated. The link is designed to separate at 129 lbs., ±6 lbs. of tensile load. A fabric tear was discovered on the bottom of the lower right side chamber. The tear was located 36 inches from the top of the slide and near the locator light battery pack. The tear measured 12 inches laterally and 26 inches longitudinally. Twigs and debris were found in both aspirator inlets. The slide/raft was checked for additional leaks after the tear was patched and the aspirators were cleaned. Two small puncture holes were found in the outboard left upper chamber between the second and third canopy posts. It also was noted that the slide surface had a hole about 3/4 inch in diameter, about 3 ft from the top upper chamber and 12 inches right of the slide centerline.

Both aft slide/rafts were examined at the manufacturing plant. The slide/raft at door 4L was not tested under pressure since it was inflated at the site. There was no evidence to indicate that the inflation lanyard had been misrigged or that any other condition existed which would have inhibited the inflation bottle from freely dropping and automatically discharging to inflate the slide/raft.

1.13 Medical and Pathological Information

The captain sustained bruises to his right hand and left leg and was admitted to the hospital; the first officer sustained a minor back injury; and the flight attendant at 1L sustained a sprained knee. A total of nine passengers sustained minor injuries, including a contused knee during the evacuation, and were treated at the airport medical facility. One person sprained an ankle. Five passengers were treated for exposure and/or hypothermia. The remaining three passengers were treated for anxiety, hypertension, and unstable angina, respectively. One of these, a female passenger with a cardiac condition was hospitalized for over 48 hours for observation which required classification of "serious injury" in accordance with the definitions in 49 CFR 830.2.

1.14 Fire

There was a localized, small fire confined to some electrical wiring adjacent to pneumatic ducting under the cabin floor. The fire self-extinguished almost immediately.

1.15 Survival Aspects

Evacuation

After the airplane came to rest, the evacuation in the cabin was initiated inadvertently by the purser stationed at door 2L. He heard no command from the flightcrew to evacuate, and although the emergency evacuation signal was activated, he did not hear it. The flight attendants at doors 4L and 4R had no awareness of an emergency situation and momentarily waited until they saw actions by the forward flight attendants before opening the doors and initiating the evacuation of the last section of the airplane.

All of the cabin doors except for 1R and 3L were opened by the flight attendants. All of the combination slide/rafts deployed automatically, and except for the slide raft at 4L, all inflated. The 1L door initially was hung up retracting into the ceiling. Subsequently, the door retracted properly and the slide/raft fully deployed and inflated. However, no one used this exit. The attendant at door 1R attempted to open his door. He pushed the handle all the way up, but nothing happened. The two slide/rafts at doors 2L and 2R were detached and used as rafts without being converted from a slide to a raft configuration. Each raft was estimated to have had about 20 passengers and crewmembers on board. The flight attendant at door 3L opted not to open her door after observing smoke from the left engine. She directed the passengers on her side across to the 3R door. Most of the passengers in the economy section went out this door. At door 4L, the slide/raft deployed but did not inflate automatically. The flight attendant chose not to inflate the slide since the door opening was close to the ground. The slide/raft at door 4R, which had deployed, was hung up and did not inflate properly after the door was opened. The flight attendant said the slide was folded in half and he kicked it open. The slide deflated shortly after it was kicked open. About 40 passengers exited through door 4R.

The flight attendants at the four forward doors did not observe that the emergency lights were illuminated during the evacuation. Most of the others said that the emergency lights were illuminated. All flight attendants stated that the emergency evacuation was controlled and the passengers were calm. They estimated that the evacuation of the airplane was completed within 60 to 90 seconds, despite some difficulties evacuating two intoxicated passengers who refused to leave the airplane and had to be bodily removed from the cabin by the flightcrew.

