FINAL REPORT

AAIU Formal Report No: 2008-023
AAIU File No: 2007-0002
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Operator:	Aer Lingus
Manufacturer:	Airbus
Model:	A330-301
Nationality:	Ireland
Registration:	EI-DUB
Location:	Approach to Runway (RWY) 22R, Chicago O'Hare Airport (KORD), USA
Date/Time (UTC):	16 September 2006 @ 21.45 hrs UTC

NOTIFICATION

The Air Accident Investigation Unit (AAIU) was informed of this event on 9 January 2007, almost four months after the incident. By that time, most records concerning the flight had been discarded, other than the Operator's Flight Data Monitoring (FDM) data. Although the aircraft was not in any immediate danger during the occurrence, the AAIU had concerns due to the reported late ATC clearance for a non-precision approach, the incident itself and the amount of time this incident was within the Operator's system without action or the AAIU being notified.

The Chief Inspector of Air Accidents, in accordance with the provisions of SI 205 of 1997, on 09 January 2007, appointed Mr. Paddy Judge as the Investigator-in-Charge to carry out an Investigation into this Incident and prepare a Formal Report.

SYNOPSIS

Three runways were in use for landing at Chicago O'Hare. The Commander, who was the Pilot Flying (PF), briefed the Pilot-Not-Flying (PNF) for an Instrument Landing System (ILS) approach to each landing runway. ATC vectored the aircraft towards an ILS approach to RWY 22R but an unexpected and unusual clearance for a non-precision approach was received shortly before commencing the approach. During the subsequent approach, in fine weather with good visibility, the PF miscalculated the rate of descent required and descended too rapidly. On realising that they were too low, power was increased and subsequently go-around power was selected for a short period. The aircraft climbed to the proper profile and a normal landing ensued. The maximum altitude deviation below the correct flight path was 774 ft. There was no injury or damage.

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FINAL REPORT

1. FACTUAL INFORMATION

1.1 History of the Flight

The flight operated from Dublin Airport (EIDW) to Chicago O'Hare (KORD) with the Commander as PF and was conducted under Instrument Flight Rules (IFR). The flight departed EIDW at 14.00 hrs UTC and was normal up to the commencement of the approach to KORD. The aircraft was given radar vectors towards an expected ILS approach to RWY 22R, for which the crew had previously briefed. The pilot stated that the flight was then cleared by ATC for an ILS 22R approach *"Glide Slope* (G/S) *unusable*" shortly before position FNUCH (**Appendix A, Chart 1**). This required reprogramming the Flight Management Guidance Computer (FMGC) and beginning a non-precision approach for which the crew had not briefed. The approach was flown with the aircraft configured for landing, gear down and flaps fully extended. The PF stated that he had initially set the correct 3º glide path angle but subsequently increased it, as he believed they were high. Shortly after position RIDGE (4.5 nm from the threshold of RWY 22R), the PF realised that he was low. Power was applied, and after initial uncertainty, the flight rapidly regained the correct profile and a normal landing ensued at 21.56 hrs.

1.1.1 PF Interview

The PF stated he had briefed the PNF during the descent for a full ILS approach to each of the three active runways, 22L, 22R and 27L, as identified on the ATIS (Automatic Terminal Information Service). Subsequent to this, the flight was given radar vectors towards an approach to RWY 22R.

About 3 to 4 nm before FNUCH, they were cleared for an "*ILS 22R approach - Glide Slope unusable*". This was the first indication the crew had that there was a problem with the ILS. Although they were uncertain about this clearance, they decided the ATC controller meant a "*localiser only*" (LOC) approach, as a G/S inoperative warning was showing on their instruments, and proceeded on that basis. He commented that late runway changes happen quite often at KORD.

This different approach clearance required reprogramming the FMGC through its keyboard on the Multi-Control Display Unit (MCDU) and beginning an approach for which they had not briefed. The PF requested the PNF to arm LOC and to set the Minimum Descent Altitude (MDA) to 1,030 ft, or MDA + 50 ft[1] in accordance with the Operator's Standard Operating Procedures (SOPs). The Progress page was selected on the MCDU and an entry made to display the distance to go in nautical miles to the threshold of the runway as calculated by the FMGC.

The approach, according to the PF's recollection, was flown with autothrottle (AT) and autopilot (AP) engaged, LOC mode engaged and with FPA (Flight Path Angle) mode[2] selected. The approach was commenced with the aircraft configured gear down, full flaps extended and was fully stabilised on the correct glide path at NOLEN, 13 miles out. The PF initially set a normal 3º descent angle but increased this subsequently in his belief that they were high. After position RIDGE, at about 200 ft above the MDA, the PF realised that he was low. His recollection was that he saw the runway and the "*landscape looked flat*".

[1] An extra 50 ft is added to the MDA due to the inertia of the aircraft in descent.
[2] This guidance mode allows the pilot to select a vertical flight path angle, as the FMGC compensates for varying groundspeed.

At this point he applied power, he believed Maximum Continuous Thrust (MCT), levelled off and started a slight climb while assessing the situation. At this point also, some doubt came into the situation with the PF believing he had called "*Go-Around*" but saying that, as the PNF did not recall it, he could not be certain. He stated that if he had not called go-around he had intended to do so.

The PF stated he then selected TOGA or go-around thrust and rotated the aircraft towards a go-around pitch attitude. He thought he had also called for go-around flaps but could not be sure. This would be normal in a go-around, but flaps were not repositioned. At this point the aircraft was climbing and the PNF told the PF that he knew what was wrong and to just level off. As they were coming into the normal visual landing slot and the aircraft was still configured for landing, the PF made a decision to land. The aircraft regained the correct profile and a normal landing ensued.

Following shutdown, there was a brief discussion of the incident where it emerged that the PF had not taken the altitude of the airport into account when mentally calculating the rate of descent required for landing. He believed this was due to insufficient time to brief for the approach and an impression that he was high. That evening the PF recorded brief notes about the flight, as was his normal procedure. The PF and PNF did not meet during the stopover, which was not unusual. On the subsequent flight back, the following night, the PF believed that they had a short discussion of the incident, which he stated the PNF did not remember. Neither pilot was sure if the occurrence was a reportable incident as such. However, both felt it should be reported due to the nature of the late change in approach procedure.

The PF had never previously encountered the ATC phraseology of "*ILS 22R approach - Glide Slope unusable*" and admitted that doubt about the clearance may have affected his performance.

The PF stated that he had not practised non-precision approaches (NPA) with intermediate platform heights as the method trained by the Operator is to use a steady rate of descent from the final approach fix (in this case NOLEN) to arrive at the MDA at or slightly before the missed approach point. The PF appeared to the Investigation to view the 2,200 ft platform restriction somewhat more desirable than mandatory.

In further communications, the PF confirmed that he had been initially trained in QFE[3] procedures.

1.1.2 PNF Interview

The PNF recollection was that the weather was fine during the approach with good ground contact but without being visual with the runway. He remembered a change of approach procedure and the unusual ATC clearance for an "*ILS 22R approach - Glide Slope unusable*" which he had not heard before. At the request of the PF, he reconfigured the FMGC for a localiser only approach, crosschecked it and checked the go-around procedure, following which he briefed the PF.

The approach seemed fine and a short distance before RIDGE he believed he selected the Progress Page on the MCDU possibly on the request of the PF. When changed to the tower frequency for landing he normally selects the Ground Control frequency on standby to prepare for a frequency change immediately after landing.

[3] An altimeter barometric setting that displays height above the runway.

This would have required him to review the KORD Airport layout – Jeppesen Chart 20-9 (**Appendix A, Chart 2**) and so he believed he was out of the loop and not monitoring the flight path for some time. He was not anticipating any problem. He remembered looking up and thinking this does not look right. The PF said, "*Something is wrong here"*. He saw the runway and the preceding aircraft ahead and knew the picture did not look right. He checked the RADALT (Radio Altimeter) versus the distance to go on the Progress Page and knew what was wrong. He believed he said to the PF "*…I know what's wrong I'll talk to you on the ground - if you level off"*. He stated that by then, "*we were about 4 miles from the threshold and 400-500 ft low, but not dangerously so, the aircraft was fully configured and we were well above the minimum descent altitude* (MDA)". The PF applied power. He did not expect him to select TOGA as he assumed the PF would use about 75% power to regain the landing slot. Having climbed slightly the aircraft continued the approach and landed normally. He did not remember the PF calling go-around or for go-around flaps and did not select flaps to the go-around position.

There was a short discussion of the incident after landing. At the termination of the flight, the PNF stated he was under the impression that the PF was going to submit a Captain's Special Report (CSR) and assumed he did.

Later he had checked the time required to physically change the approach on the MCDU. He could not do this in less than 10 seconds. In addition, 12 seconds was required for checking ATC ground frequency and selecting it on the radios.

He believed there was a good professional relationship between himself and the PF and was upset that he had not monitored the situation adequately as he had not expected anything abnormal to happen.

1.1.3 Head of the Air Safety Office (ASO) Interview

The Head of Air Safety (HAS), when interviewed four months after the occurrence, recalled that three to four weeks after the event the PF visited him. The PF discussed submitting either a confidential report or a CSR through normal executive channels.

Two to three weeks afterwards a written report was submitted by the PF. This confidential report inaccurately stated that the aircraft arrived at 100 ft above minima at 3 nm before the runway. This confidential report, de-identified and undated, was immediately typed up and sent by the HAS to Flight Operations Management (Flt Ops). The HAS kept no records and had no further contact, at that time, with the PF in accordance with the confidential system guidance as given in the Air Safety Manual.

However, the HAS was subsequently involved in investigating the occurrence and interviewing the crew who, he stated, cooperated fully.

The HAS felt he was somewhat limited in his ability to assess the occurrence, when it was initially reported, as his background was technical without any flying experience.

None of the staff members in the ASO had flying experience and only the HAS had investigation training. He therefore, on the verbal information supplied to him by the PF, the lack of any data from the flight and his own lack of operational expertise, was in a limited position to assess whether this was a reportable occurrence or not and to advise what reporting channel should consequently be used.

1.2 Injuries To Persons

No injuries were reported to the investigation

Injuries	Crew	Passengers	Total in aircraft	Others
Fatal:	0	0	0	0
Serious:	0	0	0	0
Minor:	0	0	0	Not applicable
None:	12	307	319	Not applicable
TOTAL:	12	307	319	0

1.3 Damage To Aircraft

None.

1.4 Other Damage

None.

1.5 Personnel Information

1.5.1 (Commander)

Personal Details:	Male, aged 48 years
Licence:	ATPL
Last Periodic Check	13 Sept 2006
Medical Certificate	01 Sept 2006

Flying Experience:

Total all types:	11,938	hours
Total all types PI	8,648	hours
Total on type:	2,986	hours
Total on type PI	2,900	hours
Last 90 days:	126	hours
Last 28 days:	75	hours
Last 24 hours:	0	hours

Duty Time:

Duty Time up to incident:	9 hours
Rest period prior to duty:	40 hours 10 mins

1.5.2 (First Officer)

Personal Details:	Male, aged 42 years
Licence	ATPL
Last Periodic Check:	27 April 2006
Medical Certificate:	25 August 2006

Flying Experience:

Total all types:	6,861	hours
Total all types PI:	0	hours
Total on type:	1,618	hours
Total on type PI:	0	hours

Last 90 days:	144	hours
Last 28 days:	43	hours
Last 24 hours:	0	hours

Duty Time:

Duty Time up to incident:	9 hours
Rest period prior to duty:	96 hours

Both pilots' licences were valid with current medicals, instrument ratings and competency certificates issued by the Irish Aviation Authority (IAA).

1.6 Aircraft Information

There were no significant defects in the Technical Log. Neither powerplant nor the maintenance condition of the aircraft, which was properly certified, was a factor in this incident.

1.7 Meteorological Information

Meteorological Actual Reports (METARs) for KORD for the day were obtained. These indicated that, at the time of the event, it was a clear day with some cloud at high levels. The METAR recorded at 21.51 hrs UTC, shortly after the occurrence, shows a wind velocity of 160º/13 kts, 10 miles visibility[4], few clouds at 12,000 ft, broken cloud at 25,000 ft, temperature 25°C, and dew point 14°C with a sea level pressure of 29.92 inches[5]. The weather reports for one hour before and after the event are similar, indicating a fine autumnal day with good visibility and a slight crosswind from the left for approach and landing. Conditions were similar to those photographs later recorded on approach to KORD ILS 22R (**Appendix B**).

1.8 Aids to Navigation

The ILS on KORD RWY 22R transmits on 111.3 MHz with an inbound bearing of 220º. Chicago ATC's records indicate that the RWY 22R glide slope was out of service from 21.20 hrs to 21.57 hrs. The occurrence happened during this period.

1.9 Communications

1.9.1 Air Traffic Control Clearance Phraseology

The flight crew both stated that they felt uncertainty about the ATC approach clearance phraseology of an "*ILS 22R approach - Glide Slope unusable*", which they did not clarify. They stated that they believed the approach clearance should have been for a "*localiser only approach*" for which they would have been cleared in their native JAR[6] environment from whence the aircraft departed.

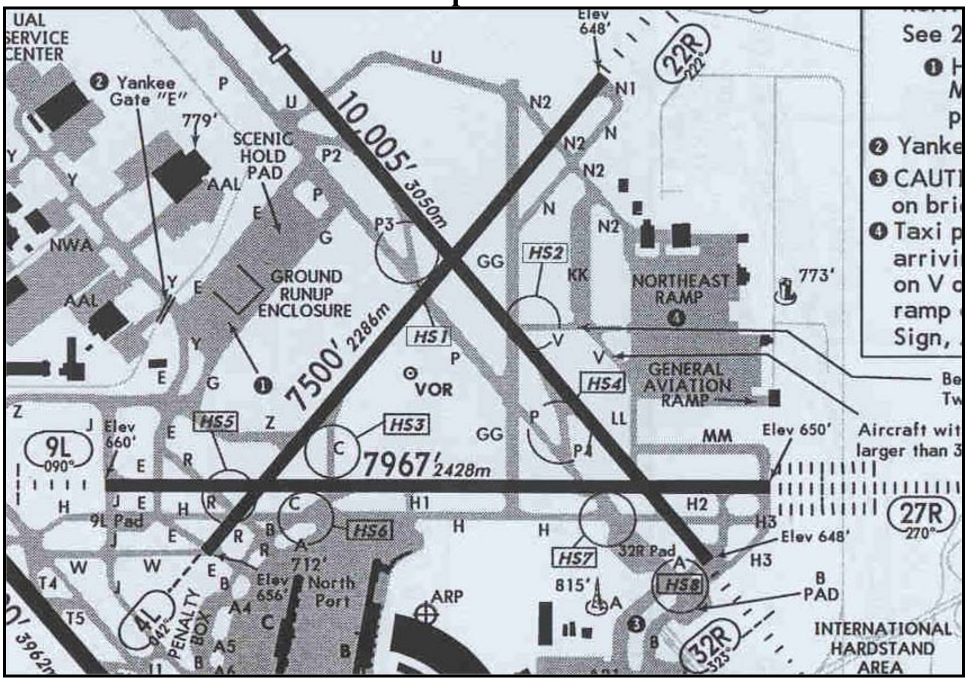
The Investigation is aware that the clearance for an "ILS approach - Glide Slope unusable" is given in other regions of the world in circumstances where the ATC glide slope monitoring status indicator is unserviceable but the ILS is transmitting.

[4] Visibility in excess of 10 miles is not recorded.
[5] A sea level pressure or QNH of 29.92 inches converts to 1013.2 hectopascals or standard atmospheric pressure.
[6] Joint Aviation Requirements are used by 42 European countries.

1.10 Aerodrome Information

Chicago O'Hare airport is one of the busiest airports in the world with normally three runways in use for landing and a similar number in use for take-off i.e. six in total. This results in a busy air traffic environment. During the approach, the crew consulted the KORD Airport layout plate – Jeppesen Chart 20-9, which is shown in **Appendix A, Chart 2**. Generally, a flight from the direction the aircraft was coming may expect an approach on to RWY 22R or RWY 27R, both relatively short runways for an A330, or more infrequently to RWY 27L a much longer runway. The approach was made to RWY 22R, a 7,500 ft runway with an intersecting runway, RWY 09L/27R towards the end.

Graphic 1



Part of KORD Jeppesen Chart 10-9

Following a landing on 22R, an aircraft may exit the runway via taxiway C - the shortest distance to the International Hardstand Area at lower right where it will park. However, exiting by taxiway C is not always achievable, especially by heavier aircraft, and later exits to the left may have to be used. It was therefore important for the crew to prepare carefully for after-landing instructions.

It is noted that KORD is the only airport in the Operator's long haul network whose altitude is significantly above sea level, the threshold of the runway being at 651 ft AMSL[7].

1.11 Flight Recorders

1.11.1 Cockpit Voice Recorder

Data unavailable.

1.11.2 Flight Data Recorder

Data unavailable.

[7] Above Mean Sea Level.

1.11.3 Flight Data Monitoring (FDM)

The following data in **Table 1** is derived from both the Operator's FDM system for the incident flight and the published approach plate, Jeppesen Chart 21.8 of 10 MAR 06 (**Appendix 1, Chart 1**), as used by the flight crew. **Graphic 2** overleaf depicts **Table 1** in graph format.

