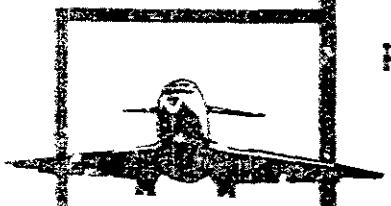
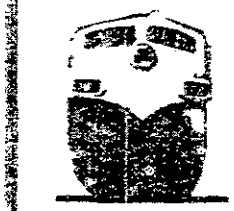
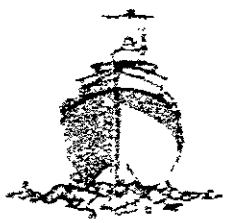
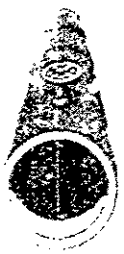








PB84-910413

NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

AIRCRAFT ACCIDENT REPORT

SCANDINAVIAN AIRLINES SYSTEM
FLIGHT 901
McDONNELL DOUGLAS DC-10-30
JOHN F. KENNEDY
INTERNATIONAL AIRPORT
JAMAICA, NEW YORK
FEBRUARY 28, 1984

NTSB/AAR-84/15

UNITED STATES GOVERNMENT

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. NTSB/AAR-84/15	2. Government Accession No. PB84-910415	3. Recipient's Catalog No.
4. Title and Subtitle Aircraft Accident Report—Scandinavian Airlines System Flight 901 McDonnell Douglas DC-10-30 Norwegian Registry LN-RKB John F. Kennedy International Airport Jamaica, New York, February 28, 1984		5. Report Date November 15, 1984 6. Performing Organization Code
7. Author(s)		8. Performing Organization Report No.
9. Performing Organization Name and Address National Transportation Safety Board Bureau of Accident Investigation Washington, D.C. 20594		10. Work Unit No. 3894-A 11. Contract or Grant No. 13. Type of Report and Period Covered Aircraft Accident Report February 28, 1984
12. Sponsoring Agency Name and Address NATIONAL TRANSPORTATION SAFETY BOARD Washington, D. C. 20594		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract 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.

17. Key Words Landing accident, autothrottle speed control system, crew overreliance, crew procedures, wind shear.	18. Distribution Statement This document is available to the public through the National Technical Information Service Springfield, Virginia 22161		
19. Security Classification (of this report) UNCLASSIFIED	20. Security Classification (of this page) UNCLASSIFIED	21. No. of Pages 85	22. Price

NTSB Form 1765.2 (Rev. 9/74)

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.

CONTENTS

NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C. 20594

AIRCRAFT ACCIDENT REPORT

Adopted: November 15, 1984

SCANDINAVIAN AIRLINES SYSTEM FLIGHT 901
MCDONNELL DOUGLAS DC-10-30
NORWEGIAN REGISTRY LN-RKB
JOHN F. KENNEDY INTERNATIONAL AIRPORT
JAMAICA, NEW YORK
FEBRUARY 28, 1984

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.

1/ All times herein are Greenwich Mean Time based on the 24-hour clock. (Subtract 5 hours to obtain Eastern standard time.)

2/ VORTAC - Very high frequency omnidirectional range/tactical air navigation - A navigation aid which provides both VOR and TACAN azimuth and distance measuring equipment at one site.

3/ ARINC - Aeronautical Radio Incorporated; a telecommunications company which provides nationwide communication services for the air transport industry.

4/ ATIS - Automated Terminal Information Service provides current, routine information to arriving and departing aircraft by means of continuous and repetitive broadcasts throught the day or a specified portion of the day. Each time the information is updated a sequential phonetic alphabet letter is assigned, i.e., information alpha, bravo, etc.

The systems operator 5/ 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 II 8/ 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 bugs 9/ 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.

5/ Systems operator is the SAS designation for flight engineer or second officer.

6/ Instrument Landing System is a precision instrument approach system which normally consists of electronic components defining the localizer, glideslope, outer marker, middle marker, and high intensity approach lights.

7/ Runway visual range is the maximum distance in the direction of takeoff or landing at which the runway or the specified lights or markers delineating it can be seen from a position above a specified point on its centerline at a height corresponding to the average eye-level of pilots at touchdown.

8/ ILS Category II - An ILS approach procedure which provides for approach to a height above touchdown of not less than 100 ft and with runway visual range of not less than 1,200 ft.

9/ Bug is a moveable pointer on the radio altimeter which can be set to a preselected radio altitude; when the aircraft descends to this altitude, an aural and visual warning is activated.

10/ V_A is the SAS designation for approach speed; V_{TH} is the SAS designation for threshold speed.

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 reversers 11/ 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.

11/ SAS procedure for use of reverse thrust states: The engine 2 reverser shall normally not be used except when landing at Copenhagen. If, however, runway conditions are such that Pilot in Command deems that all engine reverse thrust may be required, there is no restriction on the use of engine 2 reverser.

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 re-entered 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	Crew		Passengers	Other	Total
	Cockpit	Cabin			
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

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.

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.

Figure 2.—Flight 901 at 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:

- o Flight precautions for [instrument flight rules] IFR, icing and turbulence.
- o Occasional moderate mixed icing in clouds and in precipitation below 12,000 to 14,000 ft.
- o Severe turbulence across the forecast area. (See SIGMET Alfa series for high level turbulence and SIGMET Charlie series for low level turbulence.)
- o Low level wind shear potential across the entire forecast area due to strong cyclonic circulation associated with a West Virginia low pressure center.
- o Occasional moderate turbulence below 17,000 ft due to wind shear. . . . Strong low-and mid-level winds.
- o Occasional moderate turbulence between 17,000 to 38,000 ft due to wind shear aloft and jetstream.
- o 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.
- o 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

Approximate Height (ft above the surface)	Computed Wind Speed (knots) (tailwind)
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 lever was placed in the emergency position and the control lever 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., $\pm$ 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_1s 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

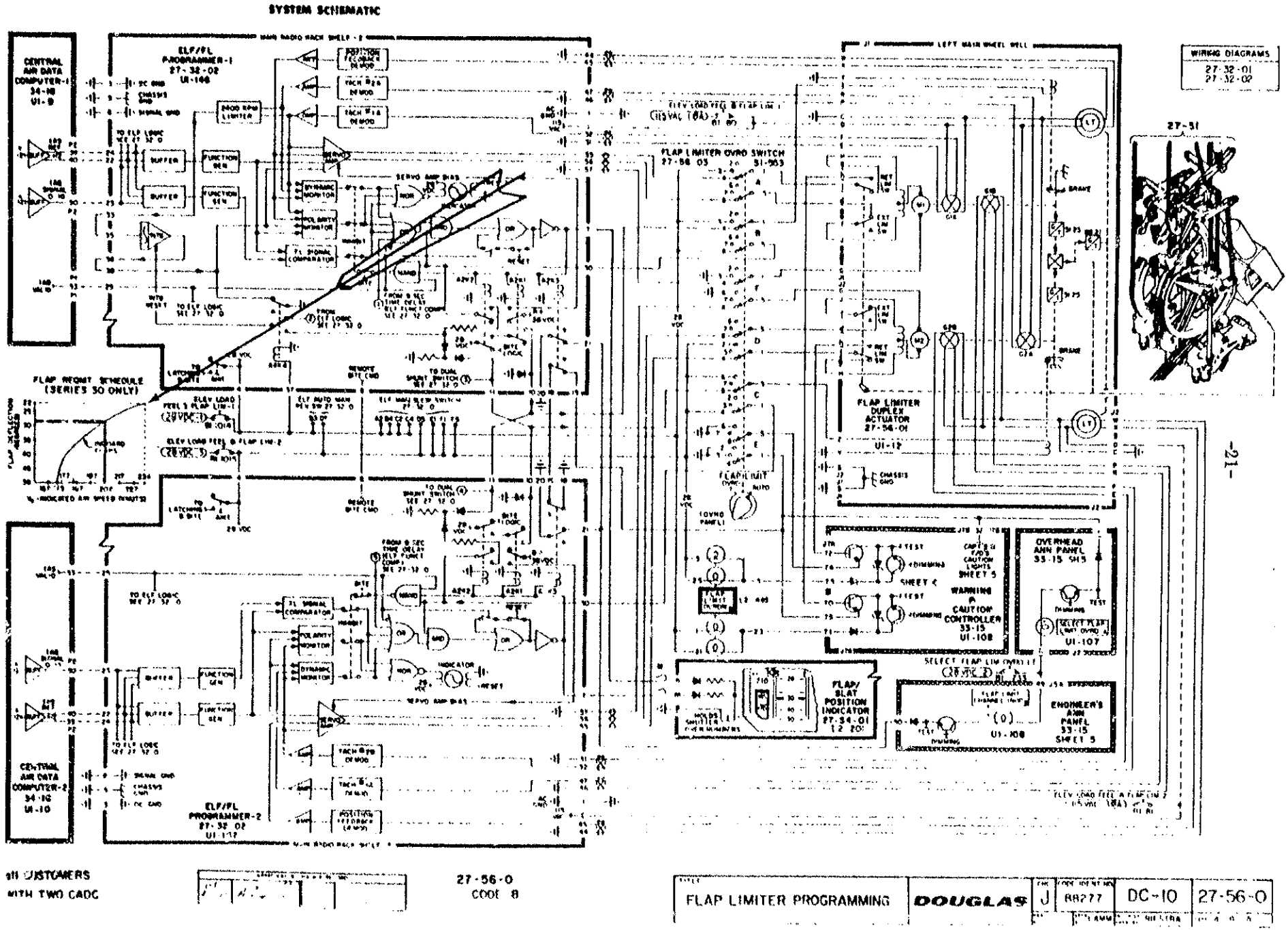
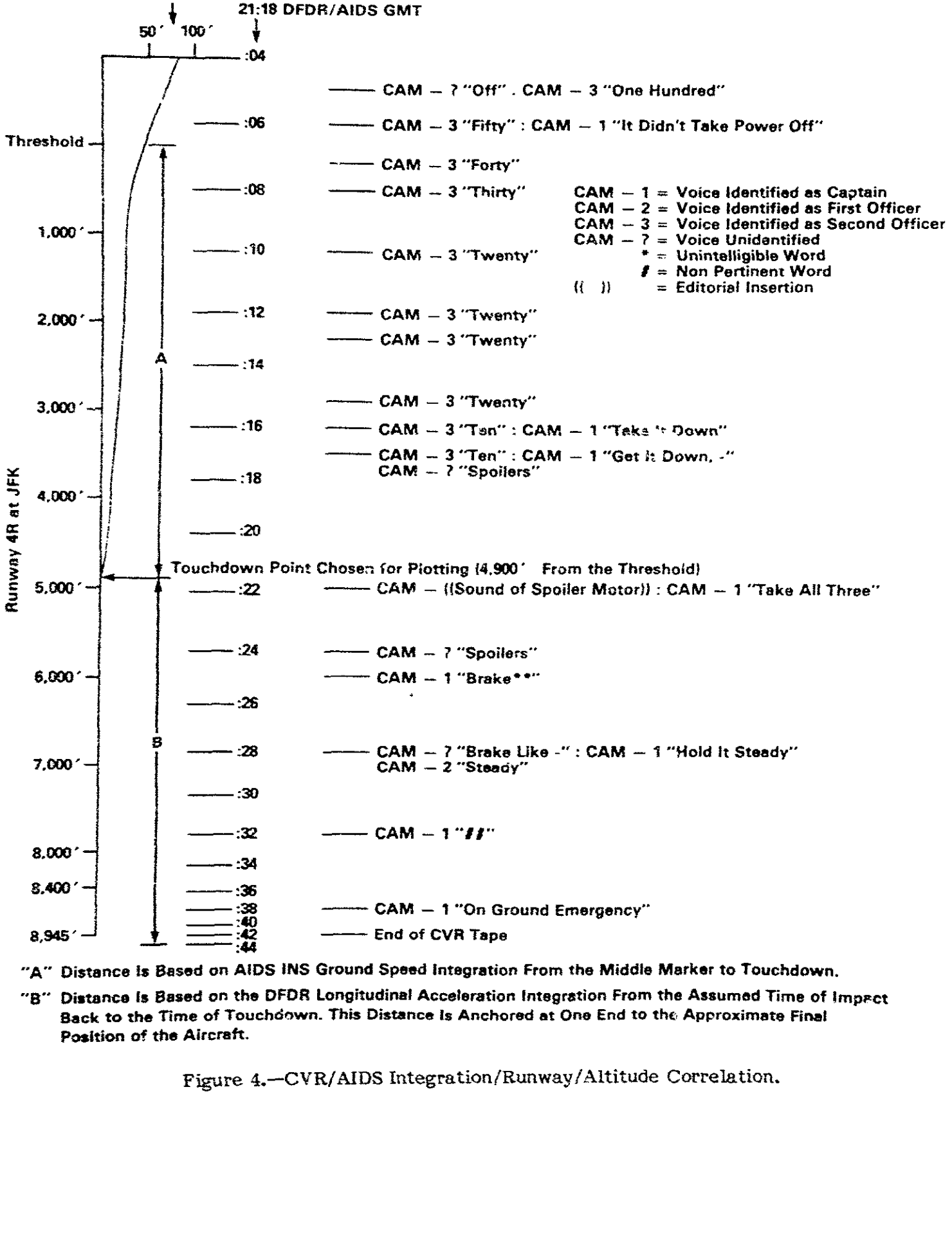


Figure 3.--Flap Limiter System.



