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Air Canada Flight 624 Accident, Halifax Nova Scotia, 29 March 2015.

Accident report critique by Capt. Steve Last

The Canadian Transportation Safety Board (TSB) report into the Air Canada Airbus 320 accident (released 18 May 2017) shows that the 138 passengers and crew on Flight AC624 missed almost certain death by a split second, and survived purely by chance. The aircraft went below the runway level for several seconds, and without the sheer good luck that the airport is on top of a low hill, it would have been Canada's worst ever airline catastrophe for civilian casualties.

Shortly afterwards, TSB Chair Kathy Fox said "We've got to look at the flight crews and the airlines and what kind of procedures they're using during approach and landing to reduce the chance of an accident." **But the report completely ignored two crew procedure deficiencies that led up to the accident, which remain unchanged today.**

The overwhelming impression given by the TSB report is that the accident was the result of an unforeseeable combination of procedural paperwork issues, bad weather and runway lighting problems. In fact it was entirely predictable, and easily preventable with a small change in pilot duties that has been used by other airlines for decades.

This document contains additional information that the author believes is necessary to understand the accident's origins, and for the prevention of future accidents in similar circumstances.

Steve Last, August 2017. www.picma.info

Air Canada 624 Halifax Accident Report Critique - introduction.

Background. Shortly after midnight on 29 March 2015, Air Canada flight 624 crashed at Halifax, Nova Scotia, while attempting to land in a severe snow storm. The crew of the Airbus A320 were making a "Non-Precision" approach which meant their instruments did not show any vertical guidance from a source on the ground.

The approach was steeper than planned and the aircraft struck the ground short of the runway. Among the 138 people aboard there were injuries but no fatalities; the aircraft was destroyed and there was considerable damage to ground equipment. The Canadian Transport Safety Board conducted an investigation and its report A15H0002 was released on 18 May 2017.

The report runs to some 80 pages plus appendices, covering the history of the flight and post-impact aspects including survival issues, and consists of factual information, an analysis, findings as to cause, risk and other matters, and safety action subsequently taken**.**

Report deficiencies. The author believes that the report omits some very significant matters that consequently affect a reader's ability to understand the causes of or contributing factors to the accident, the safety deficiencies identified, and ways to prevent similar occurrences in future. In the author's opinion, in this respect it does not meet the fundamental purpose of an accident report.

This critique must be read in the context of the full report as it is limited to only paragraphs regarding events prior to the aircraft hitting the ground. No other parts of the report are in question, and this document does not address any post-impact matters or those relevant to survival. Public domain information and the questions that are raised are shown alongside extracts from the report.

A major problem is that although the report describes and analyses events, it does not contain flight recorder or voice recorder records or a detailed graphical representation of the flight profile and associated events, which are vital to properly understanding how the accident came about. For that reason Fig.1 has been constructed from material in the report. It must be emphasised that this is only an attempt to clarify the limited and sometimes conflicting information in the report. It is entirely unofficial and should not be relied on without further verification.

Altitude and height recordings and indications. A very important factor in the accident was the weather, and the associated low temperature which affected the aircraft's altitude instruments. The aircraft's main altimeters get their information from air pressure which is assumed to be at a standard temperature. At low temperatures air is denser and this causes altimeters to over-read.

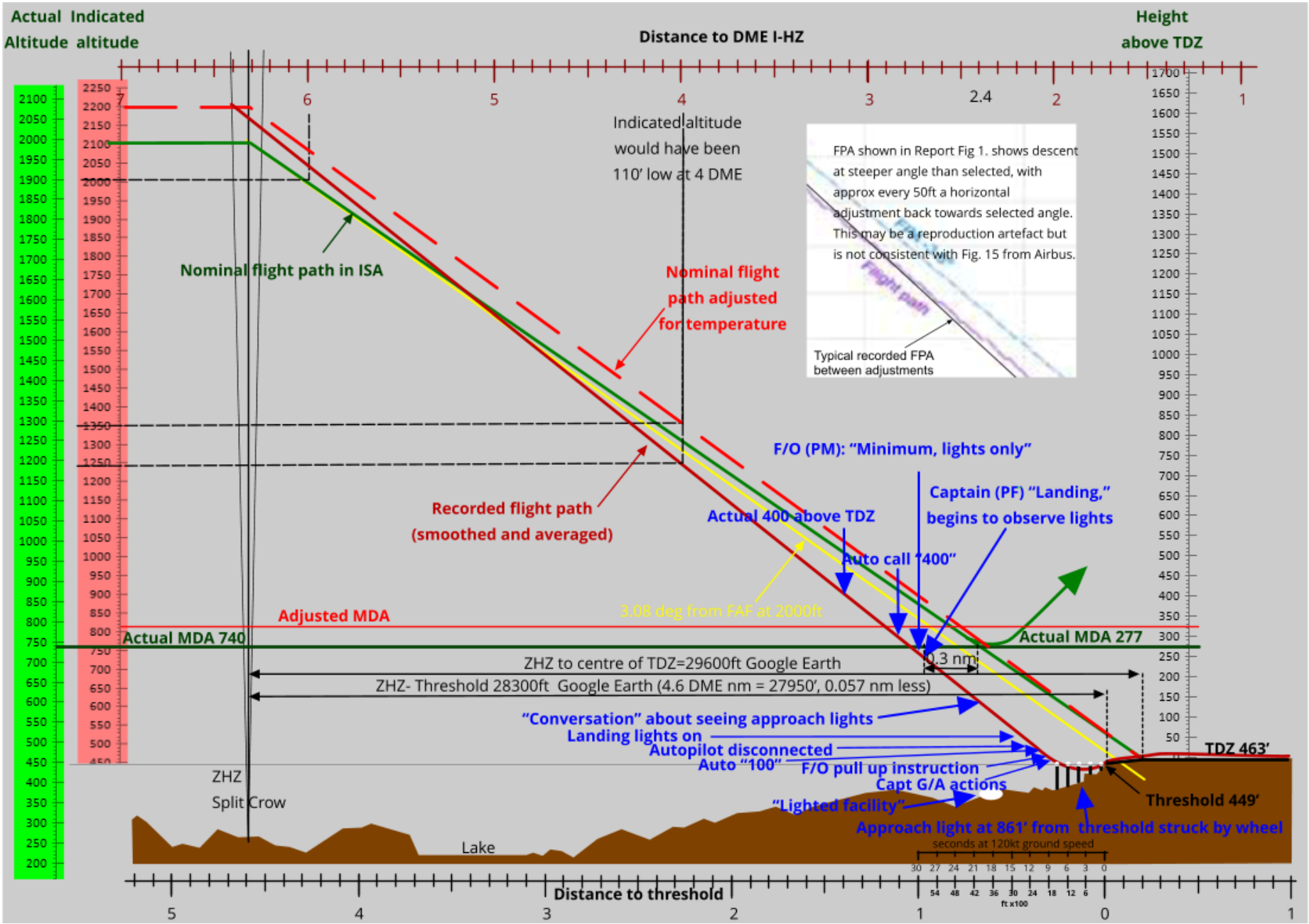
In most airline operations these altimeters read relative to either sea level or an arbitrary standard value. However for approach and landing, the significant factor is the altitude relative to the planned touchdown point on the runway - the "touchdown zone" (TDZ).