Table 1

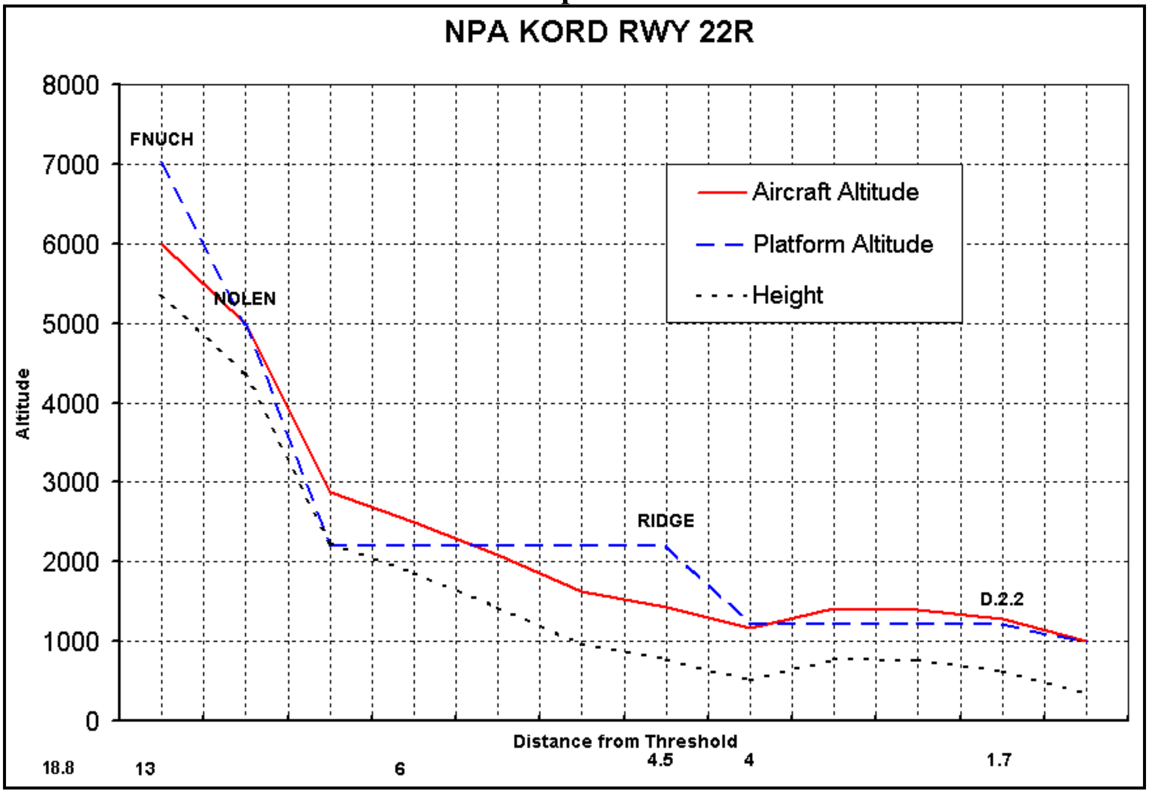
Waypoint	*ORD DME*	*Dist to RWY*	*Aircraft Altitude*	*Platform Altitude*	*Deviation from Platform*	*Aircraft Height*	*Ideal Height*	*Deviation from ideal*
FNUCH	19.5	**18.8**	**6,000**	7,000	-1,000	5,349	6,086	-737
NOLEN	13.7	**13**	**5,000**	5,000	0	4,349	4,208	+141
	8.7	**8**	**2,880**	2,200	680	2,229	2,590	-361
	7.7	**7**	**2,500**	2,200	300	1,849	2,266	-417
	6.7	**6**	**2,080**	2,200	-120	1,429	1,942	-513
	5.7	**5**	**1,620**	2,200	-580	969	1,619	-650
RIDGE	5.2	**4.5**	**1,426**	2,200	-774	775	1,457	-682
	4.7	**4**	**1,160**	1,220	-60	509	1,295	-786
	3.7	**3**	**1,420**	1,220	200	769	971	-202
	2.7	**2**	**1,400**	1,220	180	749	647	+102
D.2.2	2.4	**1.7**	**1,280**	1,220	60	629	550	+79
	1.7	**1**	**1,000**	980	20	349	324	+25
RWY	0.7	0					0	

Approach Data – RWY 22R KORD

NOTES on Table 1:

1) Data taken from the FDM is identified by bold type, approach platform restrictions by yellow and deviation by red.
2) *Height* refers to the distance the aircraft is above the ground (specifically the runway Touchdown Zone) whereas *altitude*, which the pilot flew, refers to the distance of the aircraft above sea level.
3) The *ORD DME* was not recorded by the FDM, fix information was. ORD DME distances are derived from a 0.7 nm correction added to the recorded Distance to Runway. This is calculated from the D2.2 fix on the chart (2.2 – (0.4+1.1) = 0.7 nm).
4) *Dist to RWY* and *Aircraft Altitude* were obtained from the aircraft's FDM recordings.
5) *Platform Altitude* is taken from the published approach and is explained in Section 1.16.1.
6) *Deviation from Platform* is the result of *Aircraft Altitude* less *Platform Altitude.*
7) *Aircraft Height* is height above the touchdown zone (651 ft AMSL) of the runway at that time, calculated at *Aircraft Altitude* less 651 ft.
8) *Ideal heights* have been calculated from the published groundspeed on the chart of 140 knots at a rate of descent of 753 ft/min. This equates to a rate of descent of 322.7 ft per NM. The descent rates published on the chart vary from 319 ft to 323 ft per NM for groundspeeds from 100 kts to 160 kts.
9) *Deviation from ideal* results from *Aircraft Height* less *Ideal Height*.

Graphic 2



NOTE: Scale distance in the above graphic is non-linear.

The data showed the flight crossing waypoint FNUCH at 6,000 ft or 1,000 ft lower than the published approach height. This is a common ATC procedure. Passing NOLEN the aircraft was correctly positioned on the vertical profile. At 6 nm from the runway, it had descended 120 ft below platform. It continued the descent and reached its maximum deviation (774 ft) at RIDGE, 4.5 nm from the runway threshold.

At 4 nm, the flight was at the lowest point during the incident, 1,160 ft or 509 ft above the ground. However, platform deviation had reduced to 60 ft - as the platform height reduced from 2,200 ft to 1,220 ft at RIDGE. From this point, the aircraft climbed and subsequently tracked the correct profile.

The FDM data showed that the approach was conducted with both autopilot (AP) and autothrust (AT) engaged, gear down and full flaps extended. At 4 nm, the PF initially applied Maximum Continuous Thrust (MCT) for 5 seconds followed by Take-Off/Go-Around (TOGA) thrust. The PF disconnected the autopilot and increased the nose-up pitch attitude from +1° to +7.5°. TOGA was engaged for 4 seconds after which power was reduced. The aircraft configuration of gear down and full flap deployed was not changed.

1.12 Wreckage and Impact Information

Not Applicable.

1.13 Medical Information

Not Applicable.

1.14 **Fire**

Not Applicable.

1.15 **Survival Aspects**

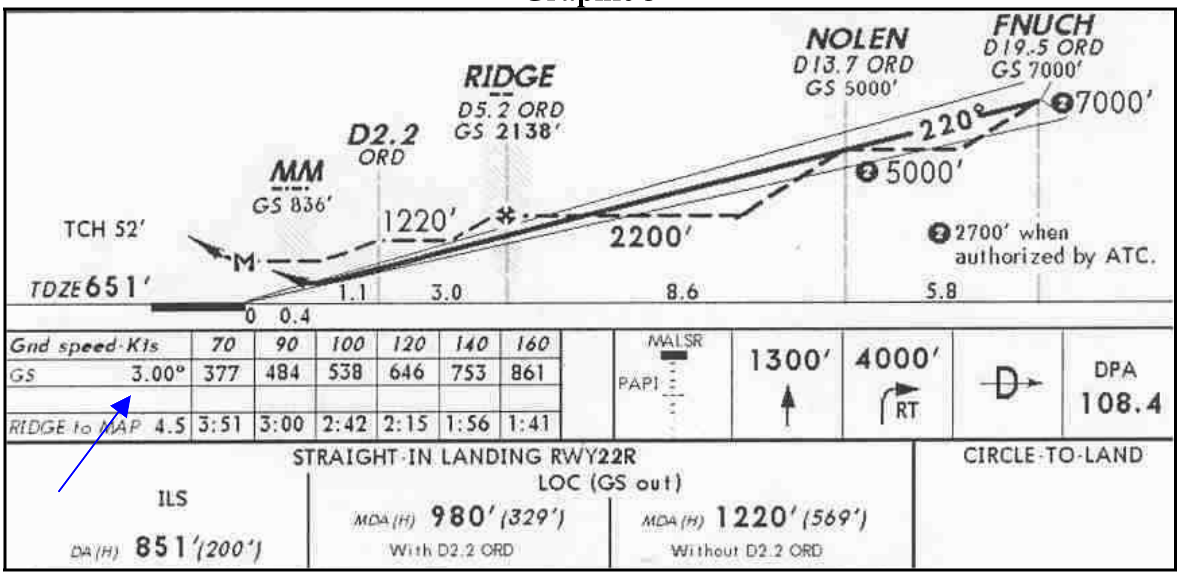
Not Applicable.

1.16 **Tests and Research**

1.16.1 **KORD/ORD ILS 22R Glide Path**

This Graphic depicts the glide slope/glidepath[8] of the published ILS RWY 22R at KORD and is an extract from Jeppesen Chart 21.8 of 10 MAR 06, **Appendix A, Chart 1.**

Graphic 3



Glide Path ILS 22R KORD –

NOTE:

- The glide slope (GS) is shown as a 3.00º angle (see blue arrow).
- NPA platform altitudes, the minimum altitudes during that sector of the approach, are shown as a dashed line.
- The NPA platform altitude shows above the glide slope at RIDGE and D2.2
- The terminology used on the chart for an approach with a glide slope inoperative is "LOC (GS out)"

Due to the unusual depiction of platform heights above the glidepath at RIDGE and D2.2, the Investigation examined this further. Calculations of the descent angles from each platform height fix point to touchdown are detailed in **Table 2** below.

[8] In this document, the term glide slope refers specifically to the vertical element of the ILS beam whereas glidepath refers to the descent profile determined for vertical guidance during any final approach.

Table 2

	Platform Altitude	*Platform Height*	*Stage Distance*	*Total Dist*	*Total Dist ft*	*Slope*	*Descent angle*
FNUCH	7000	6349	5.80	18.90	114,912	0.055	3.16
NOLEN	5000	4349	8.60	13.26	80,648	0.054	3.09
RIDGE	2200	1549	3.00	4.66	28,360	0.055	3.13
D2.2	1220	569	1.50	1.66	10,120	0.056	3.22
Touchdown	651	0	0.16	0.16	1,000	0.000	0.00

KORD RWY 22R Glidepath angles

NOTE: A touchdown distance of 0.16 nm (1,000 ft) has been added, as landing aircraft should touchdown 1,000 ft down the runway.

Calculations show that the glidepath and glide slope angle at FNUCH is close to 3.2º and at NOLEN 3.1º. The glidepath at the Final Approach Fix RIDGE is 3.1º and at D2.2, 3.2º. This reflects the Jeppesen approach chart depiction of platform heights above the published 3º glide slope.

In view of the differences between the published glide slope and the angles calculated the Investigation requested a copy of the USA FAA approach chart in force on the date of the event. The heights, distances and glide slope angle on the FAA 22R AIP chart (**Appendix A, Chart 3**) were identical to those on the Jeppesen chart. As a result, latitude and longitude coordinates for each platform point and the runway threshold were requested through the National Transportation Safety Board (NTSB) of the USA. From these, inter-fix distances were calculated using the Haversine[9] formula. The calculations confirmed the accuracy of the distances published on the AIP chart. Minor differences in distance (a maximum of 266 ft at NOLEN) due to rounding up were noted, but the accuracy of the inter-stage distances published on the charts was confirmed. These minor differences did not affect the calculations in the *Slope* or *G/P angle* columns above.

Approach designs in the United States are published under Terminal Design Procedures (TERPS). In TERPS, the larger air transport Group 4 aircraft is assumed to be over the runway threshold at 55 ft when landing. The approach 3º glide slope was consequently assumed to pass through that point and the resulting altitudes at the Fixes were calculated as per **Appendix C**. This also showed a similar picture to the above regarding the glidepath.

1.17 Organizational and Management Information

1.17.1 General

Standard Operating Procedures (SOPs) are guidelines or directives designed to protect the aircraft, its crew and passengers by giving a standard set of actions to deal with situations. Within the context of this Investigation, of initial interest are the Operator and Manufacturer published SOPs for operation of the aircraft, which the crew should have followed during the approach. Of further interest is the incident classification system published by the Operator and the method used to report and record the incident. Of relevance also are the FDM system that revealed the occurrence, the procedures associated with FDM and the function of and procedures within the Air Safety Office.

[9] The Haversine formula is an equation used in spherical trigonometry that gives great-circle distances between two points on the surface of a sphere by using their longitudes and latitudes.

1.17.1.1 Operations Manual Part A – SOPs for Approach and Go-around

The Operator has published general crew guidance and SOPs for approach in its Operations Manual (Part A Date: 01/01/04, Issue 2).

8.1.2 GENERAL GUIDANCE

> *One of the main reasons for collision with terrain would appear to be complacency, or lack of a sense of immediate danger, in the cockpit. It is suggested that the best remedy lies in the realm of cockpit procedures, particularly during initial approach. It is imperative, during descent and approach, that Commander and co-pilot independently monitor the navigation of the aircraft and thus eliminate gross navigational errors.*
>
> *Navigation, of course, is three-dimensional and height should be monitored as well as geographical position. It is important, therefore, that the PM* (Pilot Monitoring i.e. PNF) *particularly does not allow supplementary activities to distract him from monitoring of the aircraft's position or of its altitude.*

8.4.8.1 STANDARD APPROACH PROCEDURES - GENERAL

> *It is company policy that every approach is stabilised early enough for pilots to be able to detect wind shear or other unacceptable deviations from the correct flight profile.*
>
> *1,000 ft Gate: On all approaches at 1,000 ft above terrain, as measured by the radio altimeter, the aircraft should be stabilized in the planned landing or final approach configuration, and the glide slope or correct vertical profile established. If these criteria are not met, then serious consideration should be given to initiating an immediate go-around or missed approach.*

8.7 APPROACH ANGLE NON PRECISION APPROACH

> *In all cases of final approach where no glidepath reference is available (e.g. no ILS, VASI, etc.), the flying pilot shall aim for a 3° glidepath.*

The Operators Operations Manual Part B1-33 specifies the Operating Procedures for a Selected Non-Precision Approach on the Airbus A330.

DESCENT PROFILE

> *Pilots should arrange descent profile to fly continuous descent approaches where possible, subject to remaining at or above minimum descent altitudes.*

The SOPs for approach include:

> *PM calls out recommended/hard altitudes for each nautical mile of the approach (Where these are not promulgated on the approach plate, insert the runway threshold in the MCDU PROG page and calculate estimated altitudes for each NM).*

GO-AROUND

Part of the SOPs for go-around states *"Once the decision has been taken to Go-around during final approach no decision to abandon this shall be taken."*

Once the go-around has been initiated, the aircraft FCOM (Flight Crew Operating Manual Volume) 3.2.3 SOP initial actions for go-around are:

Apply the following three actions simultaneously:

THRUST LEVERS	*TOGA*
ANNOUNCE	*"GO AROUND – FLAPS"*
ROTATION	*PERFORM*

1.17.1.2 Data Gathering Systems Agreement (DGSA)

Over 20 years ago, the operator and its pilots implemented an Operational Monitoring System whose principles were incorporated in an agreement, the DGSA. It states that the system aims to enhance flight safety by monitoring data on an active basis to detect *undesirable practice and negative trends* and correct them *before they can ever be manifested as accidents or incidents.* The agreement also guarantees the internal confidentiality of the system's workings and data.

ICAO Annex 6 Part I Paragraph 3.2.3 requires the operators of aeroplanes of a certificated take-off mass in excess of 27,000 kg to establish and maintain a Flight Data Monitoring Program as part of its Accident Prevention and Flight Safety Program, effective from 1 January 2005. Paragraph 3.6.4 states that the flight data analysis programme shall be non-punitive and shall contain adequate safeguards to protect the source(s) of the data. ICAO Safety Management Manual (SMM) Doc 9859 AN/460 in paragraph 16.3.5 states, regarding a Flight Data Analysis (FDA) programme, that; *the details are normally contained in a formal agreement between management and flight crew*. As a consequence of this the parties then reviewed the DGSA to ensure it was ICAO Annex 6 compliant and the system was thereafter referred to as the FDM program.

Although the system is designed as non-punitive and should not be used to monitor or check a pilot's judgement, it can be used in defined circumstances, such as to remedy individual bad practice or training issues, or in association with an incident investigation, hence the sensitivities associated with FDM use. Usually though, it is more concerned with general trends in the operation or, as in this case, particular types of approaches at specific airports.

It is noted that paragraph A8 of the DGSA states that the FDM data will be provided on request to the Investigator-In-Charge (IIC) in the event of an accident/incident category A & B as defined in the Aer Lingus Safety Manual. However, under S.I. 205 of 1997 paragraph 9, the AAIU may take possession of whatever data it deems relevant to investigating an occurrence and the voluntary provisions of the DGSA no longer apply.

1.17.1.3 Air Safety Office (ASO)

Guidance on Safety Management Systems is provided in the ICAO Safety Management Manual (SMM) Doc 9859 AN/460. Chapter 12 outlines operator guidance for a Safety Office, part of which includes the requirement for selection of staff with adequate skill sets and relevant experience and to provide subsequent safety training. The Air Safety Office has three staff, all from a technical or administrative background.