"A" Distance Is Based on AIDS INS Ground Speed Integration From the Middle Marker to Touchdown.

"B" Distance Is Based on the DFDR Longitudinal Acceleration Integration From the Assumed Time of Impact Back to the Time of Touchdown. This Distance Is Anchored at One End to the Approximate Final Position of the Aircraft.

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

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.

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).

Time from Touchdown (21:18:21.6) (Seconds	Events
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.

14/ Friction value is an index number relatable to friction coefficient.

National Transportation Safety Board
Washington, D.C. 20594

Scandinavian Airlines System
DC-10-30 LN-RKB
JFK International Airport, New York
Feb. 28, 1984

Effective Braking Coefficient Derived From DFDR Decelerations — CF6-50 Engine Turbine Reversers Inoperative

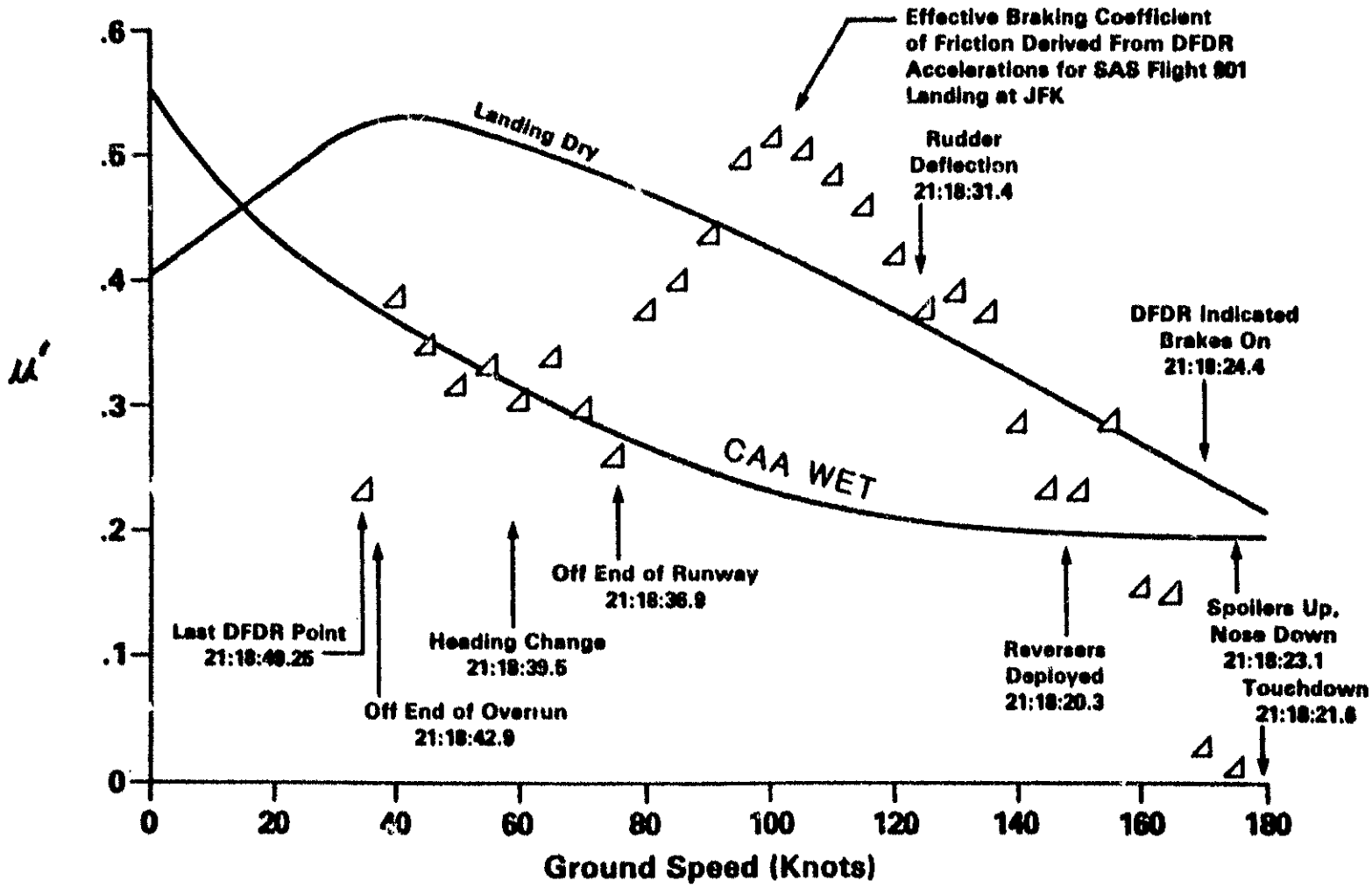


Figure 5.—Effective Braking Coefficient Derived from DFDR.

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

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 and 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.

15/ 1/P = Pilot flying the airplane
2/P = Nonflying pilot (Assisting Pilot)
S-O = Systems operator or (flight engineer).

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 tc 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.

Callouts in a normal 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 tc 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.

CALLOUT	BY	CALLOUT INDICATES
"RADIO HEIGHT" e.g. "ONE ZERO ONE TWO"	R/P* L/P*	Radio Altimeter passing 2500 ft. during letdown. 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.

(8) Pull-Up On ILS or Precision Approach Radar (PAR) Approaches

The approach shall be abandoned and a pull-up be commenced if:

- The official visibility is below the applicable company minimum at or after passing the outer marker or equivalent position,
- the approach is not stabilized at approx. 500 ft RH,
- at DA/DH the pilot is unable to make a landing by use of visual guidance,
- visual guidance is lost after passing DA/DH,
- at CAT I minimum on approaches to CAT II min, if requirements for CAT II are not fulfilled and visual guidance not obtained.

(9) Autothrottle

Autothrottle shall be used according to recommended procedures in respective AFM/AOM. It is an effective means of reducing pilot workload and facilitates precise speed control.

Due regard must be paid to the limitations of the Autothrottle System. The 1/P (pilot flying) shall monitor its function and immediately disconnect it if discrepancies or uncomfortable operation is observed.

The throttles shall always be guarded below 1,500 ft to permit the pilot to promptly counteract ineffective or erratic throttle control. This is especially important in wind shear and turbulence conditions to prevent programming of excessive thrust reductions.

(10) Duties and Responsibilities - Flight Personnel

During flight the systems operator (S/O) shall:

Operate and monitor the S/O Panel according to valid procedures and immediately inform the pilot-in-command of any irregularities and malfunctions, or if normal operating limits are exceeded.

Assist the Pilots in communication and navigation including preselection of VHF COM frequencies, change of ATC transponder codes and resetting of the altitude preselect system according to the pilot-in-command's discretion.

Receive weather broadcasts and currently keep the pilot-in-command informed of changes.

Assist the Pilots in keeping look-out during VMC, particularly in terminal areas.

Act as relief pilot during cruise from top of climb to top of descent, including change of flight level.

In cooperation with the other crewmembers prepare applicable reports.

Partake by use of applicable charts in the navigation of the aircraft and monitor Descent/Approach and Take-off/Climb procedures when other duties permit.

Assist in keeping the passengers informed of the flight's progress through loudspeaker announcements, as directed by the pilot-in-command or copilot.

2. ANALYSIS

2.1 General

The flightcrew was properly certificated in accordance with existing regulations of Denmark, Norway, and Sweden; there was no evidence that any physical factors affected their performance.

The airplane was properly certificated, equipped, and maintained in accordance with existing regulations and approved procedures of the State of Registry. All three engines and reversers functioned normally and reverse thrust was produced in proportion to the flightcrew's demand on the engines on which reverse thrust was selected. The airplane's autothrottle speed control system and related systems had repeated discrepancies reported since January 8, 1984. The discrepancies involved the system's failure to reduce throttle setting to maintain airspeed at the selected value. Corrective actions, in the form of component replacements, were accomplished through the morning of February 28, 1984, when the No. 2 autothrottle speed control computer was replaced at the termination of the aircraft's flight into Stockholm. The system again malfunctioned on the first leg of the accident flight into Oslo when the captain selected a 50-knot airspeed reduction and the autothrottle did not retard to the selected speed.

2.2 The Accident

The investigation disclosed that the landing approach was conducted in weather characterized by a low ceiling, low visibility, and light drizzle and fog. Although the runway was wet, there was no standing water.

The examination of data from the airplane's digital flight data recorder and the aircraft integrated data system recorder indicated that the approach was normal as the airplane descended to about 800 ft AGL. Although the groundspeed showed that the airplane was experiencing a tailwind component, the indicated airspeed was stable and the airplane was following the ILS glideslope.

After descending through 800 ft, however, the airplane's indicated airspeed increased to the point that the airplane passed over the runway threshhold at about the proper crossing height, but about 50 knots faster than the prescribed reference speed. Thereafter, the airplane floated, touching down on the runway at least 4,000 ft beyond the threshhold. The theoretical stopping distance for a DC 10 configured as Flight 901 was for the touchdown exceeded the length of runway remaining even for dry runway conditions. The Safety Board, therefore, concluded that runway condition was not a factor in the accident and has directed its attention toward reasons for the long and fast touchdown and the flightcrew's decision to continue the landing rather than initiate a missed approach.

Since the autothrottle speed control system (ATSC) was used throughout the approach for airspeed control, the Safety Board examined the following factors as they may have led to the long and fast touchdown:

- The performance of the ATSC system before and during the approach.
- The flightcrew's decision to use and rely on the ATSC system.
- The flightcrew's role in monitoring the performance of automated systems and related operating procedures and training.

The Board also sought to determine:

- The flightcrew's knowledge of touchdown position on the runway and the airplane's stopping performance.

Autothrottle Speed Control System.--The ATSC system components had been damaged and contaminated during the accident. Thus, the system's preaccident condition could not be established. However, the previously reported discrepancies in the system and the flightcrew's observation that the system had malfunctioned on the previous leg of the flight indicate the possibility that an intermittent fault was affecting the system's performance during the accident approach.

The flightcrew recalled dialing 168 knots into the autothrottle speed select window, a selection which was verified during the postaccident examination of the module. A properly operating ATSC would have modulated the position of the airplane's throttle in order to decelerate to and maintain the selected speed. The recorded data show that the throttle positions did retard and the engines went to flight idle rpm as the airplane began to descend from 1,500 ft. The airspeed did begin to decrease in response to the reduced power. However, as the airplane descended through about 800 ft, the throttles moved toward higher power and the engines responded by increasing rpms to about 84 percent N_1. The airspeed began to increase, but there were no indications of appropriate throttle corrections by the ATSC system. The flightcrew recalled that the ATSC did not retard the throttle as expected when the airplane descended below 50 ft. The evidence provided by the recorded ATSC mode and throttle position parameters verifies that the throttles were not responding to ATSC commands.

The Safety Board considered the possibility that wind shear could have affected the airplane's flightpath and the ATSC performance. At the outer marker, the airplane was experiencing a 30-knot tailwind component which diminished between 1,500 ft and the surface at a nearly linear rate with change of altitude to a 2-knot tailwind at the surface. This type of wind condition would initially cause the ATSC to command a lower engine power setting than that which would be commanded in a stable wind condition in order to produce an inertial deceleration needed to maintain the stabilized selected airspeed and the ILS glideslope. On the other hand, while the average engine power required would be lower throughout the approach, the constantly decreasing groundspeed as the airplane decelerated would require gradually increasing power in order to keep the airplane on the ILS glideslope at the selected approach airspeed. The wind shear calculated to have existed at the time of this accident, however, was mild and did not exceed an average change of 3 knots in the longitudinal wind component for each 100 ft of altitude change. The certification approval for airborne navigation instrument and flight control systems for category II approaches requires that the systems

demonstrate the capability to track the glideslope and maintain airspeed within specified tolerances while penetrating a wind shear having 4 knots per 100 ft variation from 500 ft to the surface. Further, during a previous accident investigation, 16/ the Safety Board had examined the performance of a DC-10 autopilot system in an emergency simulation when the airplane was subjected to a decreasing tailwind shear in excess of 4 knots per 100 ft. The simulation showed that the ATSC performs satisfactorily under these conditions. Therefore, the Safety Board concludes that the nonresponsive performance of the ATSC on the SAS flight was not caused by wind shear.

While the evidence is conclusive that the airplane's ATSC system was faulty, the Safety Board considered the intended role of such systems in its assessment of accident cause. The ATSC is required aboard the airplane only to conduct category III approaches. Although it is extensively used to reduce pilot workload, it is not required to be installed for this purpose. As with other aircraft systems, the possibility of erratic operation caused by a component malfunction is present and pilots are expected to monitor and disconnect or override such systems when unacceptable flightpath or speed deviations are apparent. Since the flightcrew of Flight 901 was able to disconnect or override it, the Safety Board cannot conclude that the ATSC system's malfunction caused or even directly contributed to the accident.