Crash/Fire/Rescue Response

The JFK Port Authority of New York and New Jersey emergency crews were notified initially at 2119 hours, when the call came that an SAS 747 "was lost on ground radar" on runway 4R near runway 14/32. This call came from the JFK Tower on the emergency conference circuit. Crash/fire/rescue (CFR) units responded from both CFR garages with six CFR trucks and 12 firefighters. The first two CFR trucks from the satellite garage arrived on the scene in slightly over 1 minute. The crew chief, who was aboard truck No. 1, stated that he had seen the aircraft off the end of the runway and partially submerged in the Thurston Basin. He notified the police desk to upgrade the emergency at 2121. No fire was visible. About 80 percent of the passengers had exited the aircraft. He observed a number of passengers and crewmembers forward of No. 1 engine, two of whom were in the water. The crew chief entered the water and assisted about 12 passengers who were in a slide/raft in the basin at the end of the approach lighting system pier. Several firefighters escorted passengers on the end of the pier over the left wing and back onto the pier and away from the aircraft.

Shortly thereafter, the crew chief proceeded to the right side of the aircraft and observed another slide/raft adrift in Thurston Basin forward of the No. 3 engine. He then entered the water with a line and swam to the raft; he and the raft were then pulled to shore by fellow firefighters on the other end of the line. After leaving the water, the crew chief observed a cockpit crewmember inside the aircraft at door 4R and advised him to exit expeditiously.

The crew chief estimated that all passengers were on land and safely clear of the aircraft within 5 to 7 minutes of the initial alarm. Within approximately 20 minutes after the accident, all passengers had been boarded on mobile lounges. Those without injury were taken to the International Arrivals Building at JFK. Those who were injured or appeared injured were transported initially to the airport medical clinic. Persons requiring further medical attention were transferred to a nearby hospital.

Upon completion of passenger evacuation operations, airport CFR vehicles remained in strategic positions around the aircraft. New York City Fire Department fire equipment also stood by on the north side of Thurston Basin with suction pumps placed in Thurston Basin to provide additional water if required.

1.16 Tests and Research

1.16.1 Time of Touchdown

The time of touchdown was established by relating the events that can be associated with an airplane approaching and coming in contact with the runway surface. Based on the data from the AIDS and the DFDR, touchdown was determined to be at 21:18:21.6. About 1.5 seconds before touchdown, the elevators deflected significantly to an aircraft noseup position, which is indicative of a flare to cushion the touchdown. At 21:18:21.6, the vertical acceleration had nearly reached a peak, longitudinal acceleration began decreasing, the spoiler handle and the panel were retracted, thrust reversers on engines Nos. 1 and 3 were stowed, the wheel brake switches were off, the nose gear strut switch was in the air position, and the radio altimeter read about zero ft. At 0.7 second after touchdown, the vertical acceleration peaked and the longitudinal acceleration continued to decrease. Immediately upon touchdown, the spoiler handle and panel were in the extend position, and the nose gear strut switch was recorded in the ground position.

1.16.2 Point of Touchdown

The point at which the airplane touched down on the runway was calculated as follows:

1. The AIDS recorded inertial navigation system (INS) ground speed for the time period from the middle time of the recorded outer marker (OM) signal to the recorded sound to the touchdown was integrated to compute distance traveled after passage of the outer marker. This computed distance was compared with the actual distance from the OM to the approach end of the runway.

2. Similar calculations were made using passage of the middle marker (MM) as the position reference.

The integration of groundspeed from the middle time of OM reception to time of touchdown was 20,793 ft. The actual distance from the OM to the approach end of the runway is 16,196 ft. Therefore, the calculated position of touchdown using this method was 4,597 ft down the runway. The integration of the groundspeeds from the middle time of the MM reception to the time of touchdown was 7,539 ft. The actual distance from the MM to the approach end of the runway is 2,610 ft. Therefore, the calculated position of touchdown using this method was 4,929 ft.