The Operator's Air Safety Systems and procedures are published internally in its Air Safety Manual (ASM), Revision 1 March 2004:

> *The primary objective of the Air Safety organisation is the discovery and elimination, or avoidance of risk.* The *Air Safety Office provides an independent safety oversight of operations*.

A secondary function is to investigate any accident or incident involving one of its aircraft.

The ASO is an advisory, not an executive, function. As such, it did not, at the time of the incident, report through the management structure but independently to the Accountable Manager[10], in this case the Chief Executive.

The ASO operates two incident reporting systems, one a non-punitive system and the other a confidential system. The ASM gives examples of incidents that may be reported through the non-punitive incident reporting system. However, no examples or guidance is given regarding incidents that may be reported by means of a confidential report.

Paragraph 2.1.1 of the Air Safety Manual (ASM) states:

It is the responsibility of the Head of Air Safety to (inter-alia):

9. Operate a Confidential Reporting System. The Head of Air Safety has absolute discretion in the handling of all information provided under this confidential system, detailed in Part 2, Para 2.5 of this manual.

Part 2, paragraph 2.5, outlines the confidential reporting system procedures. Here the HAS is authorised to accept a confidential report from any staff member, who may report in person, by phone or anonymously. If the reporter supplies a name it must be deleted after 48 hours, after which time the HAS does not contact the reporter. The HAS has absolute discretion in handling the information supplied and the ASM states he may decide that *"anonymised details of confidential reports may be published in the interests of enhancing Air Safety*".

It is noted that neither the management chart in 1.3 nor management functions chart in 2.1.5 reflected the management structure at the time.

1.17.1.4 Operator Incident Classification

Part 3 of the Air Safety Manual covers Incident categories or classification and reporting procedures. Paragraph 3.2.1 defines Safety events under the following categories:

Category A: Major Accident
Category B: Serious Incident
Category C: Incident

The ASM continues by defining these categories and gives procedures to be used when an accident or incident is reported. Of relevance in this occurrence is Category C, or *occurrences that significantly reduce the Air Safety margins of the operation*. Among the many examples listed, the following are relevant to this incident:

5. *Unstabilised Approach,*
9. *Altitude Deviation in excess of 300 feet,* and ……
42. *Any event, which may provide useful information for the enhancement of Air Safety*

[10] The nominated manager who had corporate responsibility for ensuring that all operations and maintenance activities can be financed and carried out to the required standard under JARs.

1.17.1.5 Operations Manual – Incident Reporting

The Operator, in Part A, 11.2 of its Operations Manual, publishes crew procedures for accidents and incidents.

In 11.2.1, an incident is defined as:

For Flight Operations' purposes an incident is defined as any occurrence, other than an accident, associated with the operation of an aircraft which: (Seven examples are then given of incidents of which the most relevant is)

> *(b) Under slightly varied circumstances, may have jeopardised the safety of the passengers, crew or aircraft, or may have resulted in an aircraft accident and/or incident.*

Section 11.2.2 of the manual continues by outlining the procedures for informing base. It further states that if a Commander is in any doubt an incident signal should be raised.

Section 11.2.3 lists the subsequent executive action to be taken.

Section 11.3 introduces Mandatory Incident Reports and gives many examples of a list of incidents that must be reported, which include:

> *11.3.2.13 When a Height Control error of more than 300 feet occurs*.

and

> *11.3.2.33 When Any Event, which may provide useful information for the enhancement of air safety, occurs.*

It also states that the list is not exhaustive.

The ASM states that the line manager must report incidents directly to Operations Control. The Duty Operations Controller will promulgate an Incident Signal, such Incident Signals being copied to the relevant Irish Authorities, namely the IAA and the AAIU. The HAS also has the authority to raise an Incident Signal. It also states that Incident Signals concerning events in Category A and B must be discussed, before transmission, with the Chief Executive.

1.18 <u>Additional Information</u>

1.18.1 International Civil Aviation Organisation (ICAO)

ICAO publishes internationally agreed procedures for civil aviation. These agreed procedures are translated into local law by individual States. ICAO was founded as a result of the Chicago Convention of 1944. The Convention recognises that every State has exclusive sovereignty over the airspace above its country. The ICAO procedures are published in the form of Annexes to the Convention on International Civil Aviation of which there are 18. Standards and Recommended Practices (SARPS) are published in each Annex; a Standard is compulsory, a Recommended Practice is desirable.

Relevant to the ATC dimension of this incident are:

> Annex 2 (Rules of the Air).
> Annex 10 (Aeronautical Communications), Volume II covers Procedures.
> Annex 11 (Air Traffic Services) of which ATC is a subset.

The SARPS in Annexes 2 and 6 cover rules and operation of the flight while those in Annexes 10 and 11 and the PANS ATM (Procedures for Air Navigation Services – Air Traffic Management) govern the application of the Procedures.

1.18.1.1 ICAO Annex 2 (Rules of the Air)

Section 3.6 in Note 2 states*: If an air traffic control clearance is not satisfactory to a pilot-in-command of an aircraft, the pilot-in-command may request and, if practicable, will be issued an amended clearance.*

1.18.1.2 ICAO Annex 10, Vol. II (Aeronautical Communication Procedures)

Annex 10, Aeronautical communications, contains five volumes of which Volume II covers Communication Procedures including those with PANS status.

PANS or *Procedures for Air Navigation Services are approved by ICAO for worldwide application. They contain, for the most part, operating procedures regarded as not yet having attained a sufficient degree of maturity for adoption as International Standards and Recommended Practices, as well as material of a more permanent character which is considered too detailed for incorporation in an Annex, or is susceptible to frequent amendment, for which the processes of the Convention would be too cumbersome.*

Part 5.1 General states inter alia:

5.1.1.1 ICAO standardized phraseology shall be used in all situations for which it has been specified. Only when standardized phraseology cannot serve an intended transmission, plain language shall be used.

> ***Note** - Detailed language proficiency requirements appear in the Appendix to Annex 1.*

5.1.1.3 Recommendation. — In all communications, the consequences of human performance which could affect the accurate reception and comprehension of messages should be taken into consideration.

> ***Note** - Guidance material on human performance can be found in the Human Factors Training Manual (Doc 9683).*

5.2.1.9.1 Communications shall be concise and unambiguous, using standard phraseology whenever available.

In addition:

- Section 5.2 covers Radiotelephony procedures and,
- Subsection 5.2.1.5.8 gives standard words and phrases that shall be used in radiotelephony communications.

Standard phraseologies for these procedures are further outlined in ICAO Air Traffic Management Doc 4444, ATM/501 where Section 12.3 deals with ATC phraseologies and Section 12.3.3 covers Approach control services. The phraseology published here is for general type approaches but that phraseology is amplified in the Manual of Radiotelephony Doc 9432 AN/925, Third Edition 2006 where it states" *ICAO phraseologies are developed to give efficient, clear, concise and unambiguous communications*". However, it further states, "*it is not possible to provide phraseologies to cover every conceivable situation which may arise and the examples contained in the manual are not exhaustive, but merely representative of radio telephony phraseology in common use*".

Instrument approach phraseology is covered in Chapter 7.3 Approach Control – IFR Arrivals, and clearance examples are given for ILS (7.3.1) and NDB (7.3.2) approaches. Although phraseology examples of various types of radar approaches are given, there are no examples of approaches for either a localiser or a VOR approach.

1.18.1.3 ICAO Annex 11 (Air Traffic Services)

This Annex pertains *"to the establishment of airspace, units and services necessary to promote a safe, orderly and expeditious flow of air traffic. A clear distinction is made between air traffic control service, flight information service and alerting service. Its purpose, together with Annex 2 is to ensure that flying on international air routes is carried out under uniform conditions designed to improve the safety and efficiency of air operation"*.

1.18.1.4 Filed Differences

Where differences exist between the national legislation of contracting states and an ICAO Annex the state is required to notify ICAO of those differences.

The Supplement to Annex 10 shows that both Ireland and United States have notified ICAO that no differences exist in regard to this Annex.

The Supplement to Annex 11 shows that Ireland has notified ICAO that no differences exist whereas no information has been received from the United States.

1.18.2 Localiser Approach ATC Clearance

The Investigation therefore contacted the Federal Aviation Administration (FAA) of the United States and both local and international Authorities of Europe to clarify ATC clearance phraseology for a localiser approach.

1.18.2.1 USA - Federal Aviation Administration (FAA)

The FAA clarified the clearance as follows. The relevant FAA/ATC procedures for an NPA with a glide slope unusable are given in two manuals; guidance for pilots is provided in the Aeronautical Information Manual (AIM), and for ATC controllers in the Air Traffic Control Handbook.

1.18.2.1.1 Aeronautical Information Manual – FAA publication

The Aeronautical Information Manual (AIM) advises:

AIM 1-1-9. Instrument Landing System (ILS):(j) Inoperative ILS Components (2) Inoperative glide slope. When the glide slope fails, the ILS reverts to a non -precision localizer approach.

In communication with the Investigation, the FAA stated that this paragraph does not constitute any basis for the phraseology that is used by the controller in such cases, it simply makes the pilot aware of the limitations on the navigation signal in this configuration.

1.18.2.1.2 Air Traffic Control handbook, 7110.65 – FAA publication

The FAA has indicated that the Air Traffic Control handbook, FAA Document 7110.65 establishes the criteria and phraseology to be used by the controller.

Section 8, Approach Clearance Procedures, states inter alia:

4-8-1. APPROACH

a. Clear aircraft for "standard" or "special" instrument approach procedures only. To require an aircraft to execute a particular instrument approach procedure, specify in the approach clearance the name of the approach as published on the approach chart. Where more than one procedure is published on a single chart and a specific procedure is to be flown, amend the approach clearance to specify execution of the specific approach to be flown. If only one instrument approach of a particular type is published, the approach needs not be identified by the runway reference. An aircraft conducting an ILS/MLS approach when the glide slope/glidepath is reported out of service shall be advised at the time an approach clearance is issued. Standard Instrument Approach Procedures shall commence at an Initial Approach Fix or an Intermediate Approach Fix if there is not an Initial Approach Fix.

PHRASEOLOGY-
(To authorize a pilot to execute an ILS/MLS approach when the glide slope/glidepath is out of service),

CLEARED (type) APPROACH, GLIDE SLOPE/GLIDEPATH UNUSABLE.

EXAMPLE-
………….
"Cleared I-L-S Runway Three Six Approach, glide slope unusable."

NOTE:

The name of the approach, as published, is used to identify the approach, even though a component of the approach aid, other than the localizer on an ILS or the azimuth on an MLS is inoperative.

1.18.2.2 ATC Localiser Approach Clearance - Ireland

The Investigation has not been able to identify any documentation defining the ATC phraseology that should be used for a localiser non-precision instrument approach. Following queries to the Irish Aviation Authority (IAA) the Investigation has been informed that the standard ATC clearance for such an approach is "*Cleared localiser only approach, RWY XX*".

1.18.2.3 ATC Localiser Approach Clearance - UK

The United Kingdom ATC Radiotelephony Manual is titled CAP 413, Edition 16. Examples of radar, VDF, NDB and VOR approaches are given in this manual. Localiser Only approaches are not covered. The UK CAA has informed the Investigation that the normal ATC clearance in UK airspace for an approach with an inoperative glide slope is "*Cleared for Localiser Approach Runway XX*".

1.18.2.4 ATC Localiser Approach Clearance - JAR

The Joint Aviation Authority (JAA) Administrative & Guidance Material Section One: General Part 3: Temporary Guidance Leaflets in Section 1, Part 3, 6-38 states;

7.1 The following items should also be included in flight crew training programmes:

(a) knowledge and understanding of standard ATC phraseology used in each area of operations.

JAR-OPS, Section 4/Part 2 Procedures (App. 2-6 01.0606.988) defines what is meant by area of operation and the factors that limit its extent:

1. Areas of Operation

1.1 The Authority, when considering the issue of an AOC, should stipulate a geographical limit within which the operation is to be confined. In some circumstances it will be appropriate to permit commercial operations 'world-wide' or 'with no geographical limit'.

1.2 The following factors should be taken into account when deciding the Area of Operation within which Commercial Air Transportation will be permitted…

d) The need for the Flight Crew to comply with non-standard ATC requirements such as:
- the use of non-standard phraseology;
- the use of altitude clearances in metres;
- the use of altimeter settings

JAR FCL 1 and 2 also cover ATC phraseology but this is in association with initial pilot training in standard communication procedures and phraseology. The Investigation has been unable to discover any other relevant ATC phraseology references in JAA publications.

1.18.3 Minimum Heights - General

As the aircraft was flying in the United States at the time of the event, the Rules of the Air appropriate to that region were in force. FAR Part 91 (Applicable to all aircraft) Section 91.119 states, inter alia:

Except when necessary for take-off or landing, no person may operate an aircraft below the following altitudes:

(b) Over congested areas. Over any congested area of a city, town, or settlement, or over any open air assembly of persons, an altitude of 1,000 ft above the highest obstacle within a horizontal radius of 2,000 ft of the aircraft.
(c) Over other than congested areas. An altitude of 500 ft above the surface, except over open water or sparsely populated areas. In those cases, the aircraft may not be operated closer than 500 ft to any person, vessel, vehicle, or structure.

However, as the aircraft nears the runway it needs to descend and the minimum heights for this phase of flight are published using approach design criteria.

1.18.3.1 Minimum Heights - Approach

Approach design guidance criteria are published in ICAO PANS-OPS DOC 8168 and TERPS procedures in the United States, which are similar to PANS-OPS. In the approach design, a platform height is the minimum obstacle clearance height for a specific sector of an approach. Platform heights are published to ensure the aircraft is at a safe height above the ground at all times during instrument approaches. The obstacle clearance heights are derived from a complex three-dimensional surface projection based on the PANS-OPS criteria above.

1.18.4 Mandatory Occurrence Reporting

As a result of Directive 2003/42/EC of the European Commission, the Irish Aviation Authority issued Aeronautical Notice (AN) No. G10 Issue 1 of 31/08/2005.
This covers mandatory reporting of relevant occurrences and contains a comprehensive list of aircraft operations, maintenance, repair and manufacturer-related occurrences that must be reported.

It is noted that since this incident Statutory Instruments S.I. No. 285 of 2007, European Communities (Occurrence Reporting in Civil Aviation) Regulation 2007 has been enacted into Irish Law and updates AN G10 above.

While not related to this specific occurrence the Investigation also notes that company procedures do not reflect S.I. 205 of 1997, which in Regulation 11 states:

When an accident or serious incident to which these regulations apply occurs, the pilot, or if the pilot is incapacitated, the operator of the aircraft, shall, as soon as practicable, send notice of the accident or serious incident to the Chief Inspector at the AAIU by the quickest practicable means available and, in the case of an accident, shall also immediately notify the Garda Síochána[11] or, if it occurs outside the State, the appropriate local authorities.

1.18.5 PF Reporting of Occurrence

The PF stated that he had intended to report the occurrence but was not sure what method to use. There were three available:

1) A CSR, the normal method of reporting operational events to Flight Operations Management (Flt Ops),
2) A report directly to the Fleet Captain or,
3) A report through the ASO.

Although the PF was not happy with the poorly executed approach he did not believe an incident had occurred as he was not aware how significant the deviation was until he later saw the FDM data.

He was more concerned about the safety aspects of the event and how a late change in approach procedures led to a miscalculation on his part. He felt he was a conscientious operator and that if it had happened to him it was liable to happen to anyone. He said that at no point did those, his peers, with whom he discussed the occurrence, suggest that an incident should be reported. On balance he had felt, as the issue was safety related, it should be reported through the air safety system. He had felt that the confidential reporting system in place within the ASO might make it stand out and if questions arose from the evaluation of the incident by Flt Ops, they could be directed to him via the ASO.

Some weeks later, the PF visited the ASO and discussed his memory of the occurrence and possible reporting methods. He subsequently submitted a confidential report to the ASO approximately a month to six weeks after the incident. When contacted by the FDM Review Group he submitted a written report and cooperated fully with them. He found that his impression of being high during the approach did not agree with the FDM data. His earlier impression, he accepted, was incorrect.

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[11] Irish police force.

The PF stated he had not read what he subsequently considered to be the relevant section of the Operator's Administration Manual, Part A, 11.3.2, in relation to the occurrence that stated:

3.2 Incidents which must be reported…
13. When a height control error of more than 300 feet occurs.

He only realised the limitations and inappropriateness of reporting the occurrence through the confidential reporting system much later when he read the Operator's Air Safety Manual.

1.18.6 Flight Operations Management Interview

The result of submitting a confidential de-identified report was that Flt Ops Management, when informed, believed that they were not in a position to determine who was involved in the incident or when it happened and therefore it could not be identified, so no further action was taken concerning the report at that time. However, the judgement of Flt. Ops was that if the occurrence was significant, it would eventually emerge as an incident through the Operator's FDM program. This in fact occurred.

Flt. Ops, at that time, was commencing a management restructuring process that resulted in the then Chief Pilot assuming responsibility for corporate safety and the ASO reporting to him.

1.18.7 Operator's Reporting and Recording System

The Operator has a number of different systems, both manual and automatic, for reporting or recording operational and technical events, of which the following are of significance in this investigation:

(a) Operational occurrences during flights are normally reported by a CSR that a captain can complete post flight. This is a hand written document and is processed by the executive function of Flt. Ops. That system was not used in this case.
(b) As with most major airlines a confidential reporting system is available to any staff member who may not want to be identified. This function is part of the Operator's ASO and was used by the PF.
(c) The Operator also maintains a Flight Data Monitoring (FDM) programme where operational parameters associated with the flight are automatic evaluated and monitored. This is discussed in Section 1.18.8. FDM data has been used to analyse this event.
(d) Flight Data Recorder data is normally only used to investigate accidents or incidents. However, in exceptional circumstances where events occur that are not recorded by either a Post Flight Report (PFR) or FDM and where further investigation is needed, FDR data may be used by the Operator in accordance with the DGSA.