Flightcrew Performance.--The flightcrew had been aware that the ATSC system had performed erratically before commencing the approach. It had, in fact, performed erratically on the previous leg of the flight and although subsequent operation was normal, the crew knew that there had been no intervening maintenance. There is no evidence that the flightcrew considered this previous erratic operation in its decision to use the ATSC for the approach. Had they considered its previous faulty operation and intentionally decided to use the ATSC regardless, the pilot should have been prepared to revert to manual throttle control if erratic throttle movement or unacceptable airspeed excursions occurred. Detection of these excursions, however, was dependent upon vigilant monitoring of the airspeed instrumentation by the crew.

The flightcrew, in preparing to use the ATSC for the approach, calculated the approach reference speed to be 154 knots. The last speed dialed into the ATSC command module, however, was 168 knots. The flightcrew's postaccident statements and recorded cockpit conversation imply that the difference was an intentional compensation for a potential wind shear encounter. While an airspeed additive is appropriate for some wind shear conditions, it was not an appropriate action for the frontal type of wind shear that was present during this approach. In fact, the SAS Flight Operations Manual states that 15 knots must be added to the approach and threshhold speeds "when a wind shear is reported or anticipated after the outer marker, or whenever the wind component on the ground differs from the noted or reported at the outer marker indicating a headwind decrease of more than 20 knots." While the flightcrew had reason to anticipate a wind shear condition after passage of the outer marker, it had sufficient information to deduce that the wind shear would produce an effective headwind increase (tailwind decrease) during the approach. The airplane's INS system was indicating a tailwind in excess of 20 knots as the approach was started while the reported surface winds were light. Under the actual conditions, a speed additive would compound rather than alleviate the effect of the wind shear.

16/ Aircraft Accident Report: Iberia Airlines McDonnell Douglas DC 10-30 EC CBN, Logan International Airport, Boston, Massachusetts, December 17, 1973. (NTSB-AAR-74-14.)

The flightcrew's actions to add the 15 knots to compensate for potential wind shear without first considering the type of wind shear condition indicated by the prevailing weather and INS measurements concern the Safety Board. The Board has been a strong proponent of the adoption of comprehensive classroom and simulator training programs to increase the awareness of air carrier pilots of the wind shear hazard. The Safety Board has noted that most of the recent research regarding wind shear and most of the related material which has been circulated throughout the aviation community in the aftermath of accidents have emphasized the extreme dangers of the convective downburst or microburst type of wind shear. In an encounter with that type of wind shear, it is essential that an airspeed margin be available to compensate for a sudden reduction in the airplane's headwind. Far less emphasis has been given to the frontal system wind shear in which the airplane may encounter an increasing headwind (or decreasing tailwind) which does not challenge the airplane's performance capability but can present other subtle dangers. It is possible that the greater exposure to training material related to the convective type of wind shear has caused some pilots to believe that adding a speed margin is the safest reaction to reported wind shear without further analyzing the existing wind shear condition.

Although the flightcrew's intentional addition of 15 knots to the approach reference speed was not appropriate, the Board concludes that this also was not a factor in the accident since the approach almost certainly could have been flown to a successful landing had airspeed been controlled to the selected value of 168 knots.

The flightcrew's recollections following the accident indicate that neither the captain nor his copilot was totally aware of the airplane's increasing airspeed during the final approach. Since airspeed management, particularly during final approach, is an essential element of basic airmanship, the Safety Board must conclude that the performance demonstrated by this crew was either aberrant, or represents a tendency for the crew to be complacent and overrely on automated systems.

The Safety Board, therefore, must address the reasons why the flightcrew allowed the autothrottle system to control the airplane to an airspeed nearly 40 knots higher than the selected value. The Safety Board is concerned that an experienced, apparently well-trained flightcrew whose previous record of performance was unblemished had a lapse in which they overlooked the basic airmanship function of airspeed control on approach. Two factors which probably affected the crew's performance were (1) its habitual reliance on the proper functioning of the airplane's automatic systems, and (2) a degradation of crew coordination and nonadherence to related procedures when the first officer is flying the airplane.

At about 100 ft above minimums, the captain noted that the airspeed was high, and he brought this to the attention of the first officer, who was flying the airplane. This appears to be the only reference made to airspeed during the approach; no other required airspeed callouts were made. The captain and first officer had two direct reading instruments to alert them that the ATSC was not maintaining the selected airspeed--the airspeed indicator itself and the "fast slow" indicators of the speed control system located on the left side of each attitude direction indicator. The airspeed indicator has a movable marker or "bug" to remind pilots of approach speed. A difference between indicated airspeed and "bug speed" should alert a pilot to any discrepancy. Neither pilot of Flight 901 noted the bug position, and SAS does not require that they do so.

Another instrument that pilots are expected to crosscheck during an approach, especially a precision approach, is the vertical speed indicator (VSI). If a greater than normal descent rate is required to maintain glideslope, either the aircraft is on a "false" glidepath or the groundspeed is higher than normal. Higher than normal groundspeed could be a result of poor airspeed control or a tailwind. The crew indicated that the autopilot kept the aircraft on localizer and glidepath. They were aware of a tailwind during the approach when they called up the performance page of the command display unit and it indicated a tailwind in the vicinity of 20 knots. However, even taking into account a tailwind of this magnitude, indications of a vertical speed of 1,640 ft per minute (fpm) on the glideslope should have alerted the crew that an abnormal condition existed. A normal vertical speed would be about 800 fpm, about one-half of that actually shown. The ILS to runway 4R has a 3° glideslope and even with a groundspeed of 188 knots (168 V_A + 20-knot tailwind), the rate of descent should have been less than 1,000 ft per minute.

Even though they should have been concerned about the faulty performance of the ATSC on the previous flight, the flightcrew apparently had been conditioned by repeated successful use of the system to rely upon its performance to the extent that neither adequately monitored essential airspeed and vertical velocity instruments.

Reliance on Automated Systems.--Since the introduction of sophisticated automation that accompanied the wide-body generation of aircraft, there has been much controversy and concern over the resulting relationship between man and machine. As more computers have been added to the aircraft and control of tasks has been transferred to autopilot and autothrottle systems, the pilot's role in the aircraft operation has changed dramatically. His workload as far as physical handling of the aircraft was reduced, and in some phases of flight, totally eliminated. According to one researcher, "As computers are added to the cockpit, the pilot's job is changing from one of manually flying the aircraft to one of supervising computers which are doing navigation, guidance, and energy management calculations as well as automatically flying the aircraft." 17/

However, with increased automation, overall pilot workload has not necessarily been reduced; in most cases, it merely has shifted from performing tasks to monitoring tasks. Because increasingly more systems have been automated, a proliferation of components has resulted and the pilot "has many more indicators of component status to monitor." 18/ There is convincing evidence, from both research and accident statistics, that people make poor monitors. For example:

17/ Palmer, E., Models for Interrupted Monitoring of a Stochastic Process. NAS TM-78, 453, 1977, p.1.
18/ Wickens, C.D., Engineering Psychology and Human Performance. Columbus, Ohio; Charles E. Merril Publishing Company, 1984, p. 490.

1. Kessel and Wickens did a laboratory study to compare failure detection performance between manual and automated systems. In the manual mode, participants were actively controlling a dynamic system and in the automatic mode they were monitoring an autopilot that controlled the system. It was found that "detection performance was faster and more accurate in the manual as opposed to the autopilot mode". 19/ These results were attributed to the fact that in the manual mode, the participants remained in the "control loop" and they benefited from additional proprioceptive cues derived from "hands-on" interaction with the system. These findings were in agreement with a research study by L. R. Young. 20/

2. In the 1972 Eastern Airlines L-1011 crash into the Everglades, 21/ the crew was distracted by a malfunctioning landing gear light and failed to monitor the autopilot which was flying the aircraft. The autopilot was accidentally disengaged and the aircraft gradually descended from the holding pattern. Without an autopilot, one crewmember would have been forced to fly the aircraft and the disaster would have been avoided.

3. In 1979, the crew of an Aeromexico DC-10 stalled the aircraft on climbout over Luxembourg. The crew either intentionally or inadvertently programmed the autopilot for the vertical speed mode rather than the procedurally directed airspeed or mach command mode. The aircraft maintained the programmed climb rate throughout the climbout, but at the sacrifice of airspeed. As thrust available decreased with altitude, the engines' thrust became insufficient to sustain flying airspeed for that climb rate and the aircraft stalled, losing approximately 11,000 ft of altitude before recovery. The Safety Board concluded, "The flightcrew was distracted or inattentive to the pitch attitude and airspeed changes as the aircraft approached the stall." The probable cause of the incident was listed as "the failure of the flightcrew to follow standard climb procedures and to adequately monitor the aircraft's flight instruments." 22/

4. Another incident, almost identical to that which occurred on the Aeromexico flight, is cited in a NASA Aviation Safety Reporting System (ASRS) report:

19/ Kessel, C. and Wickens, C.D., The Internal Model: A Study of the Relative Contribution of Proprioception and Visual Information to Failure Detection in Dynamic Systems. NASA CP-2060, 1978, pp. 85-86.
20/ Young, L.R., On Adaptive Manual Control. IEEE Transactions on Man-Machine Systems, Vol. MMS-10, 1969, pp. 292-331.
21/ Aircraft Accident Report: Eastern Airlines L-1011, Miami, Florida, December 29, 1972 (NTSB-AAR-73-14).
22/ Aircraft Incident Report: Aeromexico DC-10-30, XA-DUH, Over Luxembourg, Europe, November 11, 1979 (NTSB-AAR-80-10).

> The aircraft was climbing to FL 410 with the right autopilot and autothrottles engaged and controlling the aircraft. At approximately FL 350 the airspeed was observed to be below 180 knots and decaying. The autopilot was disengaged and the nose attitude was lowered. At this point the stickshaker activated and a slight buffet was felt. Application of full power and a decrease in pitch attitude returned the airspeed to normal. Remainder of the flight was uneventful.
>
> During the climb portion of the flight the pilot stated that he believed the autopilot was in the Flight Level Change Mode (max climb power and climbing while maintaining a selected airspeed/mach). Looking back he felt that the autopilot must have been in the Vertical Speed mode, and not Flight Level Change. If this were the case with 2,500/3,000 ft per minute up selected, then the airspeed would be near normal to about FL 300 at which point the airspeed would bleed off as the autopilot maintained the vertical speed.
>
> Prevention of this incident: the pilot must at all times be absolutely sure what mode the autopilot is operating in. A continuous crosscheck of the primary flight instruments would have indicated decreasing airspeed before it became a serious problem. 23/

The examples above and the performance of the crew of SAS Flight 901 give credence to the contention that humans tend to be poor systems monitors. Kessel and Wickens attribute this to the fact that man has been removed from an active role in the man-machine control loop with the subsequent reduction in available performance cues.

In 1976 a technical paper entitled "The Automatic Complacency" was presented by an SAS captain. (See Appendix G.) The summary of the paper follows:

> This paper discusses the man-machine problem that faces the pilot in his role as a programmer and supervisor in an environment that provides automatic systems to do the work but where the redundancy concept requires the man to be in a "continuous loop" function.
>
> The paper recognizes the problem as "normal," human-engineering wise but a problem that has to be solved by giving the pilot strong incentives to interface himself with the functions of the automatics and to subordinate himself to the requirements of tedious monitoring routines and stringent flight deck procedures which he may feel as superfluous in view of the normally excellent performance of the automatic systems.

23/ Lauber, J.K., Cockpit Resource Management in New Technology Aircraft, presented at International Aeronautical Symposium sponsored by Japanese Air Line Pilots Association. August 16-18 1982, p. 11.

Researchers claim that the reliability of the automated equipment may account for the reduced vigilance of pilots using automated systems. Very unreliable equipment would lead pilots to expect malfunctions and to be proficient at handling them. A system that never fails would not pose a problem, but one with an intermediate level of failure may prove "quite insidious since it will induce an impression of high reliability, and the operator may not be able to handle the failure when it occurs." 24/

The captain of SAS Flight 901 knew that the ATSC had malfunctioned on the first leg of the flight. However, 10 hours had elapsed since the malfunction and the captain had over 5 years experience with successful autothrottle operation.

In fact, the excursion from a stabilized condition might be exaggerated even after a system anomaly is detected, because of the period required for a pilot to transition from system monitor to system controller. Time is needed to "ascertain the current status of the airplane and assess the situation," 25/ before the pilot can reenter the control loop and take corrective action.

In this accident case, about 20 seconds before touchdown, the first officer switched the autopilot from the command to the control wheel steering mode, a mode in which he manually controls the airplane's attitude. This action placed the copilot into the control loop but apparently did not prompt him to recognize or correct the the excessive airspeed. The Safety Board believes that the copilot's performance illustrates the difficulties in the transition from a monitoring to a control function as described by the researchers.

Researchers also have concluded that "prolonged use of a system in the automatic mode may lead to a deterioration of manual skills and a loss of proficiency, which may degrade performance on a manual system." Thus, even after detection of anomalous performance of an automatic system, the pilot's ability to precisely control an airplane after he reenters the control loop is degraded. Another researcher noticed that "many crewmembers have discovered this [proficiency loss] on their own and regularly turn off the autopilot, in order to retain their manual flying skills." During its investigation of this accident and associated interviews with crewmembers, the Safety Board learned that SAS and other airlines, as well as airplane manufacturers, teach and encourage the use of automated systems such as the autothrottle.

While the Safety Board believes that on balance automation has greatly improved safety and has reduced pilot workload and fatigue, there is an ever-increasing need to reemphasize to crews the need to effectively monitor critical flight instruments and systems. This requirement may be satisfied in part by introduction of procedures and training specifically designed to enhance crew awareness of excursions from programmed performance.