1.16.3 Approach Profile and Configuration from 2,000 Feet to Touchdown

About 4 minutes before touchdown, the aircraft was about 2,000 ft above ground level (AGL), tracking 015° true at about 180 knots indicated airspeed. Autothrottles No. 1 and No. 2 were engaged in the speed mode, No. 2 autopilot was in the command mode, No. 1 autopilot was off, and the flaps were set at 15°. During the next minute, the aircraft descended to about 1,500 ft AGL and the autopilot ILS mode was selected. About 3 minutes from touchdown, the autopilot switched to the localizer capture and tracking mode, the aircraft began turning toward runway heading, pitch increased slightly, and N_1 fan rotor speed began to increase. (N_1 s representing all three engine rpm percentages were used in these calculations.) The aircraft remained level for the next 1.5 minutes at a nearly constant indicated airspeed of 180 knots and an inertial navigation system groundspeed of about 210 knots, indicating about a 30-knot tailwind. About 1.5 minutes from touchdown, the flaps started down to the 22° position, the autopilot switched to glideslope capture and tracking mode, N_1 began to decrease to flight idle, the aircraft pitched over, and the aircraft began to descend. The AIDS data showed that the difference in the airplane's airspeed and the speed selected on the autothrottle system had reached at least 10 knots, which is the maximum difference measurable by the recording system.

During the first 30 seconds of descent (from 1,500 ft to about 870 ft AGL), the throttle position and engine N_1 went to flight idle, indicated airspeed increased to 190 knots and then began to decrease, and the flaps started down to the 35° position. During the next 10 seconds (from 870 ft to 700 ft), the throttles and engine N_1 came up to about 84 percent, the indicated airspeed began climbing from 180 knots, and the flaps reached the 35° position. For the next 32 seconds, until about 18 seconds from touchdown (from 700 ft to 70 ft), the throttle position and N_1 stayed about 84 percent while indicated airspeed continued to climb to a peak of 209 knots. As the airspeed increased past about 193 knots, the flap limiting system on the aircraft began to retract the flaps.(See figure 3.) The flaps continued up to about 27° at an indicated airspeed of 209 knots about 15 seconds before touchdown. About 20 seconds before touchdown, the autopilot was switched from the command to the control wheel steering mode. Three seconds later, the throttle position was reduced to flight idle at a faster rate (about 9.5° per second) than the autothrottle programming allows (2° to 3° per second). About this time, the captain stated, "It didn't take power off."(See figure 4.) At 15 seconds before touchdown, the aircraft was about 50 ft radio altitude, pitch began increasing, the airspeed began decreasing, the flaps began to extend back to the 35° setting, and the autothrottles went from the speed mode to the retard mode.

About 5 seconds before touchdown, the flaps arrived at the 35° setting, the airspeed had decreased to 185 knots, and the radio altitude was about 20 ft. At touchdown, the indicated airspeed and the groundspeed were about 179 knots.

A correlation was made between the CVR cockpit conversation, radio altitude, and position over and on the runway.(See figure 4.) Because CVR times are listed to the nearest second, this correlation is only approximate.

1.16.4 Summary of Landing Roll

Within 0.7 second after what was determined to be touchdown (21:18:21.6), the spoiler handle came out of the retract position, the spoiler panels that were measured by the AIDS system (5 left and 3 right) came out of the zero degree position, the vertical acceleration peaked, the nose gear strut switch remained in the "air" position, the longitudinal acceleration began a decreasing trend, and the Nos. 1 and 3 thrust reversers were recorded in the stowed position. At 2.0 seconds after touchdown, the nose gear strut switch was recorded in the ground position, the wheel brakes were still in the off position, the spoiler handle was recorded in the extend position, and the spoiler panel reading was about 60°. About 2.8 seconds after touchdown, recorded data showed both wheel brakes on and the No. 1 thrust reverser in the stowed position. N_1 on all three engines during this time (from 14 seconds before touchdown) was about 40 percent (equal to flight idle). Five seconds after touchdown, the N_1 began to decrease from flight idle to ground idle. About 6.4 seconds after touchdown, the No. 1 thrust reverser registered in the deployed position (these data are sampled once every 4 seconds). The No. 3 N_1 began increasing from 35 percent at 8 seconds after touchdown, and passed 90 percent at 12 seconds after touchdown. The No. 1 N_1 began increasing from 30 percent about 12 seconds after touchdown and attained 88 percent at 15.4 seconds after touchdown where the data ended. The No. 2 engine thrust reverser was in transit for 3.4 seconds and was fully deployed 7.4 seconds after touchdown but showed only a slight momentary increase in N_1 from 32 percent to 41 percent and then back to 32 percent where it remained to the end of recorded data, which for this engine was 16 seconds after touchdown.