FDR data is taken from the aircraft's digital bus and is stored in solid-state memory in the Type 1 FDR unit. The data recorded is stored digitally for a 25 hr period after which it is overwritten. The FDR is active if either engine is operating or the aircraft is airborne. As the 25 hrs time period had been exceeded, by the time of notification, FDR data was not available to investigate the incident.

1.18.8 Flight Data Monitoring System (FDM)

ICAO in its Safety Management Manual Doc 9859, subsection 16.3 Flight Data Analysis (FDA) Programme, outlines guidance for installing an FDA or FDM programme by an operator in order to provide proactive identification of hazards and avoiding accidents.

These guidelines are expanded in CAA CAP 739. The guidelines involve establishing a baseline for operational parameters, identifying and quantifying deviations from the baseline, measuring associated risk factors and taking remedial action.
Effectively FDM allows the operator to compare SOPs with what is actually achieved in everyday line flights and to adjust procedures and training where necessary in the interests of safety. It should be noted that FDM data is recorded for the full duration of the flight. FDM occurrences are later identified when trigger values or parameters set in a software algorithm are exceeded. By their nature, these values are physical measurements or combinations of measurements. FDM therefore cannot detect what it does not or cannot measure e.g. minima transgressions or human factor issues.

The Operator's FDM system was composed of the following; an onboard data storage unit, data transfer to base, data evaluation at base, identification of areas of operational risk, making changes to the operation where necessary and a feedback loop to pilots.

The FDM onboard unit stores data that is a subset of the complete FDR data, generally at a lower sampling rate to minimise storage. This data subset is saved to a Quick Access Recorder (QAR), whose storage is PCMCIA[12] based, by which means they are transferred to the Operator's FDM evaluation software at base. The QAR data is collected once monthly from the entire Operator's fleet of aircraft. A software program run by a technician then screens this data. This program identifies and rates occurrences as the parameters, or combination of parameters are exceeded. The various parameters are based on the normal operating characteristics of the aircraft and SOPs. This Operator uses 152 triggers with an additional 20 retained for further use as necessary. Occurrences are rated according to severity. They are later evaluated at monthly meetings of a Review Group.

In screening this particular event the FDM system detected a minor event - a rate of descent below 1,000 ft Radio Altitude that was higher than normal. On examining the specific parameters, the alert FDM analysis technician noticed that the approach had an unusual vertical profile and reported it to the November meeting of the FDM committee. As a result, in accordance with the DGSA between the Operator and its Pilots, the Review Group requested a CSR from the Captain. His report was received in December 2006.

1.18.9 Instrument Approach Procedures - General

An instrument approach has two requirements; both horizontal and vertical flight path guidance to navigate towards a runway. At the MDA, either visual clues must provide the pilot with adequate visual reference for landing or a go-around should be commenced.

Instrument approaches may be divided into two types; precision approaches (such as an ILS) and non-precision approaches, the essential difference being the accuracy such approaches are capable of. An ILS precision approach provides guidance that gets more accurate, horizontally and vertically, as the runway is neared. This is not the case in a non-precision approach.

1.18.9.1 Non-Precision Approach Procedures

Horizontally, a NPA approach is flown with reference to a Navaid - a ground based facility such an NDB, VOR or Localiser. The accuracy of the approach is dictated by the accuracy of the type of Navaid, the location and distance of the Navaid with reference to the runway and to what extent vertical flight guidance is available.

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[12] A small credit card sized data storage card.

If the NPA Navaid is a localiser, based on the runway with a paired DME, then the ability of the pilot to track it laterally is superior because this aid increases in sensitivity as the runway is neared. If the Navaid is a NDB located on the approach some miles from the runway, with no distance to go measurement, then it is inferior.

Vertically the flight path of the NPA is a series of stepped descents to MDA. Each descent position is fixed with reference to a Navaid. The steps or platform heights are the minimum height at which obstacle clearance is guaranteed. There are two ways of flying such an approach. The first being the original method behind NPA design; that of flying over each point and descending to level off at the next platform height in a series of discontinuous descents. The second being to try to descend along a continuous stabilised glide path that intersects each stepped descent point at the required height and distance. This latter method is only achievable when the continuous descent profile conforms to the published glide slope for the runway.

NPA approaches at an angle to the runway, requiring a visual turn at low level, are occasionally encountered at international airports e.g. VOR/DME approach 22L and Canarsie 13L/R VOR approaches at KJFK.

It is noted that most Enhanced Ground Proximity Warnings (EGPWS) are inactive once landing gear and flaps are extended on a non-precision instrument approach with the exception of Mode 1 'Excessive Descent Rate' warning and Terrain Clearance Floor (TCF). The former warning is triggered by the aircraft descending at too high a rate of descent close to the ground, or over twice the rate of descent recorded for the incident aircraft. The latter TCF warning is triggered by a descent below a reducing floor height as the runway is neared, the floor height for the last 12 miles is 400 ft, reducing linearly to zero between 5 nm and the threshold.

1.18.9.2 Flight Safety Foundation (FSF) Data

The Flight Safety Foundation Approach and Landing Accident Reduction (ALAR) Task Force[13] found that more than half the accidents and serious incidents involving Controlled Flight Into Terrain (CFIT) occur during step down non-precision approaches. Other data showed that such approaches are five times more hazardous than precision approaches. As a result, step down approaches are avoided where possible with the aviation industry striving to evolve them into constant descent angle/stabilized approaches. The report also notes that further development of Global Positioning Systems, Inertial Navigation Systems and Flight Management (FM) Computers have provided aircraft with the technical capability to provide constant descent angle capability.

1.18.9.3 Korean Air flight 801 on August 06, 1997

The ATC and Cockpit Voice Recorder (CVR) transcripts (Docket SA-517 Exhibit 12A) for the fatal Korean Air flight 801 on August 06, 1997 flying an NPA to RWY 06 at GUAM, showed the same phraseology used by ATC in "*cleared for ILS 6L approach, glide slope unusable*". The First Officer confirmed only that they were cleared for an ILS approach but did not acknowledge glide slope unusable.

Subsequent to the clearance being issued, there was a discussion by the flightcrew of the glide slope status and it was again mentioned on subsequent occasions.

[13] Flight Safety Foundation, Air Safety World, October 2007.

Although there was a NOTAM (Notice to Airmen) published indicating that the glide slope was inoperative and cockpit voice recorder transcripts show that the crew had heard that the glide slope was unusable, its status was commented on a number of times during the approach.
The airplane was cleared to land on RWY 6L at A.B. Won Guam International Airport, Agana, Guam, following the localizer only approach but crashed into high terrain about 3 miles short of the airport.

The NTSB determined that "*the probable cause of the Korean Air flight 801 accident was the captain's failure to adequately brief and execute the non-precision approach and the first officer's and flight engineer's failure to effectively monitor and cross-check the captain's execution of the approach*."

The following extract from the CVR transcript includes those parts relevant to the localiser approach.

15:39:44 CERAP KA801 cleared for ILS 6L approach glide slope unusable
15:39:48 RDO-2 Korean eight zero one roger .. cleared ILS runway six left
15:39:55 CAM-3 is glide slope working?
15:39:56 CAM-1 yes it's working
15:39:57 CAM-3 ah so
15:39:58 CAM-? Check the glide slope if working?
15:39:59 CAM-?Why is it working?
15:40:00 CAM-2 not usable
15:40:22 CAM-? (glide slope is incorrect)
15:40:37 CAM-1 since today's glide slope condition is not good, maintain 1,440, please set it
15:41:46 CAM-1 isn't glide slope working

1.18.9.4 Delta Connection Flight 6448 on 18 February 2007

The NTSB Reporter publication, Vol. 26, No. 7, July 2008, contains information on a runway overrun by Delta Connection flight 6448 (operated by Shuttle America, Inc.) while landing at Cleveland Ohio on 18 February 2007. The NTSB Reporter publication contains the following information:

"About 1458:46, the approach controller informed a Jet Link aircrew that the flight was cleared for an ILS runway 28 approach and that the glide slope was unusable. The Shuttle America flightcrew heard this transmission, and the crew began to discuss how that flight could be cleared for an ILS approach if the glide slope was unusable. About 1459:10 the approach controller instructed the Shuttle America flightcrew to descend from 6,000 to 3,000 ft, and the captain acknowledged this instruction. Afterwards the Captain stated, "its not an ILS if there's no glide slope", to which the first officer replied, "exactly, it's a localizer." During the post accident interviews, both pilots stated that they were confused by the term "unusable," but the CVR indicated that neither pilot asked the controller for clarification regarding the status of the glide slope".

1.18.10 Non-Precision Approach (NPA) Procedures - A330

NPA approaches in the A330 may be flown either using a selected or a managed approach. Airbus recommends a stabilized approach procedure for non-precision approaches. A stabilized approach means the aircraft intercepts the final descent path, at the final approach fix, in the landing configuration at the correct speed and continues descent down the flight path in a consistent and stable manner with no altitude steps.

FCOM 3.19 states that three different approach strategies are available to perform non-precision approaches:

1. Lateral and vertical guidance selected by the pilot: TRK-FPA (or HDG-V/S) modes.
2. Lateral and vertical guidance managed by the FMGC: FINAL APP[14] mode.
3. Lateral guidance managed by the FM, and vertical guidance selected by the pilot: NAV-FPA (or NAV-V/S) modes.

NOTE: SOPs require that in all cases the flightcrew, using the appropriate raw data, must laterally and vertically monitor the final approach. Where guidance for an approach is not in the database the ILS/VOR frequencies, inbound radials and minima must be manually entered and checked and the other pilot must then crosscheck for errors. Where guidance for an approach is in the database, the details must still be checked.

1.18.10.1 Selected Approach

A "Selected" approach uses the lateral and vertical guidance selected by the crew. This is a traditional NPA approach where:

(a) Horizontally, lateral guidance (e.g. VOR) is displayed on both the Navigation Display (ND) and the Primary Flight Display (PFD)[15]. The pilot can track this information in either heading (HDG) or track (TRK) mode, either being a selectable mode on the A330. In heading the aircraft flies a compass direction while in track the FMGC automatically compensates for wind/drift change therefore facilitating tracking. In addition, as in this incident, the pilot can select the aircraft to directly track a localiser signal.

(b) Vertically either a specific flight path descent angle (FPA) or a rate of descent in ft/min (V/S) can be set. The FPA mode compensates for changes in groundspeed and maintains a constant descent angle so in theory by selecting FPA with a flight path angle that matches that published on the ILS chart, the aircraft should maintain the glide slope correctly to MDA. However, in practice the pilot needs to start the descent before the required point due to the inertia of the aircraft and regularly re-adjust the FPA as deviations from the required descent profile arise.

It should be noted that, as in this incident, a Selected Approach procedure is normally used to conduct a localiser approach; the horizontal mode being LOC and the vertical being FPA.

1.18.10.2 Managed Approach

In a managed approach, lateral and vertical guidance is provided by the FMGC. This type of approach requires (a) a high degree of positional accuracy from the FMGC and (b) that a valid approach procedure is already stored in the navigation database. The pilot effectively selects the required NPA from the FMGC and all frequencies and parameters associated with the approach are then automatically selected by the navigation system. Following interception of the inbound track a virtual or pseudo glide slope, commonly referred to by the pilots as the "brick", is generated by the aircraft's navigational system and displayed on the flight instruments. Either the pilot or the autopilot can track this down to the MDA.

[14] This is a Flight Management (FM) mode displayed by the system on the pilots' PFDs.
[15] The ND and the PFD are flight instrument displays used to navigate and fly the aircraft.

1.18.10.3 Lateral Guidance

In the lateral guidance mode, lateral control is supplied by the FMGC and vertical guidance, or flight path control, by the pilot. This mode is a combination of both managed and selected guidance, as high positional lateral navigation is supplied but no glide path angle guidance is available.

1.18.10.4 A330 Procedures

FCOM 3.3.19 details approach guidance for LOC non-precision approaches.

> *The Standard Operating Procedure of this section can be used for flying LOC approaches, provided the following approach guidance items are observed.*
>
> *For LOC… intermediate and final approach, use the LOC… mode for lateral navigation, associated with the FPA (or V/S) for vertical navigation.*
>
> *Vertical navigation must be monitored using raw data (altimeter, distance to the runway given by radio-navaid).*

FCOM 4 details the FMGC mode change when TOGA is selected and the FMGC enters GO-AROUND mode:

> *When the GO-AROUND phase is engaged, the previously flown approach is automatically strung back into the flight plan at the end of the missed approach procedure.*
>
> *In the GO-AROUND phase, the system makes no predictions. Consequently, CLB and DES modes are not available, and the pilot must observe constraints.*
>
> *When the aircraft leaves the GO-AROUND phase, all predictions and modes become available again. In a go-around, the managed speed is green dot.*

NOTE: In the go-around the pilot must observe whatever speed and altitude constraints are applicable. Green dot is the speed corresponding to the best lift-to-drag ratio.

1.18.10.5 Navigation Database

Following the introduction of the A330 in 1994, the Operator flew NPAs using managed approach procedures. In July 2001, FCOM Bulletin 10-2 was issued by Airbus, which required the operator to individually validate each non-precision approach, as the validity of the navigational database could not be guaranteed. Following this Bulletin the Operator, in line with industry practice, decided against using "Managed Approach" procedures at all times because, as the database changed with each ARINC cycle (28 days), it was not practical to continuously validate every non-precision approach that might occasionally be used, both for destination airports and alternates.

Subsequent to this incident, as part of the preparation for P-RNAV[16], the Operator received confirmation from its navigation database supplier by copy of a Letter of Approval (LOA) that its navigation database production process meets the integrity requirements of FAA RTCA[17]/DO-200A and Eurocae ED76[18] standards for processing aeronautical data.

[16] Precision RNAV (P-RNAV), having a navigation performance equal to or better than a track keeping accuracy of ± 1.85 km (± 1 NM) for 95% of the flight time of all aircraft using Precision RNAV equipment.

[17] Radio Technical Commission for Aeronautics functions as a Federal Advisory Committee in the USA.

[18] A European standard that covers flight critical and essential navigational data as established in ICAO SARPS Annex Appendix 7.

The Operator has informed the Investigation that, because of this LOA; it is now satisfied with the validity and integrity of its navigational database for NPAs and is in the process of retraining its crews in non-precision approaches. This is being done as part of the Operator's Spring 2008 training program.

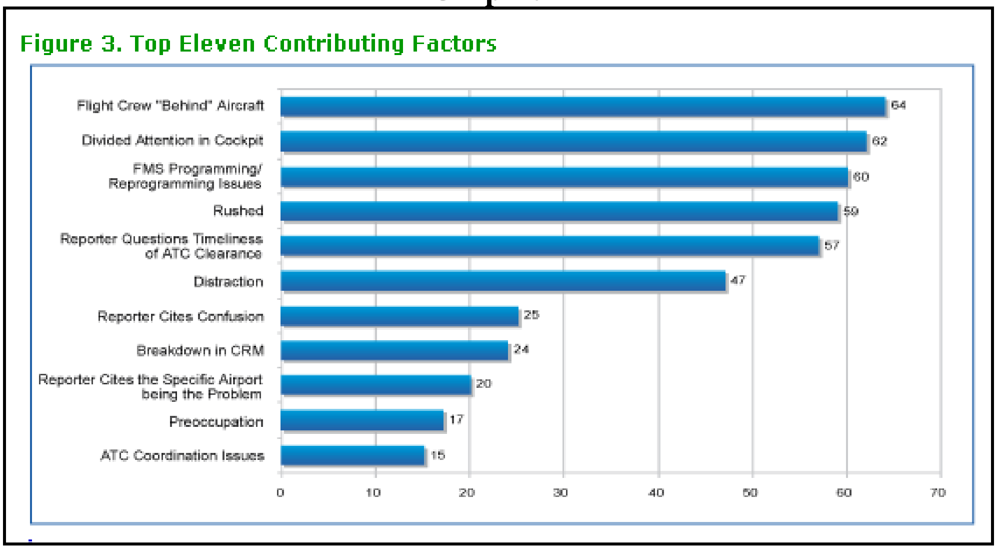
1.18.11 In-Close Approach Change (ICAC)

In the USA, a late runway change by ATC that results in an incident is also known as an In-Close Approach Change (ICAC**).** In "Callback", published in November 2007 by NASA's[19] Aviation Safety Reporting System (ASRS), 313 ICAC events are recorded for air carrier operations in the USA since 1996.

The article states "*A typical ICAC event involves a late or changed runway assignment that may require a flight crew to make multiple changes to the autoflight system within a short period of time, often resulting in increased workload and potential data entry errors.*"

It is noteworthy that the ASRS's analysts identified Flight Crew Human Performance as the most frequently occurring primary problem. The report also lists Contributing Factors as follows in **Graphic 4.**

Graphic 4



Callback ASRS, November 2007

Callback further states, *"For pilots, a change in runway assignment often involves changes to their arrival routing and transitions - further adding to their communication, traffic watch and arrival task workload in an already high-workload environment. The need to program these changes in aircraft equipped with complex FMS navigation systems compounds the problem, as waypoints, routing, transitions and runways must be quickly and accurately re-entered into the computer. The task saturation that can accompany these changes can result in data entry errors and contribute to a variety of downstream impacts including a breakdown in crew coordination, cockpit monitoring tasks, un-stabilized approaches, loss of separation, wake vortex encounters, and track, altitude and speed deviations."*

1.19 Useful or Effective Investigation Techniques

Not applicable.