Crew Coordination, Procedures, and Training.--A comparison of the CVR transcript with SAS airspeed and altitude callout procedures disclosed that the crew omitted several required calls during the ILS approach to JFK. Altitude callouts were not made for "Glide Path Coming" and "Glide Path Capture." An unintelligible comment made near the OM (1614:16) may have been the required call for this point on the approach.

24/ Wiener, E.L., and Curry R.E., Flight-Deck Automation: Promises and Problems, NAS TM-81206, p. 10.

25/ Boehm-Davis, D.A., Curry, R.E., Wiener, E.L., and Harrison, R.L., Human Factors of Flight-Deck Automation - NASA/Industry Workshop, NASA TM-81260, January, 1981, p. 6.

Required airspeed callouts were neglected even more than altitude calls, and this may have contributed to the crew's lack of airspeed awareness, been symptomatic of it, or both. The second pilot (nonflying pilot) is required to state the flap configuration airspeed at about 1,000 ft radio height or the point where the landing flaps are set. If the airplane is not at the desired approach speed at or below 1,000 ft radio height, the second pilot was required to call out "not stabilized." At 1,000 ft radio height, Flight 901 actually had 190 KIAS rather than the commanded airspeed of 168 KIAS. No callout was made. At or below "500 ft radio height and not at desired speed," the nonflying pilot is required to say, "Not stabilized, pull up." Flight 901 had an airspeed of about 190 KIAS at 500 ft radio height and no callout was made. At 1618:01 (about 150 ft radio height), the captain called "high." "Speed High" is a required callout for a V_{TH} more than 5 knots high. At 150 ft radio height, the speed of Flight 901 was about 208 KIAS rather than 168 V_A. Although the systems operator (flight engineer) has no specified airspeed calls to make, he is required to monitor "all Descent/Approach. . . procedures when other duties permit." In this case, it does not appear that the systems operator had other duties that would have precluded his noticing and commenting on excessive airspeed during the approach.

The speed callout procedure set forth in the SAS Flight Operations Manual, requiring only a callout of "Speed Low" or "Speed High" if the final approach and threshold speed deviate more than 5 knots from the target speed, may not be sufficient to alert a crewmember to a dangerously low, or as the case may be, high speed condition. The Board believes that in addition to low or high, the actual deviation above or below reference speeds should be a required callout, i.e. +10, +20, -10, -20, etc.

The purpose of airspeed and altitude callouts is to provide checks and balances between flightcrew members. Verbalizing selected performance parameters not only reinforces each crewmember's perception of aircraft performance, it also enables pilots to better assess each other's situational awareness.

In another accident investigated by the Safety Board, the adverse effects of neglecting required callouts on crew coordination and performance also was illustrated. On July 9, 1978, the pilot of an Allegheny Airlines BAC 1-11 flew an uncoupled ILS approach 61 knots above reference speed and landed about half-way down runway 28 at Monroe Airport, New York. The aircraft came to rest over 700 ft past the departure end of the runway. In its report of the accident, 26/ the Safety Board stated:

> The National Transportation Safety Board determines that the probable cause of the accident was the captain's complete lack of awareness of airspeed, vertical speed, and aircraft performance throughout an ILS approach and landing in visual meteorological conditions which resulted in his landing the aircraft at an excessively high speed and with insufficient runway remaining for stopping the aircraft, but with sufficient aircraft performance capability to reject the landing well after touchdown. Contributing to the accident was the first officer's failure to provide required callouts which might have alerted the captain to the airspeed and sink rate deviations. The Safety Board was unable to determine the reason for the captain's lack of awareness or the first officer's failure to provide required callouts.

26/ Aircraft Accident Report: "Allegheny Airlines, Inc., BAC 1-11, N1550, Rochester, New York, July 9, 1978" (NTSB-AAR-79-2).

Several airlines have instituted simulator training programs to emphasize crew coordination and provide assertiveness training for copilots and flight engineers. Many of these programs emulate the "Line-Oriented Flight Training" (LOFT) concept developed by Northwest Orient Airlines and the National Aeronautics and Space Administration (NASA). 27/ The emphasis of LOFT training is not on individual performance, but rather on the development of effective crew interaction skills. SAS has had LOFT programs in effect prior to the accident. The captain had received the last such training on December 15, 1983, the first officer on February 2, 1984, and the systems operator on September 3, 1983.

In the Allegheny Airlines accident, the captain was flying and the first officer was responsible for monitoring the approach. In the SAS Flight 901 accident, the flying roles were reversed, a situation in which crew coordination tends to be degraded as evidenced by NASA/ASRS incident reports. One study of such data concluded: "The belief that the flightcrew operates more efficiently when the captain is flying than when he is performing PNF (pilot-not-flying) duties is given a measure of support with these incidents." 28/ This finding is attributed not to a lack of flying competence by first officers, but rather to the lower efficiency of captains in the monitoring role. The failure of the crewmember monitoring "consists of either a failure to detect the departure from expected performance in time to prevent the unwanted occurrence; a failure to communicate the detection in a timely and effective manner; or less frequently, a failure to take effective action when an adequate and timely monitoring communication does not elicit an appropriate response." In addition, it was found that while crews performed better when the captain is flying, "there was considerable evidence that the importance of the monitoring function was not well understood by either pilot or, if well understood, was frequently neglected."

Because of the increased potential for a breakdown in crew coordination when captains and first officers customarily exchange flying duties, the Safety Board believes that training programs must highlight the responsibility of the nonflying crewmember for monitoring pilot's performance, especially in light of the influences of automation on the extent of monitoring tasks.

Runway Touchdown Position/Stopping Performances.--Another area of concern regarding the flightcrew's training stems from the crew's decision to continue the landing approach rather than go around and from the actions taken by the first officer once the aircraft touched down.

The FAA-required field length criteria provides that the airplane's demonstrated dry runway performance would allow it to pass 50 ft over the runway threshold at its reference speed, be landed, and stopped fully (without using reverse thrust) within 60 percent of the total effective runway length. For a wet runway, an additional 15 percent margin is arbitrarily added to compensate for the reduced braking coefficient. The airline data provided to flightcrews so that they can determine the suitability of a destination runway in accordance with this required field length criteria is presented in terms of the maximum airplane weight at which a landing is permitted under the prevailing condition. These data showed that a DC-10-30 may land on runway 4R at JFK with either wet or dry surface conditions with 35° flaps at all weights up to the airplane's structural maximum landing weight of 186.4 metric tons. With this information, the flightcrew would have recognized that the safety margin available on runway 4R in

27/ Lauber, J.K., and Foushee, H.C., Guidelines for Line-Oriented Flight Training, Vols. I and II, NASA CP-2184, August 1981.
28/ Orlady, H.W., Flight Crew Performance When Pilot-Flying and Pilot-Not-Flying Duties Are Exchanged. NASA CR166433, June 1982, p. 4.

Flight 901 was greater than the safety margins required since the airplane was over 10 metric tons below the maximum permissible landing weight. The crew does not routinely compute the actual runway length needed to comply with the required field length criteria if the airplane weighs less than that permitted. However, such a computation would have shown that the airplane could have landed on a 7,000-ft-long runway with the required safety margin. Thus, the criteria would indicate that the airplane could be landed and stopped on a wet runway in about 4,200 ft, about 50 percent of the length of runway 4R, without using reverse thrust. The McDonnell Douglas Corporation more conservatively calculated that the airplane would take as much as 4,200 ft to stop on a wet runway after the touchdown using reverse thrust. Assuming a normal touchdown 1,500 ft beyond the runway threshold, the airplane would be stopped with 2,700 ft of runway remaining. Thus, it is reasonable to assume that the flightcrew believed that a considerable runway safety margin existed. However, they should also have recognized that the safety margin will be reduced by a long touchdown and high speed. Flight 901 touched down at 179.5 KIAS, 36 knots fast and about 4,700 ft beyond the runway threshold.

The captain estimated that the aircraft made a normal touchdown "at least one-third down the runway," and the first officer estimated that the aircraft landed halfway down the runway. One-third of the runway length is 2,800 ft, leaving only 5,600 ft on which to stop the aircraft. Given a stopping distance of about 4,200 ft, the captain was somewhat optimistic about his ability to stop the aircraft, even if he was under the impression that he landed on speed, one-third down the runway. Had he been alert to the 36-knot speed additive, he should have been concerned about the available stopping distance and ordered a go around. Actually, the aircraft had, only about 3,700 ft (8,400 ft minus 4,700 ft at touchdown point) remaining from touchdown to the end of the runway.

Admittedly, precise calculations are difficult, if not impossible, to make while flaring the airplane, and the absence of distance-remaining markers on runway 4R made it difficult to estimate the point of touchdown. The lack of a requirement for runway distance markers has been of continued concern to the Safety Board and has been the subject of numerous recommendations to the FAA over the past 14 years. This concern was reiterated again in the case of the World Airlines DC-10 accident at Boston; the case of the Air Florida accident at Washington, D.C.; and the Safety Board Safety Study, "Airport Certification and Operations" (NTSB/SS-84-02). The latter report states in part that distance markers "would provide to flight crews, on landing, a way of quickly ascertaining the amount of remaining runway ....." As of this date, distance markers are not mandatory; however, FAA policy on runway distance-remaining markers has been reevaluated and their use is now "permitted" on any runway. Moreover, these markers now are eligible for funding under the Airport Development Assistance Program (ADAP) for runways used by turbine-powered airplanes. The Safety Board also strongly supports simulator training programs to provide a better appreciation for the magnitude of the increased stopping distances required at higher than design touchdown speeds.

After Flight 901 touched down, the captain instructed the first officer to use full braking and to use all three engine thrust reversers. However, the first officer initially used only "light to moderate" brake application; full reverse power on engines 1 and 3 was approached only about 12 seconds after touchdown. As the landing roll progressed, the first officer began to brake harder. When the captain saw the end of the runway, he got on the brakes and the pedals went down farther. Neither pilot recalled noticing the color-coded runway centerline and edge lights that warn pilots of the impending end of the runway.

The SAS flight operations manual provides, "Maximum braking (if circumstances demand) -- depress brake pedals fully and hold." This procedure will achieve maximum antiskid system effectiveness to minimize the stopping distance. The procedure is used only when needed, because of the discomfort it causes passengers and the additional stresses it places on the aircraft. However, it was a vital measure for this crew to take and the captain did call for maximum braking. Maximum braking is the type of procedure which should be practiced in the simulator where possible.

Nothwithstanding the application of less than maximum braking immediately after the airplane touched down, the airplane achieved deceleration comparable to the maximum deceleration values demonstrated during certification. The Board cannot ascertain whether higher deceleration would have been attained with fully depressed brake pedals.

Although the first officer believed that he had used maximum reverse thrust on all three engines until just before the airplane ran off the end of the runway, this is not supported by AIDS data. No. 2 thrust reverser was fully deployed, but the engine showed no increase in power past 41 percent N_1 (idle reverse rpm is about 29 percent N_1). No. 2 thrust reverser is normally not used and a lockout device prevents its use before compression of the nose gear strut. According to the SAS flight operations manual, "If, however, the pilot-in-command deems that all engine reverse thrust may be required, there is no restriction in the use of engine 2 reverser." While use of full reverse thrust on No. 2 engine would only reduce the stopping distance about 50 to 100 ft., its use in appropriate circumstances should be instinctive. It appears that the first officer was not trained either in the aircraft or in the simulator to use all three thrust reversers.

2.3 Survival Aspects

The accident was survivable. Because of the relatively low impact forces, there were no passenger seat separations or failures. The unoccupied second observer cockpit jumpseat was, however, partially separated because the galley was displaced forward as a result of an overload failure of attachment bolts. The impact forces were even lower in the aft cabin. Persons seated in that area characterized the impact as "nothing serious." For the same reason, the aft flight attendants at doors 4R and 4L apparently were not certain that an impact had occurred and they were in doubt about whether to initiate an emergency evacuation. The flight attendant at door 1L sustained the only impact-related injury, a sprained knee, when the floor beneath her ft was displaced upward by the hydrodynamic pressure generated when the airplane struck the water.

The 1R door was inoperative because the mode selector lever probably was jarred out of the emergency mode during impact. The door was opened and functioned properly in the emergency mode during postaccident tests. Although some discrepancies in equipment manifested themselves during the emergency, the evacuation was carried out expeditiously and effectively.

The first crash/fire/rescue (CFR) units arrived at the aircraft within a little over a minute from the time of the notification. Although no firefighting actions were required, the rescue efforts by emergency crew personnel were exemplary. The crew chief's action in entering the water of Thurston Basin in order to retrieve the drifting slide/raft full of passengers showed selflessness and initiative. All passengers were removed from the water within 15 minutes after the arrival of CFR personnel. The

rescuers' prompt action to remove the survivors from the hostile environment was exemplary.