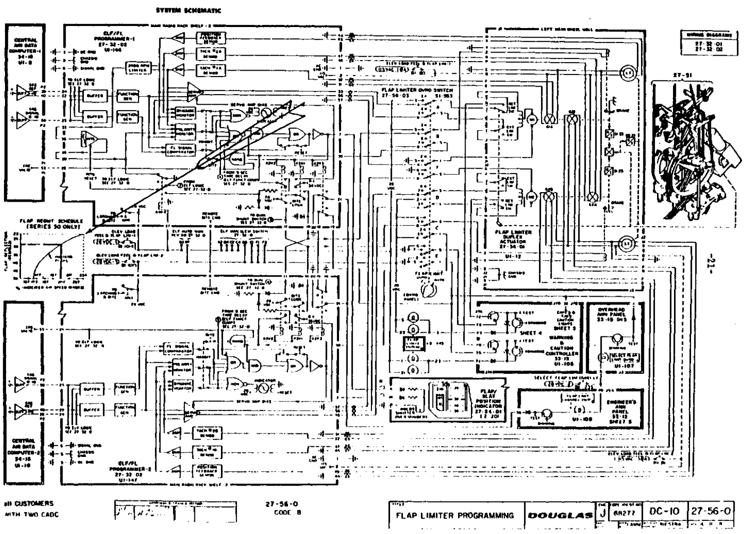

Figure 3.--Flap Limiter System.

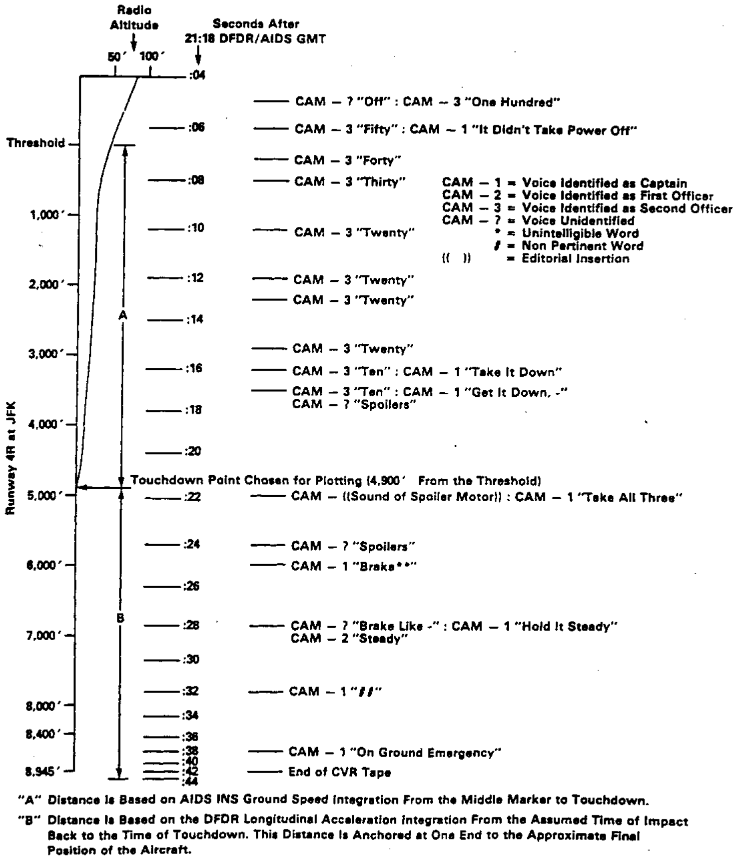

Figure 4.—CVR/AIDS Integration/Runway/Altitude Correlation.