[19] The National Aeronautics and Space Administration of the USA.

2. ANALYSIS

2.1 Overview

The Investigation has determined that the following were not significant factors in the event:

- The incident happened in fine weather.
- There were no operational or equipment problems with the aircraft.
- The crew were both experienced and familiar with the aircraft.

The Investigation initially examined this occurrence regarding its severity followed by its sequential links or chain of events. In addition, systemic issues associated with reporting the incident are also examined. These are listed below in the order encountered by the flight:

- ATC phraseology for an approach with the glides slope inoperative.
- Non-precision approaches in modern technology aircraft.
- Crew performance and human factors.
- Non-precision approach design.
- The Operator's Air Safety System

2.2 The Incident

2.2.1 General

The salient feature of this approach was an inappropriate descent below the vertical profile resulting in a substantial deviation at RIDGE, the Final Approach Fix, of 774 ft below the platform height. As identified in Section 1.18.3 flights in the USA may not be conducted over a congested area at a height less than 1,000 ft, or over other areas at less than 500 ft in Visual Flight Rules (VFR). However, although the flight was in VMC[20] and VFR could have been declared, the Operator does not recommend VFR approaches in the United States since accepting a VFR clearance requires the pilot to provide his own aerial separation from other aircraft, a requirement that is the normal function of ATC under IFR. The Operator's policy is due to its belief that this is a safer option. The flightcrew had not deviated from this policy and accordingly the aircraft was still under ATC control and operating under IFR at the time of the occurrence.

FAR Part 121.661 requires the pilot not to *descend below the pertinent minimum altitude for initial approach (as specified in the instrument approach procedure for that facility) until his arrival over that facility*. This requirement was complied with.
Thereafter when the pilot accurately flies the lateral and vertical profile for an instrument approach, the approach is conducted with adequate clearance of all obstacles on the ground. The platform heights published for a non-precision approach are calculated in accordance with the regulations in force, in this case TERPS, and provide sufficient height to allow the aircraft to safely approach the runway in IMC[21].

A descent below those heights endangers an aircraft if the pilot cannot see the obstacles. In this case, the local terrain is relatively flat and the flightcrew appeared to have adequate visual reference to avoid obstacles but the descent was significantly below obstacle clearance limits. However, the aircraft was not in immediate danger due to the fact that adequate visual reference existed in the prevailing meteorological conditions.

[20] Visual Meteorological Conditions.
[21] Instrument Meteorological Conditions, i.e. the aircraft is flown by reference to instruments only.

2.2.2 Standard Operating Procedures (SOPs)

The Operator's Approach SOP requires that the correct instrument glide path profiles be adhered to during an approach. The SOPs for approach state, "*In all cases of final approach where no glidepath reference is available (e.g. no ILS, VASI, etc.), the flying pilot shall aim for a 3° glidepath*." In addition, they also state "*Pilots should arrange descent profile to fly continuous descent approaches where possible, subject to remaining at or above minimum descent altitudes*."

However, FDM showed the PF initially set a glidepath angle of 3º but that he subsequently increased it. PF stated that his reason for increasing the descent rate was that he had miscalculated the rate of descent needed by not taking the height of the airport into account when calculating the height loss required and therefore over estimated the rate of descent required. SOPs are designed to eliminate mistakes, such as this erroneous increase in descent rate.

The Operator's general crew procedures or SOPs for approach require that: *PM* (PNF) *calls out recommended/hard altitudes*[22] *for each nautical mile of the approach (Where these are not promulgated on the approach plate, insert the runway threshold in the MCDU PROG page and calculate estimated altitudes for each NM)."* While heights for each nautical mile were not published on the approach plate the MCDU PROG information displayed by the FMGC should have enabled the correct altitude/height to be calculated in this case. Both pilots agreed that information was displayed during the approach. Had the call outs been made the flightcrew should have detected the deviation. It appears that those call outs were not made by the PNF who was also apparently unaware that the PF had increased the flight path angle.

The aircraft operation FCOM 3.3.19 states:

Standard Operating Procedure of this section can be used for flying LOC approaches provided….. Vertical navigation must be monitored using raw data (altimeter, distance to the runway given by radio-navaid). This SOP required the PF to observe the DME distances at RIDGE and conform to the published platform height. That was not done in this case. At positions other than the stipulated positions, the height/distance relationship calculation is more complex and this is further complicated by the DME not reading zero at the threshold. This is discussed further in Section 2.4 of this Report.

The Operator SOPs for go-around state *"Once the decision has been taken to Go-around during final approach no decision to abandon this shall be taken.* The aircraft configuration of gear down and full flaps deployed was not changed during the approach**.** Although the PF believed he had called Go-around the PNF did not recollect that. The FDM data showed that, if the PF intended to Go-around, the correct procedure was not followed; Go-around flap was not selected, the aircraft with a pitch change of +6.5º was not rotated to the correct Go-around pitch attitude and the autopilot was disconnected.

The Investigation is therefore of the opinion that though the PF may have been considering this action it is probable that it was not announced. If the command had been voiced with Go-around flap called for, and the PNF had not complied with the instruction, it is most unlikely the PF would not have remembered such a serious issue.

[22] Hard altitudes are published altitudes that must be complied with.

2.3 ATC Factors

2.3.1 Overview

While the ATC clearance was not a causal factor in this incident, it nevertheless appears as the initial destabilizing link in the chain of events and is thus considered by the Investigation as a contributory factor. In the JAR and other international environments in which the pilots had flown, the clearance would have been for a "localiser" or "localiser only" approach, thus warning pilots that the vertical guidance element of the flight path is not available - that it is a non-precision approach and that localiser minima apply. It is eminently arguable that the clearance given "*ILS approach, glide slope unusable*" amounts to exactly the same thing. This is particularly so in light of the fact that the pilots reported glide slope inoperative flags showing in their PFDs during the approach. However, it is a clearance a non-USA pilot would not expect and, even though he might logically deduce what it means, it introduces an element of doubt into the situation, which is not an ideal way to start a particular type of instrument approach that is recognized as having a much higher inherent risk factor.

Although the Rules of the Air require the pilot to seek clarification of an ambiguous clearance, this is not always immediately possible at very busy periods in international airports. There is a possibility that radio traffic was high at KORD and they may have had little opportunity of clarifying the clearance. Unfortunately, due to the late reporting of the incident, ATC tapes were not available to establish if this was the case.

It is an unfortunate fact that clearances into busy airports in the USA, when multiple runways are in use, are frequently only given very late in descent and immediately before beginning the approach. Because of this, multiple briefings are needed to cover the approach eventualities envisaged. Equally, on occasion, runway changes have to be given immediately before beginning an instrument approach. Although the function of ATC is the safe, orderly and expeditious flow of air traffic in the use of approach path and runways, this is sometimes at the expense of systematic procedures in the cockpit, where FM technology requires a longer lead in time to an approach.

It is noted that the glide slope was unserviceable from 21.20 hrs to the time of the incident or about 20 minutes before the incident approach was commenced, but the flightcrew were unaware of it and stated that the ATIS did not include this information. The Investigation was unable to discover if other aircraft ahead had been issued with the same approach clearance by ATC while the flightcrew were on frequency.

In any case, there should have been adequate time to alert the flightcrew in advance of this major change to the approach procedure, as late changes in approach procedure are particularly difficult for pilots operating modern technology aircraft. This issue has already been discussed in the November 2007 issue of Callback, Section 1.18.9, where ICAC incidents were discussed.

As ATC records are unavailable for the time of the event, the Investigation is unable to comment further on the issue of late runway approach clearances by ATC at KORD, even should it wish to do so.

2.3.2 ATC Clearance Terminology and Phraseology

To a pilot unfamiliar with the clearance "*ILS approach, glide slope unusable*" the clearance itself is an apparent contradiction in terms. The contradiction arises in that an ILS has two elements, a localiser and a glide slope. If either is inoperative then it is not an ILS.

Such a clearance introduces a logical contradiction at a sub-optimal moment, which naturally results in the uncertainty expressed by the pilots.

A further issue is in the expression "*glide slope unusable*". To a pilot not familiar with FAR terminology the word "unusable" is imprecise as unusable may not mean that it is not working, just that it should not be used. Generally either "unserviceable" or "inoperative" convey the meaning that something is not working. Therefore, the mental picture conveyed to the pilot by the clearance "*cleared ILS, glide slope unusable*" can vary from a pilot who is familiar with the phraseology, to a pilot who expects a full ILS display but that ATC cannot confirm the glide slope is functioning properly. In the former case, the pilot will correctly ignore whatever display the glide slope shows but in the latter, there can be a tendency, especially in cases of overload and uncertainty or where local phraseology is in place, to follow an erroneous glide slope if it is displayed.

In the latter case the glide slope and its status, at a minimum, becomes a serious distraction as may possibly have happened in Korean Flight 801 referred to previously in Section 1.18.7.3 with the captain saying "*yes, yes it is working"* but later that the "*….glide slope condition is not good…".*

It is unclear from the NTSB report on the above accident if the PNF of that flight, who operated the radio, had ever heard that particular clearance phraseology previously. The ATC controller transmitted," *Korean Air eight zero one...cleared for the ILS runway six left .. glide slope unusable."* The first officer responded, "*Korean eight zero one roger .. cleared ILS runway six left,*" an incorrect reply as he did not acknowledge that the glide slope was unusable, though the transcript shows that the flightcrew had heard it.

More recently the information released in the NTSB Reporter, regarding the Delta Connection Flight 6448 overrun (see Section 1.18.9.5), indicates that this confusion concerning an ATC clearance for *an ILS approach*, *glide slope unusable* is not confined to international non-USA pilots but, in fact, it also happens to USA pilots.

Within the FAA documentation examined by the Investigation, there are differences in phraseology regarding this type of approach:

AIM in 1-1-9 advises the pilot:

"Inoperative glide slope. *When the glide slope fails, the ILS reverts to a non-precision localizer approach"*

In the Air Traffic Control handbook, 7110.65 the ATC phraseology is defined as; *"Cleared I-L-S Runway Three Six Approach, glide slope unusable."* However, this manual is not readily available to pilots.

In the Jeppesen chart, which the pilots used, the terminology shown for an approach with an inoperative glide slope is "*LOC (GS out)"* (**Appendix A Chart 1**).

In the USA FAA Chart for ILS RWY 22R KORD the terminology appears to be *Loc Only* and *S-LOC"* (**Appendix A Chart 3**).

In the JAA/EU environment the Investigation has been unable to discover any published ATC clearance phraseology for use for an approach with the glide slope inoperative. However, having consulted ATC units in a number of jurisdictions, the Investigation has been advised that the same phraseology is used, i.e., a clearance for a *"Localiser"* or a "*Localiser Only*" approach.

In the above selection, the underlined eight different terms are used to describe a single type of approach.

2.3.3 Regional Phraseology Variations

Operators have a responsibility to ensure that their flight crews are trained to understand and to comply with the commonly-encountered differences in phraseology and procedures used by ATC that are likely to be encountered in the area of operation (see Section 1.18.2.4) approved in their Air Operator's Certificate (AOC)[23]. However, it is not possible to cover all aspects and all phraseologies that might possibly be used. Neither is it practical for international pilots to be familiar with all local phraseology variations, dialects or different regional interpretations that could be used.

Because of this, ICAO Annex 10 attempts to standardise ATC standard phraseology through its Manual of Radiotelephony Doc 9432 AN/925. Whereas non-precision clearance phraseology in that document is given for an NDB, a VOR and various radar approaches, it does not cover localiser approaches.

Annex 10 also states that:

> *ICAO standardized phraseology shall be used in all situations for which it has been specified.*
> *Communications shall be concise and unambiguous, using standard phraseology whenever available.*

The Investigation is of the opinion that where significant differences arise in aviation practices, such as in this ATC clearance, the various aviation authorities should resolve the matter through the agency of ICAO. This is especially so when these issues are in connection with undertakings that have a significantly higher risk factor, such as non-precision approaches, and therefore a safety recommendation is issued on this point to ICAO.

It is noted that the FAA has stated, in previous correspondence with this Investigation, that it referred this matter to their Air Traffic Safety Oversight Service for consideration.

2.4 Non-Precision Approaches

2.4.1 General

NPAs use a step down procedure with the pilot descending to an MDA in decreasing heights at specific reduced distances to the runway. However, large power and pitch adjustments need to be made during these approaches in order to achieve and maintain stepped platform heights and control speed. This results in a significantly increased workload in a dynamically evolving situation. Increased pilot workload gives less time to analyse and make decisions and therefore generates the higher risk factors as identified by the Flight Safety Foundation ALAR Task Force. Following levelling off at a platform height descent has then to be re-commenced in advance of the next specific point to compensate for the inertial lag in the aircraft in order to arrive at the MDA by and ahead of, the Missed Approach Point (MAP).

The pilot ideally wants to reach MDA established on a stable descent profile at the correct speed. Where there is any doubt about the vertical profile the pilot will normally aim to reach MDA slightly early to give himself a reasonable possibility of landing.

[23] An AOC is issued by a national aviation authority as part of the certification process for an air transport operation. A licence to operate is not issued unless the operator has an AOC.

If the aircraft arrives at the MDA too late, it is too high to land and stop on the runway and it must therefore perform a Go-around. The advent of larger and less manoeuvrable air transport aircraft with bigger engines and slower acceleration times has compounded these problems. The result, therefore, is that where the pilot becomes unsure of his along track position, there can be a tendency in VMC to increase the rate of descent in order to ensure avoiding a later Go-around. This is especially so where the runway is relatively short for the aircraft.

2.4.2 Development

NPAs were originally developed by flying to and/or from ground-based radio aids using a step down platform system to control the vertical profile. Timing was used to estimate distance to the runway threshold and advisory rates of descent being based on groundspeed. This NPA system is still used on approach charts where horizontal information may be provided by a navigation aid but the vertical flight path is usually a discontinuous series of descents. In addition, older, non-FMS equipped aircraft do not have the capability to generate an accurate distance to run to the runway; consequently an exact along track position is not available. Because of this, the flightcrew's knowledge of their vertical position in relation to the required vertical flight path angle is always inaccurate to some extent. It is therefore not surprising that non-precision approaches have a higher intrinsic risk factor than precision approaches e.g. ILS approaches. Although some NPAs have associated DMEs, the DME is often not referenced to the runway threshold, as in this case, and can therefore be an additional source of calculation error.

In modern aircraft equipped with FMS, such as this aircraft, the FMS computes the position of the aircraft continuously and accurately and therefore the distance to the runway threshold is available if selected. Theoretically, the pilot can roughly calculate in advance the height required at each mile distance from the runway. However, this assumes that he is aware in advance that this information may be required, as was not the case in this incident. It also assumes that the information he is working from is accurate and, in addition, there is the possibility that there may be significant errors in such calculations performed under time pressure, as happened in this occurrence. Ideally, the pilot wants to fly an NPA using a constant descent profile with sufficient information to regularly determine and correct his vertical flight path. Such information is not provided in current published State approach charts. The Operator subsequently informed the Investigation that it had contracted Jeppesen to include recommended crossing altitudes (derived) on all approach plates.

2.4.3 Technology Induced Constraints

In older technology aircraft, following a change of approach procedure, one pilot flew the aircraft while the other set up the required navaids following which a mutual briefing was held to ensure unanimity of view.

There are distinct advantages to FMS equipped aircraft, in holding accurate approach data in its database, but the correct approach must be selected and the FM predicted flight path crosschecked against the published approach chart. Each pilot must then verify the significant items of information contained in the approach database while the other monitors the flight of the aircraft. Following this, a mutual briefing is held. Normally this process is completed well before the approach is commenced. In this case, that did not occur due to the late ATC clearance.

Although this process substantially reduces potential errors in setting up an approach, it is time spent in activity that removes the attention of each pilot from monitoring the aircraft's flight path for a longer period. That time has become longer as technology has improved.

The PNF alluded to this in his interview by his experiments with the time taken to change an approach procedure. The PNF stated that he could not physically make the changes required in less than about 20 seconds. This did not include crosschecking the approach and Go-around path in the FMGC. This coupled with preparing for the movement of the aircraft post landing meant the PNF was out of his direct monitoring function for a period.

The distance from NOLEN to RIDGE is 8.6 nm. At a speed of 140 kts the aircraft would have taken over 3.5 minutes to reach RIDGE. Assuming the PNF monitored the PF setting and commencing the correct flight path angle, he should still have had time to return to monitoring the aircraft and seeing the deviation. However, he was not expecting problems. When interviewed later by the Investigation the PNF could not recollect what preoccupied him during that critical period, but it was most likely briefing himself for post landing activity.

2.4.4 Training Issues

The Operator's training policy teaches correctly that the safest and most consistent way to fly a non-precision approach is by flying a stabilised approach with a constant descent profile that complies with obstacle clearance heights. The PF stated that he had not practiced NPA's with intermediate platform heights as the method trained by the Operator is to use a steady rate of descent from the final approach fix (in this case RIDGE) to arrive at the MDA at, or slightly before, the missed approach point. When questioned as to why he had not complied with the 2,200 ft platform restriction the PF appeared to the Investigation to consider that the requirements to fly a stabilised approach with a constant descent profile took precedence over platform heights. Neither was the requirement to conform to platform heights readily apparent in the interview with the PNF.