Although the airplane struck a rigid (nonfrangible) approach light structure, the Safety Board could not conclude that the severity of the accident would have been reduced had the approach light structure been of frangible-type construction. None-the less, the Safety Board continues to be concerned about the possible increased severity of these types of accidents which involve impact with rigid approach light structures. In fact, had the crew not successfully steered around the approach light structure, this accident may have been much more serious. The Safety Board has addressed this issue since 1977 and has monitored the progress in this area. In response to the Safety Board 1977 recommendation calling for nonfrangible approach light structure and the retrofit of all nonfrangible installation, the FAA indicated that a retrofit program would be initiated, the major portion of which would be completed in 5 years. The Safety Board more recently recommended the FAA initiate research and development activities to establish the feasibility of submerged low-impact resistance support structures for airport facilities, and promulgate a design standard if such structures are found to be practical.

The Safety Board realizes that developing a frangible submerged support structure is not a trivial problem and that a considerable amount of research will be necessary to erect an adequate "breakaway" system. The Safety Board is encouraged that the FAA currently is planning a project to develop a computer model for predicting the load behavior of such structures. However, we emphasize that the development of submerged low-impact resistance support structures should be completed as quickly as possible.

3. CONCLUSIONS

3.1 Findings

1. The flightcrew were properly certificated and qualified for the flight.

2. There is no evidence that any physical factor affected the performance of the flightcrew.

3. The airplane's gross weight and center of gravity were within specified limits.

4. The airplane was properly certificated, equipped and maintained in accordance with the regulations of the State of Registry.

5. Although the runway was wet, there was no standing water which would have degraded braking action and affected the airplane's ability to decelerate within predicted parameters. Runway condition was not a factor in the accident.

6. Although there was a tailwind condition during the approach which resulted in higher-than-normal groundspeeds, wind shear did not adversely affect the airplane's performance during the approach and was not a factor in the accident.

7. The National Weather Service wind and low-level wind shear forecasts were not precise; other aspects of the terminal forecast were substantially correct.

8. Failure to include SIGMET Charlie 9 on the ATIS was not a factor in the accident, since there was no significant low level turbulence at the time and in the area of the accident.

9. The flightcrew did not operate the airplane in compliance with applicable SAS procedures for an ILS approach. The approach was not stabilized and approach callouts required by SAS procedures were omitted.

10. Deficiencies in the SAS flight operational procedures in not requiring use of airspeed "bugs" or reminders, in not requiring monitoring and callouts of airspeed by the Systems Operator (flight engineer) during critical phases of the flight, and in not requiring callout of actual airspeed values, contributed to lack of airspeed awareness by the flightcrew.

11. The autothrottle speed control system was malfunctioning before and at the time of the accident.

12. Because of the malfunctioning autothrottle speed control system, thrust was increased when it was not needed.

13. The captain exercised poor judgment in continuing the landing approach with higher than acceptable speed rather than initiating or ordering a go-around.

14. The airplane crossed the runway threshold about 60 knots faster than the calculated V_{TH}.

15. The airplane touched down on the runway 36 knots above the programmed touchdown speed.

16. The airplane touched down about 4,700 ft from the approach end of the runway.

17. There were only about 3,700 ft of runway remaining at the point of the airplane's touchdown; insufficient distance in which to decelerate and stop the airplane.

18. Reverse thrust application was normal on the Nos. 1 and 3 engines. Reverse thrust on No. 2 engine was selected but not effectively applied. The lack of reverse thrust on the No. 2 engine did not appreciably add to the landing distance.

19. Braking and antiskid system performance was normal; however, the brake pedals were not fully depressed at the beginning of the landing roll.

20. The captain steered the airplane to the right of the runway centerline to avoid head-on contact with the approach light structure.

21. Runway 4R, the shortest air carrier runway at JFK International Airport, was designated as the landing runway because of operational factors involving traffic flow into and out of adjacent airports.

22. This was a survivable accident; the emergency evacuation was expeditious and orderly and the crash/fire/rescue response was timely and efficient.

23. The flight attendant at door 1L was injured as a result of the upward displacement and separation of the floor caused by the hydrodynamic pressure generated during impact with the water.

24. The deformation and inertia forces sustained around door 1R caused the mode selector lever to move from the EMERGENCY position.

25. The unoccupied second observer cockpit jumpseat partially separated from its floor attachments when the forward galley was displaced which in turn overloaded the seat's aft floor attachment bolts and stripped the nuts from of the bolts.

26. The flight attendants' decisicn not to open the 3L door was appropriate.

3.2 Probable Cause

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.

4. RECOMMENDATIONS

The Norwegian accredited representative and SAS informed the Safety Board on September 25, 1984, that SAS intends to modify its procedures due to the findings in the JFK accident investigation as follows:

a) SAS will discontinue the very liberal use of CWS during landing. However, we will still allow the use of CWS in landing, but apply a lowest height restriction of 1,000 ft for transfer to CWS. This will give the pilot ample time for the change over the CWS landing technique.

In marginal weather for landing, the height restriction will force the pilots to use the AUTOLAND as the primary choice for landing and the autopilot coupled ILS approach with manual landing as the secondary choice.

In takeoff the CWS may be used as hereto, with the recommendation not to be used in strong crosswind and on undulated runways.

b) Within SAS the autothrottle system has always been stressed to be a very useful tool in the stabilized approach concept. Correctly operated the ATS will highly contribute to a safe and accurate speed control until touch down.

It has also been stressed during all years that the ASI is the primary aid for speed control.

Many good articles have been written about the AUTOMATIC COMPLACENCY of which we intend to reprint and distribute systemwide, one of Capt. K.E. Ternhem, SAS. [See Appendix G.]

The DC-10 flight procedure will be revised as follows:

2.3 AUTOTHROTTLES

1/P (PF) shall operate the throttles with both ATS engaged. With ATS on or off, the speed on ASI is always primary. Manually backup the ATS as required - initiate power changes - to maintain selected speed. If the ATS operation is unsatisfactory, disconnect the ATS.

Below 1500' 1/P (PF) shall keep his hand on the throttles all the time except for short moments required to handle the FGS [panel.]

c) Until a few years ago the use of external speed bugs was not an adopted SAS philosophy. It is now up to each aircraft type to decide if the use of external speed bugs is desirable. The DC-10 group is using external speed bugs in takeoff and approach and is now introducing another speed bug at V_{TH} for landing.

We think the setting of this speed bug may be of great value as it will generate a discussion of the runway length required, flap setting, runway conditions, etc.

The speed bug will be set under Landing Data on the Descent Check List.

d) SAS has revised the reversing procedure where we are using only reversers No. 1 and No. 3.

The new procedure will call for the use of all three reversers after main gear touch down.

The above listed revisions will be available in our manuals within one to two months.

All DC-10 pilots are briefed about all changes in a circular from the DC-10 Chief Flight Instructor, and the present Recurrent Training gives our Flight Instructors opportunity to discuss details.

All DC-10 pilots are given Additional Simulator Flying according to enclosed program. [See Appendix H.]

In addition to the changes being implemented by the Scandinavian Airline System the following recommendations have been transmitted to the Director General of the Civil Aviation Administration of Norway for consideration:

Several additional corrective measures are needed in SAS's operational procedures in the areas of the "speed high" callout and the System Operators (S/O) maintaining airspeed awareness. The currently prescribed "speed high" callout requires the pilots to call out "speed high" if the desired indicated airspeed is exceeded by more than 10 knots at any point before the final approach, or on final approach if the threshold speed is exceeded by more than 5 knots. While the Safety Board believes that the current "speed high" callout should trigger increased monitoring and assessment by the flightcrew of the indicated versus target airspeed, it also believes that the actual speed values, i.e., deviations from the target airspeed, if called out, would serve as a more positive warning of the need to initiate corrective measures and/or abandon the approach, whichever is applicable.

The Safety Board believes that if the captain of Flight 901 had called out that the airspeed was 40 knots too high above reference speed, or "plus 40," rather than "speed high," during the final stages of the approach, the accident possibly may have been averted.

The Safety Board also is concerned with the Systems Operator's role in assuring adherence to proper approach speed. Although the Systems Operator is charged with monitoring the progress of the approach and with warning the pilots of discrepancies which include excessive deviations from normal approach speed, the Safety Board finds that such responsibility is not clearly reinforced by SAS's mandatory operational procedures. The Systems Operators do not compute, nor are they brought into the "loop" as to what the target V_R and V_{TH} speeds will be. The computation and awareness of these speeds is solely a function of the captain and first officer. In the instant case, the Safety Board found that the Systems Operator had no situational awareness of what the specific approach speeds should be. The Safety Board believes that SAS's overall coordination and cockpit resource management would be greatly enhanced if each flight crewmember were made aware of target approach airspeeds.

As a result of this accident, the Safety Board made the following recommendations to the Federal Aviation Administration:

Apply the findings of behavioral research programs and accident/incident investigations regarding degradation of pilot performance as a result of automation to modify pilot training programs and flight procedures so as to take full advantage of the safety benefits of automation technology. (Class II, Priority Action) (A-84-123)

Direct air carrier principal operations inspectors to review the airspeed callout procedures of assigned air carriers and, where necessary, to require that these procedures specify the actual speed deviations (in appropriate increments, i.e., +10, +20, -10, -20, etc.) from computed reference speeds. (Class II, Priority Action) (A-84-124)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JIM BURNETT
Chairman

/s/ PATRICIA A. GOLDMAN
Vice Chairman

/s/ G. H. PATRICK BURSLEY
Member

November 15, 1984

5. APPENDIXES

APPENDIX A

INVESTIGATION AND HEARING

1. Investigation

The Safety Board was notified of the accident 2129 on February 28, 1984, by the Federal Aviation Administration's Washington Command Center. Air Safety Investigators specializing in Operations, Air Traffic Control, Witnesses, Structures, Systems, Powerplants, Weather, Survival Factors, and Crash/Fire/Rescue were dispatched immediately from the Washington, D.C., headquarters office. Later Cockpit Voice Recorder, Flight Data Recorder, and Aircraft and Human Performance Specialists were assigned to the investigation.

An accredited representative from Norway, the State of Registry, and advisors from Scandinavian Airlines System, as well as the International Federation of Airline Pilots participated in the investigation as provided by the Annex 13 of the ICAO as did representatives of the Federal Aviation Administration, McDonnell Douglas Aircraft Company, General Electric Company, Air Line Pilots Association, and the Port Authority of New York and New Jersey.

2. Public Hearing

There was no public hearing held and no depositions were taken.

APPENDIX B

PERSONNEL INFORMATION

Pilot (1/P)

At the time of the accident, Captain Hans Olof Marner, 54, held Swedish Airline Transport D-License No. 301022-7136 issued on October 22, 1956, which was valid until June 30, 1984. He held ratings for single engine land (maximum 5,700 kg), multiengine land (maximum 5,700 kg), as well as type ratings in DC-6, DC-7, DC-8, DC-9, DC-10 and Convair 340/440 airplanes. He had a valid medical certificate and was required to wear corrective glasses for near/distant vision. He had completed his latest periodic flight training on December 15, 1983, and had his latest en route check on January 6, 1984. At the time of the accident, he had a total of about 18,000 flight-hours, 2,500 of which were in DC-10 airplanes as captain. He was first employed by SAS on October 15, 1951, and transitioned to DC-10 captain in 1978.

Copilot (2/P)

At the time of the accident, First Officer Eddie George Lund, 49, held a Norwegian Airline Transport D-License No. 1064 (copilot) DC-10, issued on March 1, 1979, which was valid until April 4, 1984. He held a valid medical certificate without restrictions or limitations. At the time of the accident, he had accumulated about 11,000 flight-hours, 2,500 of which was in DC-10 airplanes. He was first employed by SAS on August 15, 1966, and was upgraded to DC-10 first officer in January 1979.

Systems Operator (Flight Engineer)

At the time of the accident, Systems Operator Tord Gronvik, 40, held a Swedish Commercial Pilot's B-License No. 440611-8416 with Instrument Rating and Flight Engineer License No. MF 440611-8416 for B-747 and DC-10 (cruise only) issued January 23, 1973, which is valid until November 30, 1984. His license also included instrument ratings, single and multiengine land (5,700 kg maximum.) He held a medical certificate which is valid until November 30, 1984; he completed his latest periodic flight training on October 26, 1983, and his latest en route check on March 2, 1983.

Cabin Crew

There were eight flight attendants aboard Flight 901 when it departed Stockholm. Three Norwegian flight attendants joined the crew at Oslo's Gardemoen Airport. The following is a list of the cabin crewmembers, their nationality, position, and date of most recent recurrent training:

	Position	Date of Recent Trng.
Gerd Ringstrom (Sweden)	1-L	02/06/84
Lars Bjoerling (Sweden)	1-R	10/12/83
Per O. Larsson (Sweden), Purser	2-L	02/17/84
Conny During (Sweden)	2-R	10/11/83
Marie Bohman (Sweden), (extra)	2-L	02/27/84
Christina Bengtsson (Sweden), (extra)	2-R	11/24/83

APPENDIX B

	Position	Date of Recent Trng.
Eigil Aase (Norway), (extra)	7-H	10/25/83
Merete Thorsen (Norway),	3-L	11/10/83
Birgitta Sohlberg (Sweden),	3-R	10/14/83
Eva Henriksen (Norway),	4-L	11/02/83
Tom Strundhind (Sweden),	4-R	09/26/83

APPENDIX C

AIRCRAFT INFORMATION

The airplane was a McDonnell Douglas DC-10-30, Norwegian Registry LN-RKB, Serial No. 46871/219, manufactured in 1976, and owned by DET NORSKE LUFTFARTSSELSKAB A/S (DNL), OSLO, NORWAY.