A listing of significant events after the time established for touchdown follows:

Time from Touchdown (21:18:21.6) (Seconds	Events
0	Radio Navigation 1 groundspeed from AIDS (interpolated 179.0 knots).
0	Indicated airspeed from DFDR (interpolated 179.5 knots).
0.1	Longitudinal acceleration began decreasing trend (from DFDR).
0.7	Vertical acceleration peaked (from DFDR).
0.7	No. 3 thrust reverser last recorded in stowed position (from AIDS).
1.2	Pitch attitude reduced to nose on the runway value (from DFDR).
1.6	Spoiler panel first recorded in extended position (from AIDS).
1.7	Spoiler handle first recorded in extended position (from AIDS).
2.0	Nose gear strut switch first recorded in ground position (from AIDS).
2.7	No. 1 thrust reverser last recorded in stowed position (from AIDS).
2.8	Both wheel brakes first recorded on (from AIDS).

6.7	No. 1 thrust reverser first recorded in deploy position (data sampled every 4 seconds) (from AIDS).
8.45	N_1 on all three engines last recorded at about 40 percent (from 14 seconds prior to touchdown) (from AIDS).
8.7	No. 3 thrust reverser first recorded in deploy position (data sampled every 4 seconds) (from AIDS).
9.45	No. 3 engine N_1 began increasing above 40 percent (from AIDS).
9.7	Rudder input recorded greater than -5° (from AIDS).
11.9	No. 1 engine N_1 began increasing above 40 percent (from AIDS).
12.0	No. 3 engine N_1 passed through 90 percent (linear interpolation) (from AIDS).
15.8	No. 2 engine N_1 showed no increase past 41 percent from 12 seconds prior to touchdown to the last recorded point (from AIDS). (Throttles were not moved past 41 percent position.)
18.45	Magnetic heading deviated from runway heading (from DFDR).
18.9	No. 1 engine N_1 attained 91.9 percent at last recorded time (from AIDS).
20.7	Aircraft began pitch down (from DFDR).
21.2	Pitch attitude reached -5.89° at last recorded value (from DFDR).
21.60	Last recorded longitudinal acceleration (from DFDR).
21.63	Last recorded point from DFDR before synchronization was lost (lateral acceleration).

1.16.5 Runway Friction

Runway friction measurements were taken on 4R at JFK using a friction tester on February 29, 1984, when the runway was dry and on March 5, 1984, when the runway was wet. (See Appendix E.)

The dry test, performed at a speed of 48 mph, showed an average friction value of 0.945 [14] from the approximate point of touchdown to the approximate end of the runway. Friction was not measured on the hard-surface overrun.

The wet tests were performed at three different speeds with the following averages for the portion of the runway after the approximate point of aircraft touchdown:

Speed	Average Friction
22 mph	0.88
47 mph	0.81
65 mph	0.78

The Saab handbook defines aquaplaning (hydroplaning) as "the speed at which the friction value has dropped to 0.25."

Calculations made by the Douglas Aircraft Company show calculated effective braking coefficient of friction (Mu prime) as a function of groundspeed for the landing ground roll.(See figure 5.) The force attributed to braking was derived using deceleration data from the DFDR and calculating the drag, lift, and thrust forces on the aircraft. (The effective braking coefficient cannot be directly equated to friction values as measured with the Saab equipment.)

The FAA-approved field length for Flight 901 with a 35° flap, slats extended configuration at the prevailing pressure and temperature on a wet surface was about 7,000 ft. This field length is based upon the safety margins required by regulation to be applied to the certification landing performance of the airplane.

Figure 6 shows calculations performed by the Douglas Aircraft Company for wet and dry stopping distances for a normal landing sequence and for the accident scenario. These stopping distances are those theoretical distances which are required to bring the airplane to a full stop from the point of touchdown using the deceleration devices as indicated with the assumed braking coefficients attainable on dry and wet runways.