The Operator's SOPs clearly identify that minimum or "hard altitudes" should be called by the PNF during the approach but this did not happen in this incident. Although the Operator subsequently informed the Investigation that its simulator training sessions normally include NPAs, the event coupled with the pilot interviews leads the Investigation to believe that there is a training issue involved. The Operator subsequently supplied details of its forthcoming training programme to the Investigation. The training programme, both ground school and simulator, addresses minimum altitude issues and also covers the reintroduction of managed non-precision approaches due to its navigation database approval (see Section 1.18.10.5). The Investigation notes that the Operations Manual, Part A 8.7, specified that the pilot shall aim for a 3º glidepath. It did not provide guidance for those occasions where the glidepath was not 3º, e.g. KORD RWY 22R. The Operator has subsequently published guidance and a worked example for flightcrew that removes ambiguities regarding descent profiles. This has also reinforced the requirement to observe minimum procedure altitudes ("hard heights") when conducting NPAs. In view of these measures, no Safety Recommendation is made.

2.4.5 Approach RWY 22R Vertical Profile

There is a difference in the type of information provided on a non-precision approach from that provided on a precision approach regarding the vertical profile:

Whereas the profile shown on a precision approach is one that provides either minimum or above minimum obstacle clearance, so in effect, the majority of the approach is flown above the obstacle clearance surface.

The profile shown on a non-precision approach is the one that provides the minimum prescribed obstacle clearance or in effect, an obstacle clearance surface. When a pilot accurately flies this profile, the approach is conducted with the minimum allowed obstacle clearance. After each step down position, a new reduced minimum obstacle clearance altitude applies.

There are two problems with that type of approach. First, it is difficult to fly, as it may require large changes in both power and pitch attitudes with large rates of descent close to the ground. Secondly, as it is not fully stabilised, it is not SOP according to the company and not the recommended procedure according to Airbus.

The philosophy of a precision approach when applied to non-precision approaches is to fly a stable flight path, so that the pilot can maintain normal stabilized approach procedures. This in effect is what the PF was attempting to do and why a 3º flight path angle was initially selected. However had he done this exactly it would have resulted in the aircraft being high at the MDA (i.e. at the end of the approach), as the approach glide path angle for KORD 22R is greater than 3º as can be seen from the **Table 3** below.

Table 3

Waypoint	*ORD DME*	*Dist to RWY*	*Theoretical 3ºAltitude*	*Platform Altitude*	*Platform v Ideal*	*G/P Angle*	*Inter-Fix Angle*
FNUCH	19.5	**18.8**	6,686	7,000	314	3.18º	3.27
NOLEN	13.7	**13.0**	4,850	5,000	150	3.15º	3.08
	8.7	**8.0**	3,253	2,200	-1,053		
	7.7	**7.0**	2,935	2,200	-735		
	6.7	**6.0**	2,617	2,200	-417		
	5.7	**5.0**	2,298	2,200	-98		
RIDGE	5.2	**4.5**	2,125	2,200	75	3.27º	3.12
	4.7	**4.0**	1,980	1,220	-760		
	3.7	**3.0**	1,661	1,220	-441		
	2.7	**2.0**	1,343	1,220	-123		
D.2.2	2.4	**1.7**	1,183	1,220	37	3.57º	3.23

Localiser Approach 22R KORD

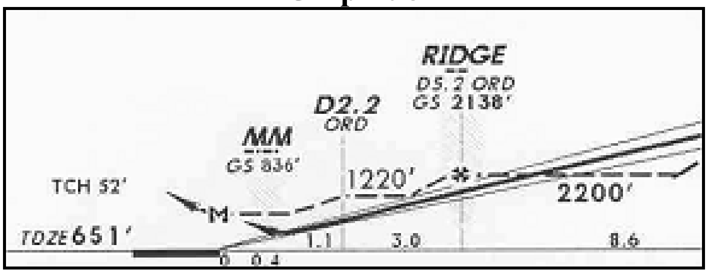
The chart above has been constructed from the data in **Table 1** with *Theoretical 3º Altitudes*, calculated using a 3º angle and distances as in **Appendix C.**

Platform v Ideal column identifies the altitude/energy requirements on the approach. It must be borne in mind that both the kinetic and potential energy of the aircraft must be absorbed in order to stop on the runway - energy levels can be traded from potential (height) to kinetic (speed) and vice versa. Therefore, if a pilot is in the red area in the above table and fast, it may be difficult to obtain a successful outcome from the approach, particularly so if the aircraft is heavy, any tailwind is involved and the runway is short. If the aircraft is in the blue area at low speed then energy levels are much lower; consequently, power is needed with a de-stabilised approach resulting.

The *G/P Angle* column identifies the descent angle of the platform heights for the published non-precision localiser approach to RWY 22R at KORD. Although the published glide slope angle is 3º, and that is the only vertical profile angle information available to the pilot, calculation shows that at the Final Approach Fix RIDGE the glidepath is 3.27º and at D2.2 it is 3.57º. This is reflected by platform heights on the Jeppesen approach chart showing above the glide slope, at RIDGE, at D2.2 and at Minima on the approach chart. In addition, the inter-fix angles confirm that picture. It is noted that there is no visual depiction of an NPA flight path on the AIP chart.

As the FPA selector of the aircraft is calibrated to a tenth of a degree and aircraft can fly to that level of accuracy, the Investigation is of the view that the published final glide slope angle should reflect reality. As the approach procedure has been constructed in accordance with TERPS and, as all the fixes are movable reference positions, the Investigation is unaware of any reason why the approach cannot be designed to provide a singular flight path angle and so facilitate stabilised approaches. The Investigation therefore believes that the FAA should review the KORD RWY 22R published glide slope and glidepath design.

Graphic 5



Extract Jeppesen 21-8 KORD ILS RWY, Appendix A

The visual picture presented on the approach chart is quite distracting and confusing to a pilot unsure of his vertical flight path. In examining the approach chart non-precision vertical profile, the aircraft is depicted as high at both RIDGE and D2.2, if it maintains platform heights. This visual depiction is correct, as was borne out by the analysis of the flight path. However it is confusing, especially to a pilot who intends to perform a stabilised 3º glide path, in accordance with his SOPs. At a quick glance all he knows is that if he follows the platform altitudes he will be high, and that is not a good option when faced with a short runway. It is possible that this confusion contributed to the pilot's decision to ignore the platform height at RIDGE and concentrate on his height/distance profile, which he had incorrectly calculated.

It is noted that on the Airbus A330 during NPAs for both VORs and NDBs a pseudo glide path is generated by the FMGC. This can be used in managed guidance in accordance with the guidance conditions outlined in Section 1.18.10.2 thus improving flight path stability and safety. However, the manufacturer states that non-precision localiser approaches should be flown in lateral (LOC) and vertical (FPA) guidance.

The Investigation questions why such a useful tool as the pseudo glide path is not made available for localiser approaches. This could provide the ability to perform these approaches more safely due to much better awareness of the flight path of the aircraft relative to the correct vertical profile and accordingly a Safety Recommendation is issued requesting the manufacturer to review the case.

2.5 Approach Preparation

2.5.1 General

In addition to laterally tracking the navaid and flying the aircraft, the pilot tactically needs to continually assess his vertical trajectory during the approach. Because of the difficulty of this exercise, when combined with the normal handling of the aircraft and ATC, checklists, etc, pilots strategically try to prepare in advance for non-precision approaches by careful briefings. Many pilots draw the approach or a table with calculated checkpoint heights and distances for the final segment of the descent as an aide memoir. This process is normally a fully coordinated flightcrew approach where the shared strength and experience of its individuals are brought to bear and errors eliminated.

2.5.2 Vertical Profile Estimation

SOPs require the PNF to call out recommended or hard altitudes for each nautical mile of the approach. Although the SOPs of the operator specify this requirement no guidance or examples on how this should be calculated is provided.

During a normal approach, an aircraft descends about 300 feet for each nautical mile on a 3° glide path. This rule of thumb enables the pilot to mentally calculate whether he is high or low on the flight path e.g. if an aircraft is at a distance of 3 nm from landing the height above the ground should be 900 feet. In addition, the height calculated must be adjusted by runway threshold elevation to give altitude. Finally, the pilot compares this reference altitude with the aircraft's altimeter to determine if he is high or low on the vertical profile. If the DME is located at the touchdown point then its readout can be used directly. If it is not, as at KORD 22R, then the DME readout has to be adjusted by its distance from the touch down point.

Where the altitudes/distances are not promulgated and the glide slope is not a 3º angle, the calculation becomes more complex. In addition, mental calculations in themselves are fallible, especially in the heat of the moment when the additional demands of operating the aircraft are to hand. Therefore, it seems appropriate that a table of distances versus heights should be published on all charts that might potentially be used for a non-precision approach, thereby eliminating such errors, and a Safety Recommendation is issued to ICAO to that effect. The Operator has informed the Investigation that a table of distances versus heights has been implemented on their US approach charts (using Jeppesen-derived data), although published data does not include this.

2.5.3 Human Factors

2.5.3.1 General

The fact that there were no adverse preconditions may have assisted in lulling the flightcrew into a false sense of security during the approach as no problems were expected. The two experienced pilots expected a simple ILS, the automatic flight systems were reliable and the weather was fine. With autopilot and autothrottle engaged the PF role is essentially monitoring the automatic flight of the aircraft to ensure it conforms to the pre-checked flight path. However, a sudden change to an approach changed the PF role completely - from monitoring to actively controlling a different flight path and with little time to prepare. It is probable that, after the long flight, flightcrew arousal levels were relatively low and therefore performance was affected. There was initial uncertainty about the clearance, both from its unfamiliar phraseology and meaning, which was not clarified.

The late and unusual approach clearance by ATC did not allow adequate time to brief for the approach. As a result, the flightcrew had no pre-shared understanding or plan regarding the approach procedure. Normal SOPs ensued, with the PNF checking approach charts and setting up the FMGC for the new approach and the PF actively using selected vertical parameters to control the aircraft.

A crew resource management (CRM) issue arose when the PF changed the flight path, while the PNF was not monitoring, and the PNF stated the PF did not communicate that fact to him. The PNF stated that he did not observe the change, as he was otherwise occupied, possibly distracted by other duties.

2.5.3.2 Clearance Clarification Difficulty

Annex 2 (Rules of the Air) allows the pilot, when unsure, to request clarification of an ATC clearance but this does not always happen in reality. The reasons for this can vary from inexperience, lack of confidence and possible loss of face, to lack of opportunity in a busy ATC environment as mentioned previously.

A pilot should question any clearance that he has doubt about and get a clear, factually correct picture of what is intended by the controller. If not clarified immediately a pilot must make some assumption about a clearance, as the aircraft continues at speed, and then act on that basis. Frequently any procrastination in immediately questioning the clearance results in the opportunity being lost as concentration becomes focused on the developing approach and an initial assumption then becomes an established fact. However, as in this case, there is usually an element of residual doubt that may distract the pilot and detracts from the normal level of confidence with which he should perform. In a multi-crew situation, other factors such as a cross-cockpit command gradient may also have a heavy influence on flightcrew decision to clarify. There is no evidence that this latter factor was at play here, just the initial uncertainty generated and a possible subsequent distraction factor.

2.5.3.3 Approach

SOPs for the approach require the PNF to call out recommended altitudes for each nautical mile of the approach. These were not published on the approach chart and the flightcrew had inadequate time to prepare them in advance. Where this is the case, SOPs recommend using the PROG page on the MCDU to check height versus distance profile. The PF did this, but incorrectly. The PNF was out of the loop and was not monitoring the vertical profile. Thus, the SOP recommendation was not complied with.

The descent profile should have been in accordance with the published platform height at RIDGE. This fix is DME based and would appear as a symbol in the PF's display. It is probable that the PF was not paying attention to the obligatory DME but more to the FMGC distance to go and trying to acquire the runway visually. This error is simple to make in an aircraft with so much information available and for processing that task prioritising is essential.

There is also the issue of the PF increasing the rate of descent substantially but the PNF being unaware of it. The Investigation notes that the hand of the PF over the FPA controller may mask a change in selection from the PNF, if the PNF is in the right hand seat. Therefore it is important for a pilot to communicate any change in selection as otherwise the change is only detected by a change of angle displayed on the PFD and then later, a change in rate of descent. During both pilot interviews, the emphasis on maintaining a stabilised descent flight path during an NPA appeared uppermost in the mind-set of both pilots.

Consequently, an approach, such as KORD 22R, which has different inter-fix angles and three platform heights, two of which appear in the chart as above the 3º glide slope, would have clashed with this mind-set. In reality, both goals are incompatible. If there had been adequate time to brief for this approach, such issues could have been discussed and resolved and the pre-approach briefing would have improved the CRM performance of the flightcrew, as there would have been a shared mental concept.

2.5.3.4 Go-Around

The data shows that the PF initially applied MCT power for 5 seconds, followed by TOGA thrust for 4 seconds but reduced this subsequently to manual thrust. The result of selection of TOGA is that the FMGC goes to Go-around mode where the command bars indicate the overshoot pitch attitude required and the navigation system indicates the Go-around path to be followed with the previously flown approach added. Speed is then referenced to minimum drag speed and power increases to maximum. Exiting from this mode is not simple.

It is unclear if the PF ever really made a decision to Go-around. What appears more likely is that the PF may have thought about it but, during his hesitation, the PNF realised what was wrong by checking the RADALT versus the distance to go and deduced that they were low early - a useful check since the terrain was flat. Although the PF appears to have been indecisive, in whether to Go-around or not, a final decision to level off was suggested by the PNF and the balance of decision-making swung to that side of the cockpit as the suggestion was adopted by the PF.

2.5.3.5 VFR Approaches

To some extent, this was essentially a visual approach under Instrument Flight Rules, as a visual approach was flown while using an NPA procedure for 22R. Visual approaches are familiar territory for an airline crew as there are occasions when approaches are conducted under VFR, varying from practice visual approaches and landings to when approach aids fail. Good airmanship requires that a pilot practice his range of skills including VFR visual approaches. If conducting a visual approach, descent should not be below a height of 1,000 ft over the ground until a 3º glide path is intersected and thereafter the descent should be on the glide path. A too early descent, in addition to obstacle clearance problems, also causes environmental noise problems when a large aircraft is flown closer to the ground than necessary, which is poor airmanship.

2.5.3.6 Visual Factors

As the approach was conducted in the late afternoon in the autumn, it is probable that the runway approach lights and the airport itself would have been difficult to identify at a distance even though the visibility was probably in excess of 10 miles (**Appendix B Photos 1 & 2**). The former was due to the southwesterly approach into diffused sun light and the latter due to lack of terrain colour contrast at that time of year.

In addition, having got low on the glide slope, the runway would have been harder to identify, as it would not appear in the normal or expected position in the cockpit windows. That low view is not one most pilots are accustomed to, as they are used to the view presented when approaching on a normal 3º glide path angle. As the aircraft got progressively lower, the view of the approach area would deteriorate and the runway would become more difficult to identify.

2.5.4 Crew Resource Management (CRM)

It was not a good crew performance from a CRM aspect, from the errors of the PF to the distraction or possible complacency of the PNF. Yet, many pilots have found themselves in a similar position at some stage in their flying career. When unprepared for an approach, or prepared for a different approach, a large change has to be made in strategic thinking and leadership is needed to ensure effective teamwork and functioning. Priorities need to be established and workload allocated - the first priority being flying the aircraft and keeping it safe. As a result attention and awareness are directed and dispersed among concurrent tasks; flying, adjusting procedures and navaids, calculating and setting new MDA, etc.

There is a limit to working memory and cognitive capacity, which, as approached, reduces the spare capacity for strategic thinking, planning ahead and analysing current tasks and results. As overload approaches these higher-level analytical facilities yield to more tactical tasks and a reactive situation develops which erodes safety margins. Tactics that have priority in an NPA are tracking the inbound bearing while keeping aware of the vertical profile required by calculating the distance/height relationship using mental arithmetic. If things do not happen as expected then mental overload can occur. In an overload, pro-active strategic management of the flight is dropped and the pilot just reacts to the developing situation. Situational awareness becomes less and judgement is consequentially impaired. There is some evidence for this in the poor communications, false hypotheses and indecision of the PF while assessing the situation. Similarly, working memory limitation may have required the PNF to revise the airport details shortly before landing so that he was familiar with the possible ATC clearances that might ensue after landing. This may partly explain why the PNF did not observe the change in descent rate during the approach.

The other routes flown by the Operator are to airports whose altitudes are close to sea level. Therefore, airport altitude is not normally a factor in calculating the height loss required during the approach. This possibly explains why the PF forgot to include runway height in his calculations. A further consideration is that the PF had been originally trained in and had used QFE procedures for much of his career. In a QFE approach, the altimeter indicates the height of the aircraft above the airport and airport elevation correction is not required.

It is of interest that there appears to have been little discussion of the incident by the flightcrew after the occurrence. Subsequently the PNF was not aware that a report had not been submitted again indicative of a communication problem. It is probable that, if communications between the flightcrew had been better, the incident would have been detected at an early stage by the PNF who was unaware of what the PF was doing and was "out of the loop".

The Operator has informed the Investigation that its CRM courseware is being modernised and updated with a project pilot tasked with leading this review. The project pilot has been selected and further training has been scheduled at a facility abroad. A recurrent CRM training module for all pilots will include inter-pilot communication requirements.

2.5.5 Reporting of Incident

Rules of the Air required that a height control error of more than 300 feet be reported. In addition, ICAO states that if any event occurs that might provide useful information for the enhancement of air safety it should be reported. The approach was stabilised but there was a substantial altitude deviation below the platform height. Operator procedures state that if a Commander is in any doubt an incident signal should be raised.

The confidential report submitted by the PF showed he believed he was 1,000 ft high through much of the approach. This is at variance with FDM data. The aircraft was on the correct vertical profile at NOLEN but got progressively below it afterwards. The confidential report stated that the aircraft arrived at 100 ft above minima at 3 nm when it was in fact 180 ft above minima at 4 nm. It did not mention the platform altitude deviation at RIDGE. Otherwise, the report accurately reflected both pilots' interviews and FDM data. The PF stated he did not initially believe that an incident had happened, as he believed he was high during the approach.