The airplane was powered by three General Electric CF 6-50C high bypass ratio turbofan engines.

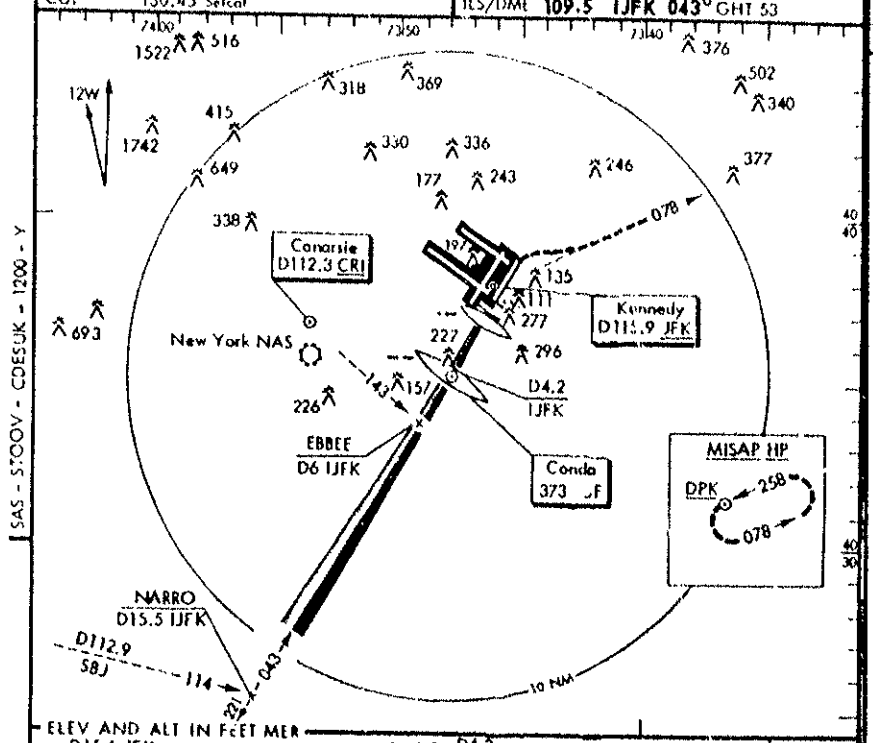
Eng. Posn.	Date of Mfg.	S/N	Total Time (hrs.)	Last Shop Visit (hrs.)
1	2/3/74	455295	29,136:00	3,969:00
2	12/24/76	517202	24,477:00	3,969:00
3	6/76	517403	16,347:00	4,933:00

Kennedy (APP/DEP: New York) JFK - KJFK 1 28 SEP 82

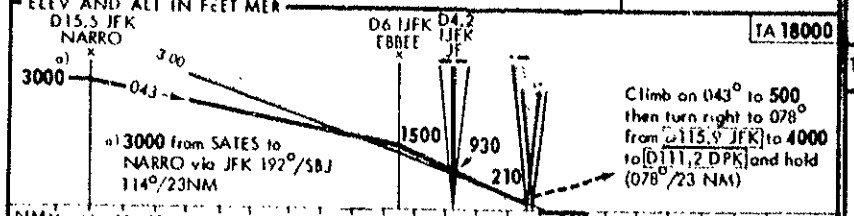
ILS - 04R

ATIS 111.20 ARR NE 115.40 ARR SW 115.10 DEP
APP RAD 127.40 132.40 134.35 120.70
TWR 119.10 123.90
GND 121.90 121.65 135.05 CLR
DEP RAD 121.10 123.70 134.35
CUT 130.45 Select

ILS/DME 109.5 IJFK 043° GHT 53



ELEV AND ALT IN FEET MER



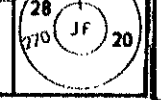
--- - DP	MA	480	100Kt 0:51	120Kt 0:42	140Kt 0:36	160Kt 0:32	180Kt 0:29

747 DC10 DC8	ILS		ILS NO GP	747 DC10 Circling DC8		Qualification requirements see OPS Info 7.1.2	DA/MA Diff: ILS 200 ILS NO GP 468 ILS CAT II 150
Planning Min WX	100/0.8		300/1.8	1000/4.8	800/3.2		
DA MA QNH/ APU U/S	220	3300	480/2.3	1020/4.8	840/3.2		
RVR/Min VIS APU OK	220	2000	480/5000	1020/4.8	840/3.2		
					Plan Alternate ADD	600/2.4	

DH RVR CAT II a)

747 DC10 DC8	115	1300

a) In addition to company Cat II requirements EFAS must be OPS.



THR ELEV 12 FT/AD ELEV 12 FT Change: Editorial

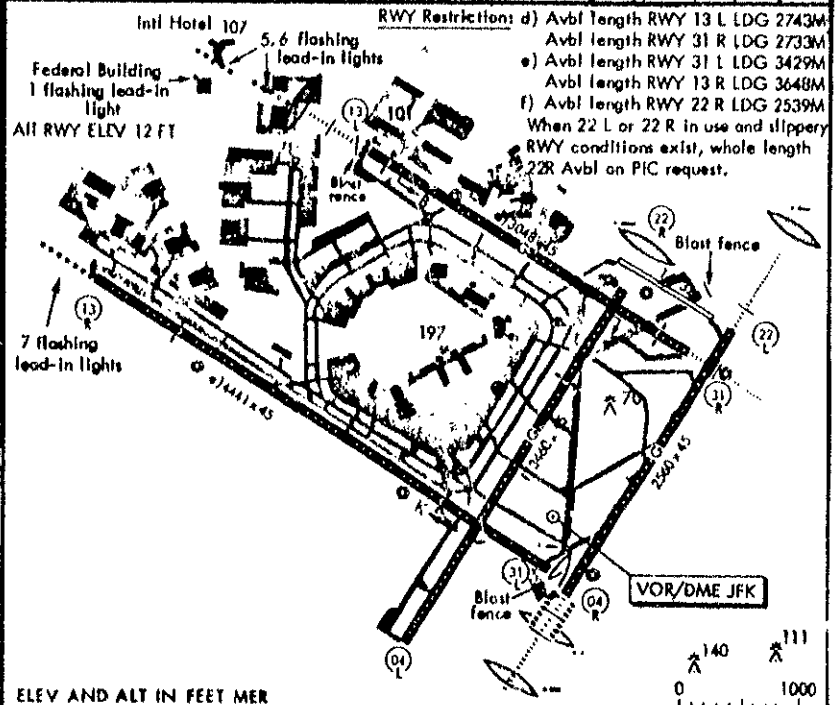
© SWR-OPLR

RWY	APL	THL	RWL	SLOPE
04R	H-B c)	H	H	0
22L	L-E c)	H	H	0
04L	b)	H	H	0
22R	a)	H	H	0

a) VASIS
b) REIL
c) 730M
RWY 31LK: 3600M
RWY 13LB. 2712M
RWY 22RA: 3180M

RWY	APL	THL	RWL	SLOPE
13R	a)	H	H	0
31L	-	H	H	0
13L	H-D c)	H	H	0
31R	L-E c)	H	H	0

RWY Restriction: d) Avbl length RWY 13 L LDG 2743M
Avbl length RWY 31 R LDG 2733M
e) Avbl length RWY 31 L LDG 3429M
Avbl length RWY 13 R LDG 3648M
f) Avbl length RWY 22 R LDG 2539M
When 22 L or 22 R in use and slippery RWY conditions exist, whole length 22R Avbl on PIC request.



ELEV AND ALT IN FEET MER

T/O	CLG Ft/QFE VIS/RVR Km/Ft	04R/22L	13R/31L,31R	04L/22R,13L	For conditions
		0/0.25 RVR 800	0/0.5 RVR 1600	0/0.4 RVR 1300	see USA RAR 16.1

VOR TEST: 115.1 0°FROM

WARNING: - RWY 14/32 may be used as parallel RWY for light ACFT
- VOR JFK UNREL beyond 30NM below 3500 FT

AD: Night flight restriction see ASIR

Ft	Km
6000	1.8
5000	1.6
4000	1.2
3300	1.0
2000	0.6

a Change: Int TKOF lengths

APPENDIX E

Airport JFK International, Jamaica , New York

DATE OF SURVEY March 5,1984 (wet test) , December 28,1983(dry test)

TYPE OF FRICTION EQUIPMENT SAAB TYPE OF FRICTION TIRE RL2

TIRE PRESSURE 30 PSI

RUNWAY 4 Right TYPE OF PAVEMENT Grooved Asphaltic Concrete

Weather Conditions (dry test) Temperature 29 Degrees F, No precipitation

(wet test) Temperature 34-36 Degrees F,Light rain .02 accumulation

RUNWAY FRICTION SURVEY RESULTS

VEHICLE SPEED MPH	20	40	60	40	40
Condition	WET MU	WET MU	WET MU	WET MU	DRY MU
SEGMENT	AVERAGE MU VALUE				
0 to 500	82	92	89	85	85
500 to 1000	95	86	89	90	94
1000 to 1500	73	64	59	63	97
1500 to 2000	78	71	62	65	98
2000 to 2500	89	87	76	73	98
2500 to 3000	89	83	77	81	98
3000 to 3500	89	85	82	80	99
3500 to 4000	96	93	86	83	98
4000 to 4500	98	94	92	96	98
4500 to 5000	94	86	85	85	98
5000 to 5500	88	83	83	78	96
5500 to 6000	84	78	73	73	91
6000 to 6500	93	86	80	75	93
6500 to 7000	89	75	67	75	93
7000 to 7500	81	78	66	77	97
7500 to 8000	88	89	81	85	97
8000 to 8400	94	80	94	91	99

APPENDIX E

Airport JFK International, Jamaica, New York

DATE OF SURVEY February 29,1984

TYPE OF FRICTION EQUIPMENT Mu-Meter

TIRE PRESSURE 10 PSI VEHICLE SPEED 40 MPH

RUNWAY 4R TYPE OF PAVEMENT Grooved Asphaltic Concrete

Weather Conditions Dry, Temperature 31 Degrees F

RUNWAY FRICTION SURVEY RESULTS

Distance from Centerline	20 Ft Right	20 Ft Left
SEGMENT	AVERAGE MU VALUE	
500 to 1000	62	60
1000 to 1500	66	64
1500 to 2000	68	66
2000 to 2500	68	66
2500 to 3000	66	66
3000 to 3500	68	68
3500 to 4000	66	68
4000 to 4500	66	66
4500 to 5000	66	66
5000 to 5500	66	66
5500 to 6000	66	66
6000 to 6500	64	64
6500 to 7000	66	64
7000 to 7500	64	66
7500 to 8000	66	66

APPENDIX F

TRANSCRIPT OF SUNDSTRAND AV-557B CVR (SN 7034) FROM SAS DC-10, JFK INTERNATIONAL AIRPORT, NEW YORK, MARCH 16, 1984

LEGEND

CAM	Cockpit area microphone voice or sound source
RDO	Radio transmission from accident aircraft
-1	Voice identified as Captain
-2	Voice identified as First Officer
-3	Voice identified as Second Officer
-?	Voice unidentified
UNK	Unknown
TWR	JFK Tower
CO	SAS Company
NYA	New York Approach Control
XXX	Other aircraft
*	Unintelligible word
#	Nonpertinent word
%	Break in continuity
( )	Questionable text
(( ))	Editorial insertion
---	Pause

Note: All times are expressed in eastern standard time.