1.16.6 Wind Shear

From about 3 minutes to 1.5 minutes before touchdown, the AIDS INS calculated winds acting on the aircraft. These calculations revealed that the winds were from about 225° to 235° true at between 26 and 32 knots, producing a tailwind of approximately the same magnitude. Aircraft true heading during this time period was between 12° and 22°.

About 1.5 minutes before touchdown, the recorded wind speed began to decrease and during the following 30 seconds, lessened to about 15 knots. About 1 minute before touchdown, the wind direction began to change gradually counterclockwise, while speed continued to decrease. By 20 seconds from touchdown, the wind acting on the aircraft was recorded to be from 144° at 8 knots, resulting in a slight tailwind of less than 3 knots. At touchdown, the winds were recorded to be from about 135° at 6.5 knots.

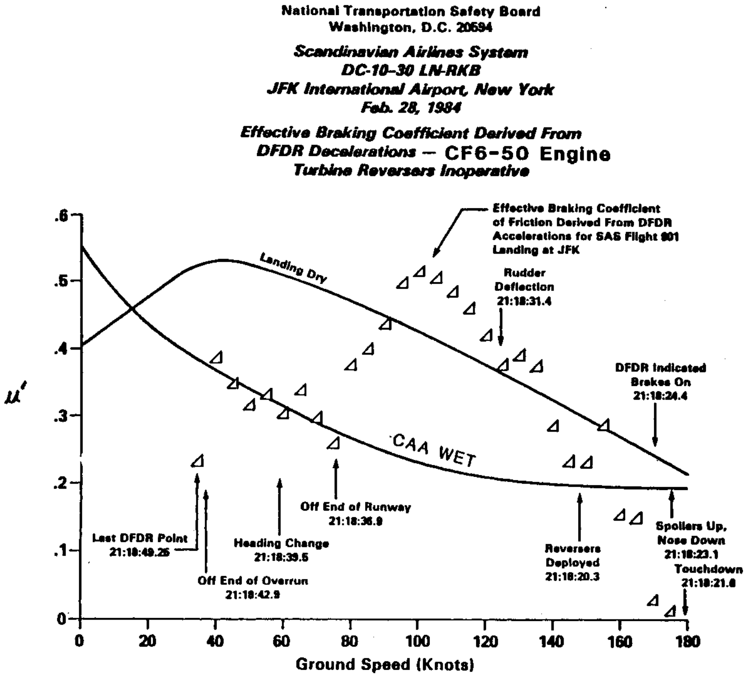

Figure 5.—Effective Braking Coefficient Derived from DFDR.

Assumptions used in analysis:

1) Aircraft weight = 172,800 kg = 380,959 lb
2) Aircraft c.g. = 18.7% MAC
3) Runway headwind = 1.2 knots
4) Turbine reversers connected and deployed
5) H_p = 700 ft, T = 7°C
6) Performance handbook = MDC-J6805
7) 35° landing flaps

(A) Performance Handbook Landing
Time from contact to:
Nose down : 3 sec
Spoiler Actuation : 0 sec
Full Spoilers : 2 sec
Brake Actuation : 1.5 sec
Full Brakes : 3.5 sec
Reverse Detent : 2 sec
Max reverse : 8 sec
Max reverse to 80 KIAS
Stow reversers at 60 KIAS
V_{TD} = 1.27 V_S = 142.8 KEAS

Stopping Distances (ft)	
Dry	2318
Wet	4206
CAA Wet	3003

(B) Performance based on AIDS
Indicated pilot actions
Time from contact to:
Nose down : 1.4 sec
Spoiler actuation : 0 sec
Full spoilers : 1.0 sec
Brake actuation : 1.8 sec
Full brakes : 3.8 sec
(assumed 2 sec after actuation)
Thrust (including reverse) based
on AIDS trace of N_1 vs speed
and reverser deployment vs speed
V_{TD} = 178.2 KTGS
V_{TD} = 179.6 KEAS

Stopping Distances (ft)	
Dry	3774
Wet	6545
CAA Wet	4744

Hp = pressure altitude
V_{TD} = touchdown speed
V_S = FAA specified stall speed
KEAS = equivalent airspeed
KTGS = ground speed

Wet distance is based on Douglas wet Mu prime.
CAA Wet distance is based on British Civil Aviation Authority wet Mu prime.