However, the PF stated that when he saw the FDM data he realised the occurrence should have been formally reported. The PF had the ability to request a copy of the FDM data for his flight in order to clarify the occurrence. This facility is rarely used by Line Pilots. The reason for this is discussed in Section 2.6.5.

Therefore, the PF neither reported the incident nor sought clarification of the occurrence but went to the ASO to discuss the matter. It is significant that of the three reporting options the PF chose an option that resulted in his flight being de-identified. When questioned about this he indicated he felt the ASO was an appropriate forum for what he believed to be an air safety incident as he felt if it happened to him, it could happen to anyone. He did not realise how circumscribed that non-executive function was, in its ability to act, until he afterwards read the details of the confidential system in the ASM.

2.5.6 Confidential Report

Confidential reporting is used by many organisations and is internationally recognised as a useful tool in safety management. In this case, however a confidential report was accepted by the ASO on an operational incident that should have been reported through the executive management function. It was accepted because the seriousness of the deviation was underestimated by the reporter and the HAS was unable to check FDM flight parameters, due to the terms of the confidentiality system. Even if he had been able to do so, it is doubtful if the HAS would have been able to correctly assess the report due to lack of operational experience, or access to such experience, by any of the staff members of the ASO.

There is also the issue that whereas the ASM gives examples of incidents that may be reported through the non-punitive incident reporting system, no guidance is given regarding incidents that should not be reported by a confidential report. If a confidential report is made concerning a mandatory reportable occurrence then the ASO, as a function of the company, is required to report what it knows about the incident, including the identity of the reporter. There are cases where such incidents are reported confidentially and anonymously, e.g. by telephone, Internet etc. In these cases, the ASO must still report the matter, if it is satisfied about the validity of the report, even though it cannot identify the reporter.

In addition, having submitted the de-identified report to Flt. Ops, there was no facility to provide any further feedback, even though the PF would have been willing to provide it. Although the ASM states that the HAS has absolute discretion in handling the confidential report, the ASO operates within an integrity system and any breach or perceived breach of integrity by an ASO would be extremely counterproductive, especially where no guidance is given. Therefore, the Investigation believes that the facility should be provided, within the confidential system, through the ASO to forward a query from management to the confidential reporter who may answer it on a voluntary basis. It also recommends that guidance should be provided in the ASM as to what is acceptable in a confidential report and what is a reportable occurrence.

Consideration should also be given to allow those within the ASO with suitable operational expertise to promptly check FDM occurrences within the terms of the confidentiality system.

The Investigation therefore recommends that the Operator review the guidelines and operating procedures of its confidential reporting system.

2.6 Operator's Safety Management System

2.6.1 General

The Operator's Air Safety System functions through normal operational reports being collected and investigated by the executive management. Here the routine line problems are addressed. In cases of accidents or incidents, the event will also be investigated by the ASO, which monitors the overall functioning of the line Departments. Critically, as with normal airline practice and in line with the guidelines in the ICAO SMM, the ASO reported directly to top management, in this case the Chief Executive where the ultimate responsibility for a safe operation lies.

The Air Safety System is not just a function of the Air Safety Office. It extends from staff culture and ethos, to SOPs and operational training, to monitoring compliance and investigating events by the executive management and to the overview exercised by the ASO.

The report of this occurrence was made not through the normal reporting channel but through a confidential system that served to both mask and delay its investigation. However, management were aware that such a report was in the system due to the transcript of the confidential report submitted by the HAS. Although aware of the report Flt. Ops management did not know how substantial the deviation was and were not in a position to determine its severity. Ultimately the strength of a system is how it deals with the exceptional and here the Operator's Air Safety System failed to identify and deal with the incident in a timely manner.

2.6.2 Occurrence Reporting

This particular case does not fall into the normal pattern of operational incidents, as the PF was unsure if an incident had occurred and probably hoped one had not. If that were the case, the pilot would be unlikely to want to check FDM data to see if an incident had occurred that warranted mandatory reporting. This is especially so as he would have, in accordance with the DGSA, to initially submit a written request stating why. If he was in any doubt, he should have reported the event as required by Air Regulations, the Operator's Operations Manual and the DGSA. Incident Signals concerning events in Category A and B, as defined in the Operator's procedures, must be discussed, before transmission, with the Chief Executive. However, legislation requires the commander, or pilot-in-command, to report any such occurrence promptly to the authorities. The legal onus is on the pilot. It is only where the pilot is incapacitated or otherwise unavailable that the responsibility defaults to the company.
It is noteworthy that the Operator's Operations Manual Part A section 1.1.1 initially states that fact. However, it subsequently outlines procedures and details of how the commander notifies its operations base and thereafter all procedures are internal company related. There are no further details given in the Operations Manual of how the commander may notify or contact the appropriate authorities[24].

[24] Notification of Authorities procedures are detailed in the ASM.

In practice, however most operators fulfil that function on the part of their pilots in the interests of speed and efficiency as the pilot may be otherwise occupied. In addition, as airlines operate internationally local procedures may vary from place to place and therefore the operator's local representative, if any, may be in a better position to fulfil that function. However, there appears to be no procedural feedback loop to the commander to inform him if or when his mandatory obligation has been complied with.

The Operator has subsequently amended its Operations Manual to comply with Mandatory Occurrence Reporting Procedures and to provide the commander with appropriate guidance concerning immediate notification of reportable events to the appropriate authorities. In view of this no safety recommendation is considered necessary.

2.6.3 Air Safety Office (ASO)

The Investigation notes that although the Operator's ASO conforms in principle to the guidance of the ICAO Safety Management Manual its specifics do not. In the ICAO SMM, reference is made to a Safety Office whereas the Operator has an Air Safety Office. It is surprising therefore, that none of the staff in the office has any experience either as a pilot or as a cabin-crew member.

In addition, investigative training has been provided to the HAS alone. Although one of the staff had crisis management training this is more relevant to post accident/incident management than preventing it, which is the function of the Air Safety Office. The Investigation therefore considers that the ASO should have access to flying and operational expertise within its office.

The Investigation believes this lack of skill sets and training in an essential airline function is inappropriate. However, the Investigation is satisfied that the HAS completed his duties responsibly and in accordance with the Operator's procedures.

Since the incident the Operator has restructured Safety Management within the organisation and the ASO function. It has assigned additional staff to the ASO including a current line pilot and an additional technical investigator. Training scheduled will include ICAO SMS courses and Air Accident Investigator courses. In view of this no Safety Recommendation is required.

2.6.4 Air Safety Manual (ASM)

The ASM is an important document where a core operating ethos of an airline is published. Here operating philosophy and policies are outlined, standards delineated and how accidents and incidents are managed is stated. The document also covers the oversight functions of the ASO, the duties of its HAS and his reporting lines. The duties of the HAS regarding the confidential system are discussed in Section 2.5.5 in which there are recommendations that affect the ASM.

In addition, the ASM categorises accidents, incidents and occurrences. This covers both mandatory and other relevant occurrences. It is noted that this categorisation did not conform to occurrence legislation in force at the time.

It is noted that neither the management chart in 1.3 nor management functions chart in 2.1.5 were up to date with organisational change.

The Investigation has been subsequently informed that Mandatory Occurrence Reporting guidance material has now been included in the Operator's Operations Manual and that the Operator has amended ASM Part 2.9.4 to address the above deficiencies.

2.6.5 Flight Data Monitoring System (FDM)

The Investigation notes that the FDM system, structures and its associated agreement in use by the Operator complies fully with the guidance for such systems as issued by ICAO in its Safety Management Manual, Doc 9859 and identified in Section 1.18.6.

However, the Investigation was concerned with the length of time taken from data being recorded on board during an occurrence to when that event was identified by FDM analysis and subsequently investigated. That length of time was due to the following factors:

1. The PCMCIA method of recording the data required physical transfer of the data.
2. The monthly procedural method of collecting the data, as aircraft were available.
3. Analysis meetings were held monthly.
4. Although not a factor in this incident, the possible unavailability of the Link person to feedback information on the occurrence could introduce a further delay.

As data was collected monthly, an event of interest may have been recorded at the beginning of that monthly cycle. In addition, as data was only removed while the aircraft was at base that too took time. Following this, the data was analysed and finally the triggered event came before the Review Group. It is probable that the average time period from occurrence to initial analysis by the group was in the order of six weeks. By that time most records concerning the flight were discarded. Therefore, it was not possible to investigate a FDM incident within a reasonable timescale.

Subsequent to the incident, the Investigation has been advised that the Operator is modifying its complete fleet to provide instantaneous download of FDM data to base post flight. This system uses microwave technology to download the compressed and encrypted data with the result that FDM data is available for screening immediately following a flight. The net effect of this is to reduce the Operator's FDM screening and analysis time by over a month therefore no Safety Recommendation is required specific to data handling.

2.6.6 Data Gathering System Agreement (DGSA)

The DGSA regulates the operation of the FDM programme within the airline. The Investigation notes that this agreement is according to ICAO guidance Doc 9859. The airline uses this monitoring program as part of its Accident Prevention and Flight Safety Program. The program is non-punitive and contains adequate safeguards to protect the source of the data.

The DGSA provided for monthly meetings of the Review Group. By the time the Review Group met other recorded data and information associated with the incident was no longer available. Generally, that was not a problem as the primary function of the FDM is to monitor trends.

However, on occasions such as this incident, specific action may need to be taken much faster. The monthly meeting structure of the DGSA inhibits that ability, as the DGSA has no provisions to speed the process. Therefore the DGSA needs to be amended to incorporate this ability. In addition, the occurrences listed in this document are no longer in line with the recent mandatory occurrence reporting requirements as outlined in Section 1.18.4.

A similar restriction to that in the ASM is found in paragraph 3.4.1.1 - that Incident signals on serious events must be discussed, before transmission, with the Chief Executive. The Investigation is of the view that, whereas this may be appropriate in internal company interface procedures, the clause is not appropriate where statutory obligations exist.

The DGSA, in paragraph D.14, permits the pilot to apply in writing (stating reasons) to view FDM data from his flight, but he can only do this with the permission of other pilots on the flight. Having formally requested the data in writing, he must state the reasons why. The Investigation believes that these restrictions are unduly cumbersome and inhibits pilot analysis of their flights and in-flight events.

The Investigation therefore recommends that both parties review the DGSA to enable speedier identification and investigation of operational incidents, to make it compatible with current mandatory reporting requirements and to facilitate pilot analysis of their particular flights.

3. CONCLUSIONS

(a) Findings

1. The aircraft was properly certified for the purpose of the flight.
2. The flightcrew were properly licensed with valid medicals.
3. The flightcrew were both experienced and familiar with the aircraft.
4. Meteorological conditions are not considered a factor in this incident.
5. There were no operational or equipment problems with the aircraft.
6. The ILS glide slope on RWY 22R at KORD failed before the aircraft commenced its approach.
7. The ATC controller gave a clearance for an "*ILS 22R – Glide slope unusable*" shortly before the approach commenced.
8. The flightcrew were unfamiliar with this clearance and it caused uncertainty.
9. This non-precision approach ATC clearance was in accordance with applicable FAA phraseology guidelines.
10. International ICAO phraseology guidance is not published for an instrument non-precision localiser approach.
11. Non-precision approaches on FMC equipped aircraft take more time to setup than on older technology aircraft.
12. The PF initially set a 3º flight path angle, in accordance with procedures, but increased it inappropriately due to an erroneous calculation.
13. The PF did not communicate this higher selection to the PNF contrary to good crew resource management.
14. The PNF did not monitor the rate of descent as required.

15. The aircraft descended during the approach to 774 ft below the platform height at RIDGE.

16. Following selection of TOGA, the PF did not continue the Go-around.

17. As VMC conditions prevailed, the PF elected to continue to land.

18. The aircraft subsequently landed without further incident.

19. The PF inappropriately reported the event through the ASO confidential reporting system.

20. The Operator provided no guidance to the ASO regarding its statutory obligation for mandatory occurrence reporting of operational events when accepting a confidential report.

21. Lack of line operational experience in the Air Safety Office impeded its response to this operational occurrence.

22. The delays, both individual and systemic, in reporting and detection of the incident were excessive.

23. The FDM system, both data handling and support agreements, impeded the speedy analysis and reporting of occurrences.

(b) Cause

1. The PF selected an incorrect rate of descent during the approach to RWY 22R at KORD due to a miscalculation of height loss required.

(c) Contributory Causes

1. The approach was not properly monitored by the PNF.

2. The late change of approach by ATC, from an ILS to a non-precision localiser approach, did not allow the flightcrew sufficient time to carry out a briefing for that particular type of approach.

3. The ATC clearance phraseology used was unfamiliar to the flightcrew and may have introduced uncertainty.

4. SAFETY RECOMMENDATIONS

1. That standard ATC phraseology be agreed, through the agency of ICAO, for an Air Traffic Control approach clearance for a non-precision localiser only, glide slope inoperative/unusable approach and that such phraseology be included in the ICAO Doc 9432 AN/925. **(SR 16 of 2008)**

2. That ICAO introduce a PANS-OPS standard requiring that a table of altitude and distance to go for each nautical mile, is published on instrument approach charts used for non-precision approaches. **(SR 17 of 2008)**

3. That Airbus considers providing a pseudo glide path display on Flight Management Computer equipped aircraft during non-precision localiser approaches. **(SR 18 of 2008)**

4. That the FAA reviews the published glide slope angle and platform altitudes for an instrument approach to KORD, ILS RWY 22R. **(SR 19 of 2008)**

5. That the Operator reviews its Air Safety Manual to ensure compliance with Mandatory Occurrence Reporting procedures. **(SR 20 of 2008)**

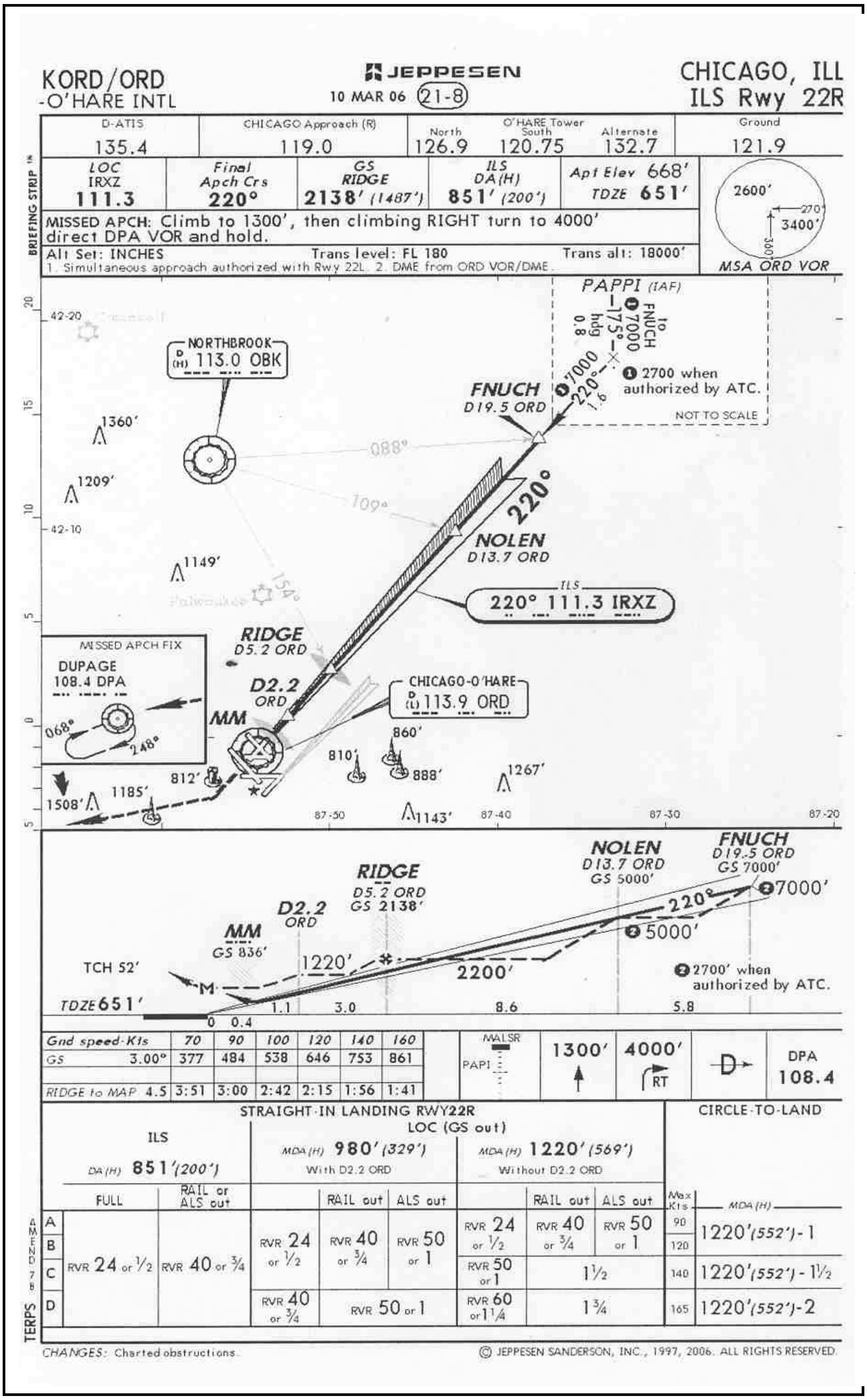
6. That the Operator and its pilots review their Data Gathering System Agreement to ensure that it is compatible with current legislation and that it enables timely investigation of operational incidents. **(SR 21 of 2008)**

Response:

The Operator has informed the Investigation that it accepts Safety Recommendation SR 20 of 2008 and SR 21 of 2008.