INTRA-COCKPIT
SPOKEN LANGUAGE

TIME &
SOURCE

CONTENT

INTRA-COCKPIT
ENGLISH TRANSLATION

SOURCE

CONTENT

AIR-GROUND COMMUNICATIONS

TIME &
SOURCE

CONTENT

((The engineer (RDO-1) received information "whiskey))

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 central 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 * * preferential use runway, advise you have whiskey

INTRA-COCKPIT SPOKEN LANGUAGE		INTRA-COCKPIT ENGLISH TRANSLATION		AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	CONTENT	SOURCE	CONTENT	TIME & SOURCE	CONTENT
1601:54 CAM-1	# vad det blaser pa lag hojd Vad dom ska spy dar bak nu	CAM-1	It's blowing # at low altitude How they might throw up in the back		
CAM-?	((Skratt))	CAM-?	((Laugh))		
1602:04 CAM-1	Dom brukar in spy som # nar det kyttar sa har	CAM-1	They usually get sick when it's choppy like this		
CAM-3	Nu har det satt ner lite grann - nu har jag information whiskey	CAM-3	Now it has decreased somewhat - now I have whiskey information		
CAM-3	Three hundred - three hundred overcast, one mile, light rain and fog, zero eight zero at four, four miles * *				
CAM-1	Det ar fint som #	CAM-1	That's as good as can be		
CAM-?	((Skratt))	CAM-?	((Laugh))		
CAM-3	* three eight zero *				
CAM-3/3	Strong strong low level wind shear				
CAM-?	Right				
CAM-2	Strong?				
CAM-2	Na na, na vad var det han sa?	CAM-2	No, no, no what did he say now?		
1602:28 CAM-3	Ja, det var nan risk med det	CAM-3	Yes, there was some [illegible] with that		
CAM-3	Potential	CAM-3	Potential		

TIME & SOURCE	INTRA-COCKPIT SPOKEN LANGUAGE CONTENT	SOURCE	INTRA-COCKPIT ENGLISH TRANSLATION CONTENT	TIME & SOURCE	AIR-GROUND COMMUNICATIONS CONTENT
CAM-1	Strong low level wind shear potential in the area	CAM-3	Strong low level wind shear potential in the area		
CAM-2	Yes	CAM-2	Yes		
1602:46 CAM-1	Kan du titta pa windshear lite grann nu da	CAM-1	Can you take a look at the wind shear now?		
CAM-2	Sextio	CAM-2	Sixty		
CAM-3	* vi ska ha femton knop pa toppen	CAM-3	* we need fifteen on the top		
CAM-1	Det ska val ga bra det dar	CAM-1	It's going to go okay		
1602:51 CAM-2	Tva tusen femhundra sextio meter ar runwayen	CAM-2	Two thousand five hundred sixty meter is runway length		
CAM-2	Vi landar med full flaps	CAM-2	We will land with full flaps		
CAM-?	Ja det * * *	CAM-?	Yes it * * *		
CAM-?	* (whiskey) *	CAM-?	* (whiskey)		
1603:11 CAM-1	Var lugn, jag har # ingen whiskey	CAM-1	Relax I don't have any # whiskey		
1603:21 CAM-1	* * da ljuger pigan * *	CAM-1	* * then the maid is lying * *		
CAM-3	Thrust computer	CAM-3	Thrust computer		
CAM	((Sound similar to ratcheting))	CAM	((Sound similar to ratcheting))		

INTRA-COCKPIT SPOKEN LANGUAGE		INTRA-COCKPIT ENGLISH TRANSLATION		AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	CONTENT	SOURCE	CONTENT	TIME & SOURCE	CONTENT
CAM-2	Go around	CAM-2	Go around		
CAM-3	* * landing gear	CAM-3	* * landing gear		
CAM-1	* * * past overhead * * *	CAM-1	* * * past overhead * * * ((a comment in Thai language))		
1604:25 CAM-1	* * da far vi aldrig komma hit mera * *	CAM-1	* * then we might never be allowed in here again * *		
CAM-?	((Skratt))	CAM-?	((Laugh))		
1604:32 CAM-3	Tanker du landa kvart over nu?	CAM-3	Are you planning to land a quarter past?		
CAM-?	* * *	CAM-?	* * *		
CAM-2	ar det framdeles * whiskey	CAM-2	Is it still * whiskey ((blocked by by radio))		
				1605:34 RDO-1	Clipper one descending to ten thousand we're heavy with Whiskey over
CAM-3	Det ar bra, det ar bra	CAM-3	That's good, that's good		
CAM-?	* *	CAM-?	* *		
1606:00 CAM-2	Hur mycket fuel har vi * *	CAM-2	How much fuel have we got * *		
CAM-1	Tjugo ton	CAM-1	Twenty ton		
1606:05 CAM-1	Jag kanner mej rik	CAM-1	I feel rich		

TIME & SOURCE	INTRA-COCKPIT SPOKEN LANGUAGE CONTENT	SOURCE	INTRA-COCKPIT ENGLISH TRANSLATION CONTENT	TIME & SOURCE	AIR-GROUND COMMUNICATIONS CONTENT
1606:14					
CAM-1	Vi skulle bara ha fjorton ton on ground	CAM-1	We were supposed to have only fourteen ton on the ground		
CAM-1	What?	CAM-1	What?		
1606:17					
CAM-3	Vi skulle ha fjorton ton on ground	CAM-1	We were supposed to have fourteen ton on ground		
				RDO-3	SAS dispatch from nine oh one
				CO	Nine oh one go ahead
				RDO-3	We get a slight delay so you will have us on ground around twenty one fifteen to twenty
				CO	Nine oh one roger and you have gate number twenty seven and baggage belt number five
				CO	Nine oh one affirmative see you on the ground
1606:57					
CAM-3	Jaha	CAM-1	Oh yes		
				RDO-3	Twenty seven belt five thank you
CAM-1	Det skall vi klara, tror jeg * *	CAM-1	That we'll manage, I believe * *		

TIME & SOURCE	INTRA-COCKPIT SPOKEN LANGUAGE CONTENT	INTRA-COCKPIT ENGLISH TRANSLATION SOURCE	CONTENT	AIR-GROUND COMMUNICATIONS TIME & SOURCE	CONTENT
				1607:44 NYA	Scandinavian nine oh one heavy descend and maintain three thousand, contact New York approach on one three two point four
				1607:50 RDO-1	Scandinavian nine oh one cleared three thousand over to one three two point four good day
1608:00 CAM-1	Three thousand armed	CAM-1	Three thousand armed		
CAM-2	Three thousand armed * *	CAM-2	Three thousand armed * *		
				1608:05 RDO-1	New York approach Scandinavian nine oh one heavy whiskey information just left seven thousand for three thousand
CAM-1	* * *	CAM-1	* * *		
				1608:33 RDO-1	Kennedy nine oh one six thousand descend three thousand whiskey information
				1608:36 NYA	Scandinavian nine zero one heavy New York turn right heading two five zero vectors ILS four right approach
				1608:42 RDO-1	Right heading two five zero nine oh one heavy

TIME & SOURCE	INTRA-COCKPIT SPOKEN LANGUAGE CONTENT	INTRA-COCKPIT ENGLISH TRANSLATION CONTENT	AIR-GROUND COMMUNICATIONS CONTENT
1608:49			
CAM-2	Two five zero	Two five zero	
L404			Lufthansa four zero heavy runway four right RVR three thousand five hundred contact to tower frequency one nineteen one
CAM-3	RVR three thousand five hundred	RVR three thousand five hundred	
1609:08			
CAM-1	Det har borjar pa att likna nat	Now this is beginning to look like something	
CAM-1	Three thousand five hundred	Three hundred five hundred	
1609:17			
CAM-3	* * nej * *	* * no * *	
1609:19			
NYA			Scandinavian nine zero one heavy descend to and maintain two thousand
1609:22			
RDO-1			Scandinavian nine zero one down to two thousand
1609:25			
CAM-1	Oh, en kilometer va?	Oh, one kilometer eh?	
CAM-2	En kilometer * * for sikt va?	One kilometer * for visibility?	
CAM-1	Ja, tva tusen fot ja	Yes, two thousand foot	
1609:46			
NYA			Scandinavian nine zero one heavy turn right heading two seven zero
1609:51			
CAM-1	Sex hundra meter, det ar dubla minimum	Six hundred meter, that's double the minimum	

INTRA-COCKPIT SPOKEN LANGUAGE		INTRA-COCKPIT ENGLISH TRANSLATION		AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	CONTENT	SOURCE	CONTENT	TIME & SOURCE	CONTENT
				1609:54 NYA	Scandinavian nine zero one heavy turn right two seven zero reduce to one eight zero knots
				1609:59 RDO-1	Scandinavian nine oh one heavy right turn heading two seven zero down to one eighty
1610:13 CAM-2	Det var one eighty?	CAM-2	That was one eighty?		
CAM-2	* * one eighty set	CAM-2	* * one eighty set		
1610:44 CAM	((Gear warning horn sounds))				
CAM-3	Ohhh	CAM-3	Ohhh		
CAM-1	Gear warning	CAM-1	Gear warning		
1610:47 CAM-2	Excuse me	CAM-2	Excuse me		
1610:52 CAM-1	Ja, det ar en # varning det dar	CAM-1	Yes, that's a # of a warning		
CAM-3	Ja den ar liksom distraherande	CAM-3	Yes, it's distracting		
1610:56 CAM-1	Alla, alla slacker den utan att tanka * *	CAM-1	Everyone, everyone cancels it without thinking * *		

INTRA-COCKPIT SPOKEN LANGUAGE		INTRA-COCKPIT ENGLISH TRANSLATION		AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	CONTENT	SOURCE	CONTENT	TIME & SOURCE	CONTENT
				1610:59 NYA	Scandinavian nine zero one heavy turn right heading two nine zero
1611:06 CAM-3	Dar uppe kommer en flygmaskin	CAM-3	Oh there you see an airplane	1611:02 RDO-1	Right heading two nine zero nine oh one heavy
CAM-?	* * *	CAM-?	* * *		
1611:16 CAM	((Sound of altitude alert))	CAM	((Sound of altitude alert))		
CAM-1	Prelevel	CAM-1	Prelevel		
1611:47 CAM-3	Ja, det kan val komma in nat skitvader sen	CAM-3	Yes, some # (bad) weather could come in later		
CAM-?	Jaha, det kan det sakert	CAM-?	Oh, yes it could		
1611:53 CAM	((Sound of radio altimeter warning))	CAM	((Sound of radio altimeter warning))		
1612:07 CAM-2	Radio height	CAM-2	Radio height		
CAM-1	One, correction, two niner one four	CAM-1	One, correction, two niner one four		
CAM-2	Passe bra	CAM-2	Suits fine		
				1612:14 NYA	Scandinavian nine zero one heavy turn right heading three one zero

TIME & SOURCE	INTRA-COCKPIT SPOKEN LANGUAGE CONTENT	SOURCE	INTRA-COCKPIT ENGLISH TRANSLATION CONTENT	TIME & SOURCE	AIR-GROUND COMMUNICATIONS CONTENT
				1612.17 RDO-1	Scandinavian nine oh one heavy turn right three one zero
				1612:34 NYA	Scandinavian nine zero one heavy turn right heading three six zero
				1612:37 RDO-1	Scandinavian nine oh one right three six zero
				1613:31 NYA	Scandinavian nine zero one heavy turn right heading zero two zero thirteen from the outer marker maintain one thousand five hundred until established on the localizer, cleared ILS four right approach
				1613:42 RDO-1	Scandinavian nine oh one heavy right heading zero two zero cleared ILS four right down to fifteen hundred to the outer marker
CAM-?	* flaps *	CAM-?	* flaps *		
CAM-?	Det kommer att ta en vaenstersving foer han tar * *	CAM-?	It will be a left turn before capture * *		
CAM-1	Vi gar ner till femtohundra och sa vidare	CAM-1	We will let down to fifteen hundred and so forth		
1616:12 CAM-1	Fifteen hundred	CAM-1	Fifteen hundred		

TIME & SOURCE	INTRA-COCKPIT SPOKEN LANGUAGE CONTENT	INTRA-COCKPIT ENGLISH TRANSLATION SOURCE	CONTENT	TIME & SOURCE	AIR-GROUND COMMUNICATIONS CONTENT
1614:16					
CAM	((Sound of altitude alert))	CAM	((Sound of altitude alert))		
CAM-?	* *	CAM-?	* *		
1614:40					
CAM-3	Ja, har vi passerat den dar Ebbe eller vad den nu heter?	CAM-3	Have we passed Ebbe or whatever its name is?		
				1614:53	
				NYA	Scandinavian nine zero one heavy runway four right RVR one thousand eight hundred
CAM-3	Oj daa	CAM-3	Oh!		
				1614:59	
				RDO-1	Nine oh one roger
CAM-2	Det ar below minimum nu	CAM-2	It's below minimum now		
CAM-1	* saettes one one five	CAM-1	* setting one one five		
				1615:00	
				NYA	Delta two twenty four runway four right RVR one thousand one thousand eight hundred
				1615:05	
				D244	Delta two twenty four
1615:09					
CAM-3	Da all vi ha Cat tva, va?	CAM-3	Now we shall have Cat two eh?		
CAM-?	Ja	CAM-?	Yes		
				1615:10	
				PAI512	And clipper fifteen twelve ja with you heavy out of sixty three for four

INTRA-COCKPIT SPOKEN LANGUAGE		INTRA-COCKPIT ENGLISH TRANSLATION		AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	CONTENT	SOURCE	CONTENT	TIME & SOURCE	CONTENT
				1615:16 NYA	Clipper fifteen twelve heavy New York heading two six zero vector ILS four right approach
				1615:21 PA1512	Two six zero for four left approach
				1615:24 NYA	Al Italia six six one zero heavy turn right three six zero
				1615:28 AI6610	Right three six zero Al Italia six six ten heavy
				1615:32 NYA	Scandinavian nine zero one heavy contact Kennedy tower one one niner point one
				1615:35 RDO-1	Roger, good day
				1615:41 TWR	Delta eight hundred four right RVR one thousand six hundred, midpoint two thousand four hundred rollout three thousand five hundred
				1615:48 DRDO	* * thanks

INTRA-COCKPIT SPOKEN LANGUAGE		INTRA-COCKPIT ENGLISH TRANSLATION		AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	CONTENT	SOURCE	CONTENT	TIME & SOURCE	CONTENT
				1615:50 RDO-1	Kennedy tower Scandinavian nine oh one heavy on the ILS for four right
				1615:54 TWR	Scandinavian nine oh one heavy Kennedy tower runway four right wind one one zero at four RVR two thousand two hundred mid point two thousand eight hundred rollout three thousand five hundred
CAM-3	Tack for det	CAM-3	Thanks for that	1616:03 RDO-1	Roger
1616:12 CAM-?	((Laugh))	CAM-?	((Laugh))		
CAM-1	# * * *	CAM-1	# * * *		
CAM-3	* sextonhundra *	CAM-3	* sixteen hundred *		
CAM-2	Exakt nar du satt dar och skulle ta over	CAM-2	Just as you were ready to take over		
				1616:16 TWR	Eastern eight ten turn left the next intersection, hold short of four left, remain this frequency
CAM-1	Dom vet nog vaara minima ska du se!	CAM-1	They want know our minimal		
CAM-1	Det varierar tydligen lite grann	CAM-1	It seems to vary a little bit		