Figure 6.—DC-10-30 Calculated Stopping Distances for SAS Accident Analysis.

1.17 Other Information

1.17.1 Scandinavian Airlines System Operational Procedures

The following information is extracted from the Scandinavian Airlines System's Aircraft Operations Manual and pertinent SAS-issued bulletins.

(1) Speed Selection Procedures For Approach Phase of Flight

Old Procedure - Prior to October 13, 1983

Neither pilot had specific duties regarding selection of speed, but both pilots were required to check.

Revised Procedure - Effective October 13, 1983

Autopilot In Command or CWS Mode - the flying pilot selects speeds, the nonflying pilot checks speeds.

Autopilot Off - the nonflying pilot selects speeds, the flying pilot checks speeds.

Latest Revised Procedure - Effective February 23, 1984

Autopilot in command mode: The flying pilot (1/P)[15] selects speed, the nonflying pilot (2/P) checks. Autopilot In Command Wheel Steering (CWS Mode) or off -- the nonflying pilot selects speed; the flying pilot checks speed.

(2) Callout Procedures

Figures 7 andFigure 8 contains a reproduction of pertinent section of Aircraft Operations Manual.

(3) Speed Control

During the entire approach, it is important to keep the correct speed with as little throttle manipulation as possible. However, the power setting must be promptly adjusted as soon as it becomes apparent that an adjustment is required.

Never go beyond the recommended speed tolerances for each phase of an approach as stated in the AFM/AOM and corrected for wind component and/or gust value, as applicable depending on aircraft type. Whenever a wind shear effect is anticipated, the speed shall be increased to compensate for the expected wind shear effect.

(4) Approach - Wind Shear

Decreasing headwind is the most dangerous. If reported or experienced before the outer marker, there is normally adequate altitude to compensate provided minimum speeds are increased accordingly.

3.3.4. Call-out procedures

It is of utmost importance that standard procedures are followed. Any intentional deviation from a standard procedure shall be clearly announced by 1/P in order to facilitate the monitoring function of 2/P. In general, internal pilot to pilot communication shall ascertain that the pilots are in full agreement regarding the progress of the flight.

However, it is important to avoid any unnecessary conversation which can distract attention.

FLIGHT PROCEDURES Flight Performance — Let—down and approach

Callouts made by a 2/P or S/O that require correcting action by the 1/P shall be answered and/or reacted upon by him, indicating that he is aware of the situation.

Failure to respond and continued failure to react shall be treated as pilot incapacitation.

The following callouts are mandatory and shall be made by the pilot specified. Callouts marked "P" shall normally be made by 1/P. If for some reason the callout is not made by 1/P, the callout shall be made by 2/P or S/O.

Callouts in a normal approach

CALLOUT	BY	CALLOUT INDICATES
"RADIO HEIGHT"	R/P*	Radio Altimeter passing 2500 ft. during letdown.
e.g. "ONE ZERO ONE TWO"	L/P*	Actual altimeter setting. *DC-10 and A300: P
"LOCALIZER COMING"	P	Localizer bar moving from full deflection.
"LOCALIZER CAPTURE"	P	A/P or F/D has captured localizer
"GLIDE PATH COMING"	P	Glide Path bar moving from full deflection.
"GLIDE PATH CAPTURE"	P	A/P or F/D has captured glide path.
"OUTER MARKER, ..." or "OSCAR ALFA, ..." or "FIVE MILES, ..."	P	Outer Marker or equivalent position plus actual crossing altitude.
"SINK RATE, ..."	2/P	Actual sink rate at approx, 1000 ft. RH after landing flaps have been set and final letdown started.
"PLUS HUNDRED"	2/P	Passing minimum plus 100 ft. and "Contact" not yet called by 1/P.
"APPROACH LIGHTS" or "RUNWAY" plus direction	2/P	Approach lights - or runway - in sight and "Contact" not yet called by 1/P.
"CONTACT"	1/P	Able to continue approach by visual reference.
Actual radio heights	2/P or S/O	Actual radio heights as required according to respective AFM/AOM in order to assist in assessment of safe threshold crossing and flare.