Appendix A

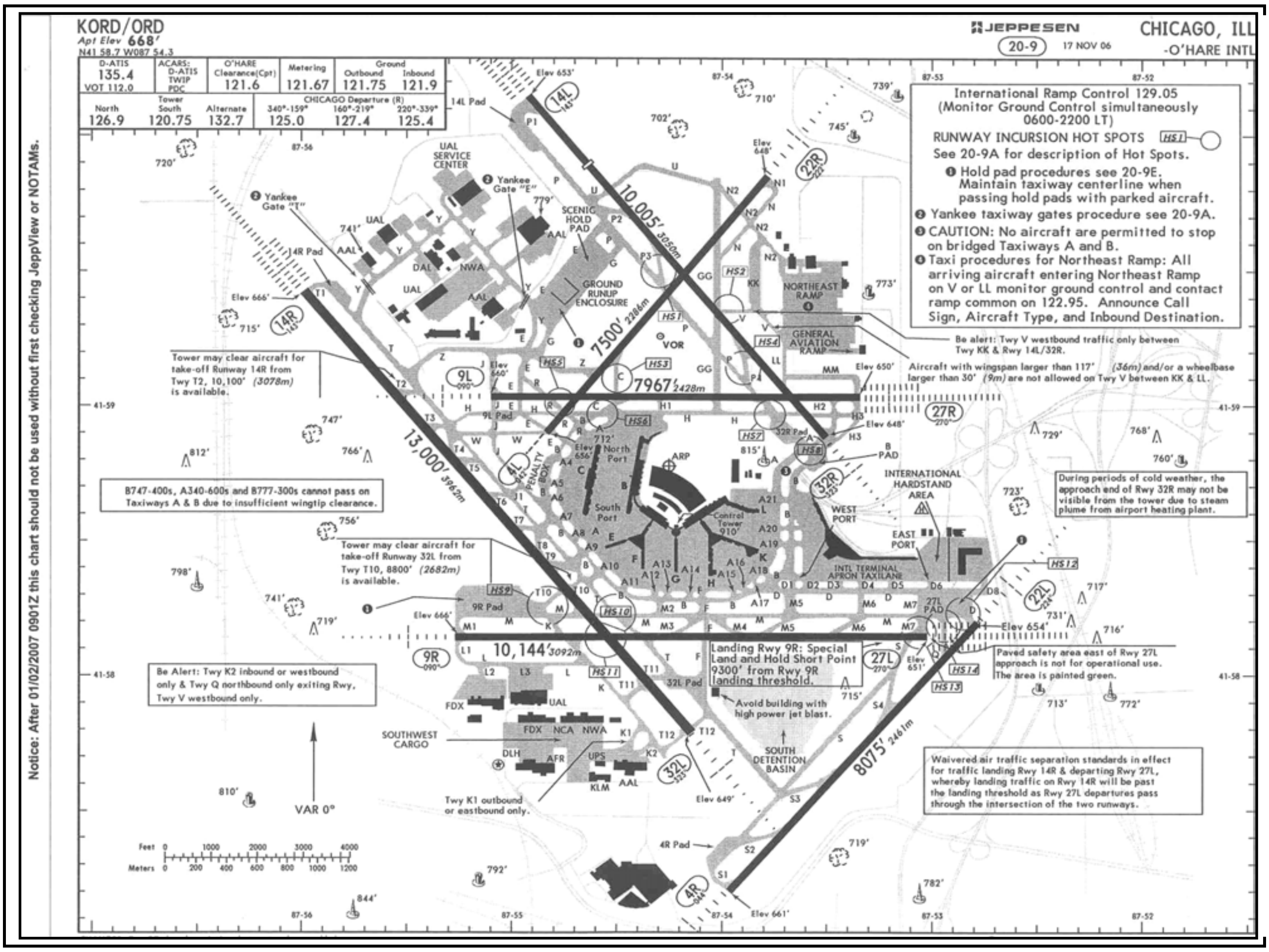
Chart 1



KORD ILS Approach RWY 22R - Jeppesen Chart 21-8

Appendix A

Chart 2

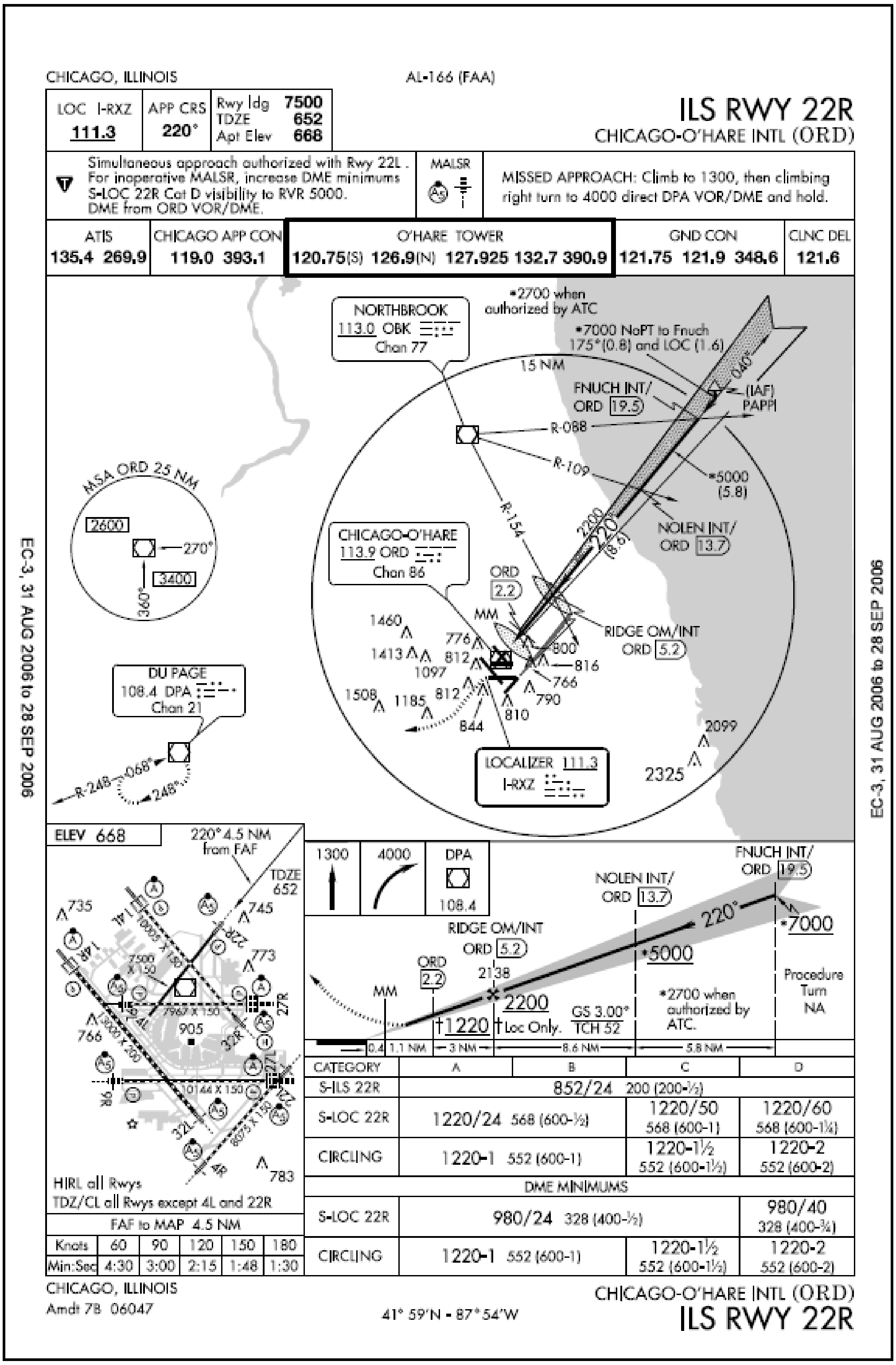


KORD Airport layout – Jeppesen Chart 20-9

In general, a traffic counter-flow system operated on the inner and outer taxiways. Circles indicate where accidental runway incursions (Hot Spots) are likely and where extra vigilance is required when taxiing.

Appendix A

Chart 3



KORD ILS RWY 22R - FAA USA

Appendix B

Photo No. 1

KORD RWY 22R Approach at 6 nm

Photo No. 2

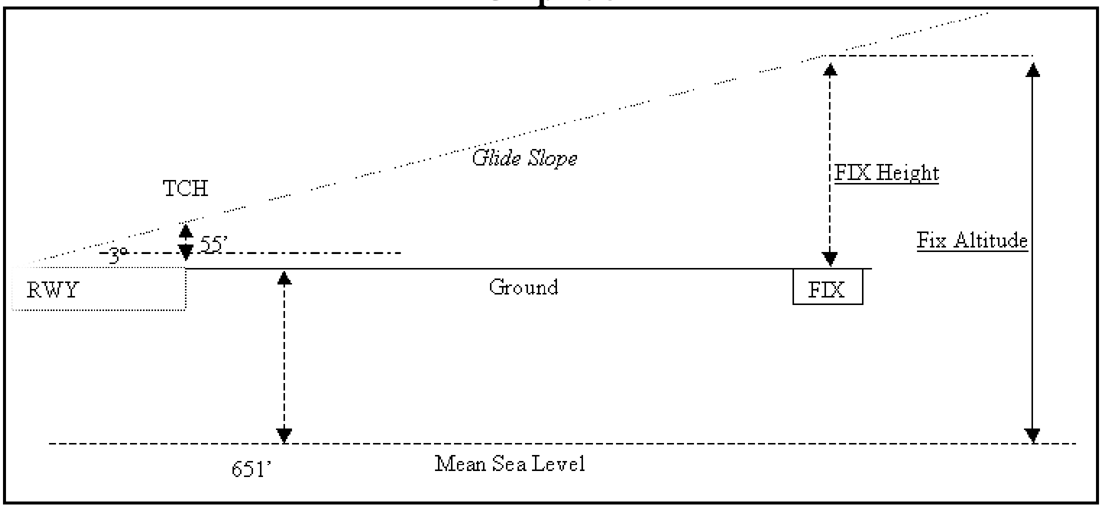
KORD RWY 22R at 3 nm in good visibility

Appendix C

KORD 22R Approach Slope Calculations

A 3º angle was assumed to commence at 55 ft over the runway threshold, which is the Threshold Crossing Height (TCH) identified in the FAA TERPS manual for larger air transport Group 4 aircraft.

Graphic 5



The Haversine formula, which is sufficiently accurate for this analysis, was used to determine inter-fix distances from their geographic co-ordinates, this when summed resulted in distances to the runway threshold. These international nautical mile distances were converted to feet.

The elevations at the various fix distances were than calculated (distance x tangent 3º). The TCH and RWY 22R altitude (55 + 651 = 706) were then added to give the *Theoretical 3º Platform Altitudes* at the fix positions.

The platform altitudes at the various fixes were taken and this height divided by the distance resulted in a slope, which was converted to a descent angle. This calculation was completed for both the angle to the threshold crossing point and the inter-fix angles.

Appendix D

Haversine Calculations

Table 4

	Latitude	Longitude	Haversine Dist	AIP Stage	Dist to RWY	Dist in ft	3º Altitude
FNUCH	N42 14 19.92	W087 37 40.84	5.7667	5.8	18.78	114,114	6,686
NOLEN	N42 09 53.48	W087 42 38.26	8.5583	8.6	13.01	79,075	4,850
RIDGE	N42 03 17.41	W087 49 58.39	2.9563	3.0	4.46	27,073	2,125
					4.00	24,304	1,980
					3.00	18,228	1,661
					2.00	12,152	1,343
D2.2	N42 01 00.60	W087 52 30.14	1.4995	1.5	1.50	9,111	1,183
					1.00	6,076	1,024
Threshold	N41 59 51.13	W087 53 46.94	0.0000		0.00	0	706

KORD 22R Haversine calculations

In theory, earth curvature should also be factored in. In practice, while this may be a factor in the longer initial *Flight Path Angle* distances to the runway from FNUCH and NOLEN, in the shorter *Inter-fix Angle* distances and in the final approach segment from RIDGE and D2.2 to the runway it has less relevance. In any case, it is not included in TERPS initial segment altitudes on instrument approach procedures.

Table 5

	Platform Altitude	Platform height	Platform height slope	Flight path Angle	Inter-Fix slopes	Inter-fix Angle
FNUCH	7,000	6349	0.056	3.18	0.057	3.27
NOLEN	5,000	4349	0.055	3.15	0.054	3.08
RIDGE	2,200	1549	0.057	3.27	0.055	3.12
D2.2	1,220	569	0.062	3.57	0.056	3.23
Threshold	706	55				

KORD RWY 22R Platform Slopes

Platform heights are derived by subtracting the runway altitude from the platform altitude at the fix. The Platform slope was then calculated by dividing the platform height by the *Dist in ft* for that segment in Table 4. Flight path angle is the angle whose tangent is the platform height slope i.e. arctan of the platform height slope. In other words the slope of the angle created by the platform height divided by the distance from the runway threshold to the nearest point of the platform height. Similarly, *Inter-fix Angle* was calculated using the height loss between the fixes divided by the *Haversine Dist*, in nautical miles, in Table 4 converted to feet.

Appendix E

Glossary

A/P	Autopilot
A/T	Auto-thrust
AAIU	Air Accident Investigation Unit Ireland
AIM	Aeronautical Information Manual - USA
AIP	Aeronautical Information Publication, published by each country
ALAR	Safety Foundation Approach and Landing Accident Reduction Task Force
AMSL	Above Mean Seal Level
AOC	Air Operator's Certificate
ARINC	Aeronautical Radio Incorporated: specifies standards for avionic equipment
ASM	Air Safety Manual.
ASO	Air Safety Office
ATC	Air Traffic Control
ATS	Air Traffic Services
B-RNAV	Basic RNAV
CAA	Civil Aviation Authority - UK
CFIT	Controlled Flight Into Terrain
CRM	Crew Resource Management
CSR	Captain's Special Report
CVR	Cockpit Voice Recorder
DGSA	Data Gathering Systems Agreement
DME	Distance Measuring Equipment
EASA	European Aviation Safety Agency - EU
ECAC	European Civil Aviation Conference - Europe
EGPWS	Enhanced Ground Proximity Warning System – aircraft system
EIDW	Dublin Airport
EU	European Union
FAA	Federal Aviation Administration - USA
FAF	Final Approach Fix
FARs	Federal Aviation Regulations published by the FAA
FCI	Flight Crew Instruction
FCL	Flight Crew Licensing
FCOM	Flight Crew Operating Manual - published by Airbus
FDA	Flight Data Analysis - the same as FDM
FDM	Flight Data Monitoring – a system used to monitor operational parameters
FDR	Flight Data Recorder
FINAL APP	An FMGC approach mode that provides both lateral and vertical guidance
Flt Ops	Flight Operations Management
FM	Flight Management – aircraft system
FMGC	Flight Management Guidance Computer – a unit within the FM/FMS
FMS	Flight Management System – aircraft FMS as a totality
FPA	Flight Path Angle – the vertical descent or ascent profile in degrees
G/P	Glide Path
G/S	Glide Slope
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HAS	Head of Air Safety
HDG	Heading mode – aircraft navigation mode
IAA	Irish Aviation Authority
IAP	Instrument Approach Procedure
ICAC	In-Close Approach Change - a late runway change by ATC
ICAO	International Civil Aviation Organisation
IFR	Instrument Flight Rules
ILS	Instrument Landing System
INS	Inertial Navigation Systems

JAA	Joint Aviation Authority
JAR(s)	JAA Requirement(s)
KJFK	New York Kennedy Airport
KORD	Chicago O'Hare Airport
LOA	Letter of Approval
LOC	Localiser only mode – aircraft navigation mode
MAP	Missed Approach Point
MCDU	Multi Control Display Unit
MCT	Maximum Continuous Thrust
MDA	Minimum Descent Altitude
METAR	Meteorological Actual Report
MOR	Mandatory Occurrence Report
NAV	FMGC Navigation mode
Navaid	A ground based RF
ND	Navigation Display
NDB	Non Directional radio Beacon
NOTAM	Notice to Airmen
NPA	Non-Precision Approach
NTSB	National Transportation Safety Board- USA
OPS	Operations
PANS-ATM	Procedures for Air Navigation Services – Air Traffic Management, ICAO
PANS-OPS	ICAO approach design criteria
PCMCIA	Personal Computer Memory Card International Association - a data card
PF	Pilot Flying
PFD	Primary Flight Display
PFR	Post Flight Report
PNF	Pilot Not Flying
P-RNAV	Precision RNAV
PROG	A FMGC Progress page that can be displayed on the MCDU
QAR	Quick Access Recorder
QFE	An altimeter barometric setting that displays the height above the runway
QNH	An altimeter barometric setting that displays altitude above sea level
RADALT	Radio Altimeter
RF	Radio Fix
RNAV	Area Navigation, navigation capability that allows the aircraft to navigate accurately outside the airways system
RWY	Runway
SARPS	Standards and Recommended Practices - ICAO
SMM	Safety Management Manual ICAO Doc 9859
SOP	Standard Operating Procedures
TERPS	Terminal Design Procedures – FAA
TOGA	Take Off/Go-Around thrust
TRK	Track - FMGC navigation mode
V/S	Vertical Speed -rate of climb/descent in ft/min
VASI	Visual Approach Slope Indicators
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions

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