INTRA-COCKPIT
SPOKEN LANGUAGE

TIME & SOURCE	CONTENT
CAM-2	Flaps twenty two
CAM-?	Flaps * *
CAM-2	Gear down

INTRA COCKPIT
ENGLISH TRANSLATION

SOURCE	CONTENT
CAM-2	Flaps twenty two
CAM-?	Flaps * *
CAM-2	Gear down

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
1616:20 E810	Eastern eight ten will do
1616:27 TWR	Eastern sixty four runway four left at kilo bravo, taxi into position and hold
1616:32 E64	That's position and hold at kilo bravo Eastern sixty four
1616:37 D224	Kennedy tower Delta two two four checking in with you on the ILS for four right
1616:42 TWR	And eight hundred, four right RVR two thousand mid point two six hundred rollout three five hundred wind one zero zero at four cleared to land
1616:50 800	Cleared to Land eight hundred thanks

INTRA-COCKPIT SPOKEN LANGUAGE		INTRA-COCKPIT ENGLISH TRANSLATION		AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	CONTENT	SOURCE	CONTENT	TIME & SOURCE	CONTENT
				1616:52 D224	Delta two twenty four runway four right wind one zero zero at four RVR two thousand mid point two thousand six hundred rollout three thousand five hundred, caution wake turbulence following the heavy jet five miles ahead
				1617:03 D224	Delta two two four roger
				1617:08 800	Eight hundred's on the miss for a * *
1617:09 CAM-3	Jaha	CAM-3	Oh yes		
				1617:12 TWR	(Cam) eight hundred roger fly runway heading, climb and maintain one thousand five hundred
CAM	((Sound of gear warning))	CAM	((Sound of gear warning))		
1617:16 CAM-2	Flaps thirty five	CAM-2	Flaps thirty five		
				1617:17 800	Runway heading up to one point five right
1617:18 CAM-2	Final flaps setting	CAM-2	Final flaps setting		
CAM-1	* titta pa vinden *	CAM-1	* look at the wind *		

TIME & SOURCE	INTRA-COCKPIT SPOKEN LANGUAGE CONTENT	INTRA-COCKPIT ENGLISH TRANSLATION CONTENT
CAM-3	Ska vi layga pa fem ton eller?	CAM-3 Should we add fifteen or?
1617:24 CAM-2	* elve *	CAM-2 * eleven *
1617:28 CAM-1	Sink rate one thousand	CAM-1 Sink rate one thousand
CAM-3	Gear	CAM-3 Gear
CAM-1	Down and checked	CAM-1 Down and checked
1617:35 CAM-2	Gear is down	CAM-2 Gear is down
CAM-3	It's down	CAM-3 It's down

TIME & SOURCE	AIR-GROUND COMMUNICATIONS CONTENT
1617:20 TWR	(Cam) eight hundred climb and maintain two thousand now
1617:23 800	Okay up to two thousand
1617:28 EI6610	El Italia six six one zero * * zero four right
1617:30 TWR	(And) eight hundred turn right heading one zero zero
1617:35 EI6610	El Italia six six one zero * * zero four right
1617:38 TWR	Scandinavian nine oh one heavy cleared to land zero four right RVR two thousand midpoint two thousand four hundred, roll out three thousand five hundred

INTRA-COCKPIT SPOKEN LANGUAGE		INTRA-COCKPIT ENGLISH TRANSLATION		AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	CONTENT	SOURCE	CONTENT	TIME & SOURCE	CONTENT
				1617:44 RDO-1	Roger, cleared to land
				1617:45 TWR	(Cam) eight hundred did you copy a right turn to one two zero now?
				1617:48 800	Right to one twenty okay
CAM-3	* completed	CAM-3	* completed		
1617:53 CAM-1/2	Plus hundred	CAM-1/2	Plus hundred		
1617:55 CAM-1	Approach lights straight ahead	CAM-1	Approach lights straight ahead		
1617:58 CAM-?	Contact	CAM-?	Contact	1617:58 EI6610	EI Italia six six one zero * * four right
1617:59 CAM	((Start of radio height warning))	CAM	((Start of radio height warning))		
1618:00 CAM	((End of radio height warning))	CAM	((End of radio height warning))		
1618:01 CAM-1	* high	CAM-1	* high		
1618:04 CAM-?	Off	CAM-?	Off		
1618:04 CAM	One hundred	CAM-3	One hundred		

INTRA-COCKPIT SPOKEN LANGUAGE		INTRA-COCKPIT ENGLISH TRANSLATION		AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	CONTENT	SOURCE	CONTENT	TIME & SOURCE	CONTENT
1618:05 CAM-3	Fifty	CAM-3	Fifty		
1618:05 CAM-1	Han drog inte av	CAM-1	It didn't take power off		
1618:06 CAM-3	Fourty	CAM-3	Fourty		
1618:07 CAM-3	Thirty	CAM-3	Thirty	1618:07 TWR	Sixty four's in position
1618:09 CAM-3	Twenty	CAM-3	Twenty		
1618:11 CAM-3	Twenty	CAM-3	Twenty		
1618:12 CAM-3	Twenty	CAM-3	Twenty	1618:12 TWR	Sixty four hold in position
1618:14 CAM-3	Twenty	CAM-3	Twenty	1618:14 UNK	Is there a tailwind on that approach?
1618:15 CAM-3	Ten	CAM-3	Ten		
CAM-1	Gaa ner da-	CAM-1	Take it down		

INTRA-COCKPIT SPOKEN LANGUAGE		INTRA-COCKPIT ENGLISH TRANSLATION		AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	CONTENT	SOURCE	CONTENT	TIME & SOURCE	CONTENT
1618:16 CAM-3	Ten	CAM-3	Ten		
1618:16 CAM-1	Fa ner den for #	CAM-1	Get it down, #		
CAM-?	Spoilers	CAM-?	Spoilers		
				1618:17 TWR	El Italia sixty six ten heavy runway four right, wind one one zero at three RVR one thousand eight hundred midpoint two thousand four hundred rollout three thousand five hundred
1618:20 CAM	((Sound of spoiler motor))	CAM	((Sound of spoiler motor))		
CAM-1	Ta alla tre	CAM-1	Take all three		
1618:23 CAM-?	Spoilers	CAM-?	Spoilers		
1618:24 CAM-1	Bromsa * *	CAM-1	Brake * *		
				1618:25 E16610	El Italia six six ten
1618:27 CAM-?	Bromsa som #	CAM-?	Brake like #		
CAM-1	Hold it steady	CAM-1	Hold it steady		

INTRA-COCKPIT SPOKEN LANGUAGE		INTRA-COCKPIT ENGLISH TRANSLATION		AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	CONTENT	SOURCE	CONTENT	TIME & SOURCE	CONTENT
CAM-2	Steady	CAM-2	Steady		
1618:31 CAM-1	# #	CAM-1	# #		
				1618:32 NYA	Scandinavian nine oh one heavy turn left at the end left at Yankee hold short of ah runway thirty one right
1618:37 CAM-1	On ground emergency	CAM-1	On ground emergency		
				1618:38 NYA	Scandinavian nine oh one Kennedy ah you okay?
1618:41	((End of tape))		((End of tape))		

APPENDIX G

THE AUTOMATIC COMPLACENCY
BY
CAPT. K.E. TERNHEM S.A.S

1. THE PROBLEM

In our role as pilots in an environment that provides technology to do the work for us automatically but not always intelligently, and without qualified interface between the individual systems, we have a problem. We are faced with a man-machine interface problem we might call "automatic complacency".

To combat the problem, it must always be borne in mind that the machine, be it even the most complex computer, is but a tool, designed to aid the man in performing certain specific tasks. The machine cannot think for us, it cannot work outside its rigidly defined performance envelope - it cannot even be complacent. Consequently, there is every reason for the man not to let these tools work on their own and without knowing their weak spots and the limits of their capabilities.

Let us look at some examples. The Autothrottle and the Autopilot normally perform their specific assignments very well but neither system knows much of what the other is doing or plans to do and neither system knows much about operational limitations (with some exceptions e.g., on DC-10). Still we seem to lean ourselves on the automatic systems - the automatic flight control systems in this particular respect - to such a degree that we may become lax in our attention to the primary flight instruments or even revise our priorities.

Using a good Autothrottle tends to degrade speed consciousness, use of Altitude Preselect tends to degrade our height consciousness, etc. We also tend to accept an inferior or even wrong performance of a system in a kind of paralyzation and as a consequence thereof, delay our actions. We also tend to correct the systems indirectly when a direct and more positive action would be more relevant.

Some examples from real life:

- In an automatic approach, a bend on the Glide Path at 500 ft caused a very marked pitch down, resulting in excessive sink rate. The pilot, though fully aware of the situation, did not react until the situation was so critical that a very low pull up had to be made.

- In nav. mode en route, the aircraft turned the wrong way over a checkpoint. Although the wrong behaviour was immediately noticed, the aircraft turned more than 45° before the pilot took action.

- En route during INS operation, the crew did not notice that the nav. mode selector had been switched to HDG. The aircraft proceeded on a straight course for five minutes instead of turning over the waypoint.

- In an approach, the Autothrottle became inactive. The speed dropped 15 kt below correct speed before the malfunction was noticed.

- The Altitude Preselect malfunctioned during descent. This went unnoticed by the pilots and an excessive undershoot was made.

- At level off by use of the Altitude Preselect, the throttles in idle, the speed dropped close to stall before detected and rectified by power application.

These examples, of which kind there are many, are not unnatural in a logical sense. They are fully explainable human-engineering wise but they should nevertheless not occur unless there is a breakdown of the normal routine.

What is disturbing is that we tend to defend ourselves by blaming the system (which is only a contributing factor) and considering it legitimate to trust the technique and change our otherwise sacred instrument scanning routine.

Another way to describe the problem is that we tend to fall out of the "loop". We have a problem of complacency and we as individuals may not be aware of it.

The problem is not the pilot but more so our understanding of the mechanism that creates the problem and also the lack of intelligent means to train the pilot into the concept of integration with a competing machine. We are, of course, also aware of the fact that our aircraft installations, though at the top of the state-of-the art, may not always be optimized in their function to serve the man.

2. THE CURE

As stated above, we do not know all the factors that create the problem and consequently, we are not prepared to give a recipe that totally eliminates the problem.

We can, however, all agree on some sound and concrete rules that, if followed, will keep us virtually out of the problem.

But first there is a need to clarify what the machine, the black box in our case, is really supposed to do for the man. We apparently make a big mistake if we believe that the machine has entered our environment for the sake of our convenience only.

These are the realities:

1. The machine does not relieve the man of his responsibilities.

2. The machine does not reduce the workload of man as regards his expected achievement.

B U T

3. The machine increases the total capacity.

4. The added capacity serves
   - to improve safety
   - to balance the workload
   - to improve accuracy
   - to improve regularity
   - to reduce costs.

In this world of realities, the pilot's managing role in the man-machine teamwork can be condensed into this sequence of actions:

Plan - Program - Confirm - Monitor - Correct - Reject if necessary.

And with these facts in mind, you may agree that when you leave it to the automatic systems:

* don't change your piloting priorities.
* be aware of the system limitations.
* be highly suspicious.
* make clear beforehand what the system is supposed to do.
* check what it's doing.
* don't hesitate to reject the aid of an inferior system.
* don't accept a system performance that you yourself under the circumstances could do safer or better.
* don't make the use of an automatic system en end in itself.

or to express these rules in a short sentence:

BE SYNCHRONIZED WITH YOUR AUTOMATIC SYSTEMS

or still shorter: BE IN THE "LOOP".

In this article we focused our interest on problems. This should not be interpreted as a case against the use of the automatics. We are all aware of the positive reasons for the extensive use of available automatic systems but that's the other and brighter side of the coin which was not the purpose for discussion this time.

APPENDIX H

SAS DC-10 ADDITIONAL SIMULATOR FLYING

DC-10 ASF ADDITIONAL SIMULATOR FLYING

FC/FP/FS	Pers. No. -	Date / 198	PI

Mandatory manoeuvres at Trainingfield	F/I sign.
1. Normal TKOF RWY 27. GW 176 tons	
2. NDB APCH RWY 27 via EEV and landing. Manual flying	
3. TKOF RWY 09 with engine flame out at V1+. GW 175 tons Engine relight after clean up	
4. CAT II APCH RWY 09 (FP/FS: LOW MIN TRA) and overshoot to NNV. No ATS.	
5. Auto APCH RWY 27 and preplanned low circuit on AP and manual landing on RWY 09. Wind 060/20 kt.	

Pilot selected manoeuvres

This Additional Simulator Flying form is intended only for record keeping purposes. As the ASF programme is meant as a pure training exercise, no grading shall be made and no comments shall be filed. However, verbal debriefing for the trainee's benefit shall be performed as usual.

The intention of the ASF is to give the pilots an opportunity in a relaxed atmosphere to train manoeuvres not normally performed in the aircraft and also practice self-selected exercises which he himself feels to be of value for his professional skill.

FS sign.	As I/P h m	As 2/P h m	As S/O h m	PI sign.