Figure 7.--SAS Callouts in a Normal Approach.

Other callouts

CALLOUT	BY	CALLOUT INDICATES
"SPEED HIGH"	P	Desired indicated airspeed is exceeded by more than 10 kts, or final approach and threshold speed by more than 5 kts.
"SPEED LOW"	P	Indicated airspeed below: - Pattern speed minus 10 kts - Approach speed minus 5 kts or - Threshold speed minus 0 kts.
"SINK RATE"	P	Rate of descent more than 1000 ft/min below 2500 ft. RH.
"GLIDE PATH"	P	Flight path deviates from ILS Glide path by more than one dot.
"NOT STABILIZED"	2/P	Aircraft not stabilized according to definition in FOM 3.1.8. para 3.3.1. at or below 1000 ft RH.
"NOT STABILIZED, PULL-UP"	2/P	Aircraft not stabilized according to definition in FOM 3.1.8. para 3.3.1. at or below 500 ft RH.
"MINIMUM, PULL-UP"	2/P	Reaching decision altitude/height in a precision approach and "Contact" or "Pulling-up" not yet called by 1/P.
"MINIMUM"	2/P	Reaching minimum altitude/height in a non-precision approach and "Contact" or "Pulling-up" not yet called by 1/P.
"DECISION POINT, PULL-UP"	2/P	Reaching Decision Point in a non-precision approach and "Contact" or "Pulling-up" not yet called by 1/P.
"PULLING-UP"	1/P	Starting a pull-up.

Figure 8.--Other SAS Callouts.

When a wind shear is reported or anticipated after the outer marker, or whenever the wind component on the ground differs from that noted or reported at the outer marker indicating a headwind decrease of more than 20 knots, the following action must be taken:

- Add 15 knots to approach and threshold speed and disregard increment requirements in AFM/AOM with regard to wind component and wind gust.
- Be prepared to pull up if sink rate increases rapidly. Make sure that pull-up procedures have been reviewed in detail prior to commencing the approach and be aware that a successful pullup may need full power and a determined rotation.
- Request ATC to keep you informed of the latest pilot reports.

(5) Use of Automatic Systems

· Use of autopilot and autothrottles need careful monitoring. Hand on wheel and hand on throttles must be stressed, with alertness for quick manual inputs. Respective AFM/AOM gives information on limitations.

(6) Stabilized Approach

An approach is stabilized when the aircraft is lined up with the runway and flown at the desired approach speed in the landing configuration maintaining an acceptable rate of descent. Only small power changes should be necessary to maintain such a stabilized approach.

ALL APPROACHES must be stabilized not later than approximately 500 ft RH. It is the duty of the nonflying pilot to monitor that the aircraft is stabilized on the approach and to warn the flying pilot if stabilization has not been attained.

(7) Pull-Up--General

A pull-up occurs when an aircraft abandons its approach to a selected runway.

In order to achieve maximum safety, it is important that the decision to abandon an approach is made as early as possible.

A pull-up, once commenced, must be completed and no attempt shall be made to reestablish an abandoned approach. The nonflying pilot and system operator, if carried, shall carefully monitor that the pull-up is performed in accordance with established procedures.

In case the nonflying pilot has taken over the controls from flying pilot in order to make a pull-up, no further change of control shall be made until the pull-up is completed.

A pull-up should not be made once the aircraft has touched down as the performance requirements cannot always be ascertained. However, training flights with a qualified flight instructor as pilot-in-command may make touch and go landings during scheduled training flights.