The aircraft is also fitted with "radio altimeters" which read the instantaneous height above the ground directly beneath. At most airports, just before landing this is effectively at the same level as the touchdown zone - **but not at Halifax**, where the runway is on higher ground than that under the approach path.

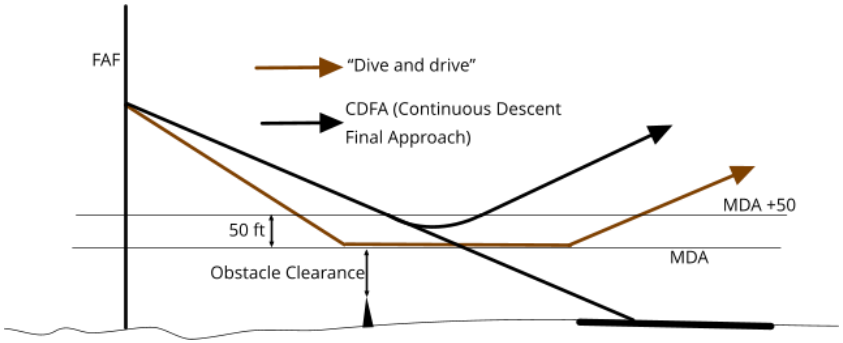
In this accident, none of the pilots' instruments were showing the altitude above the TDZ, which makes it hard to make sense of some of the reported events, so Fig. 1 shows 3 altitude scales.

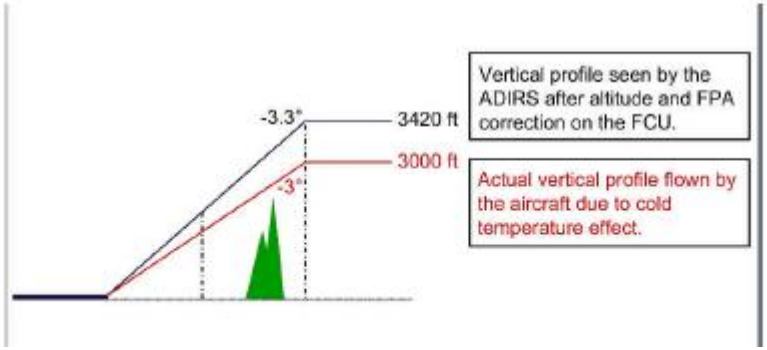
The Green scale is the ACTUAL height above mean sea level (AMSL). Pink shows what the main altimeters were INDICATING as the height AMSL. The scale on the right shows the actual height above the TDZ, which should have been zero when the aircraft touched down, but was not displayed on any altimeters.

A number of events are shown in blue, the positions are estimates from distances, altitudes or time information in the text or footnotes. The terrain information is obtained from the TSB's press conference presentation correlated with data from Google Earth.


Actual Altitude
Indicated altitude
Distance to DME I-HZ
Height above TDZ
Indicated altitude would have been 110' low at 4 DME
FPA shown in Report Fig 1. shows descent at steeper angle than selected, with approx every 50ft a horizontal adjustment back towards selected angle. This may be a reproduction artefact but is not consistent with Fig. 15 from Airbus.
Typical recorded FPA between adjustments
Nominal flight path in ISA
Nominal flight path adjusted for temperature
Recorded flight path (smoothed and averaged)
F/O (PM): "Minimum, lights only"
Captain (PF) "Landing," begins to observe lights
Actual 400 above TDZ
Auto call "400"
3.08 deg from FAF at 2000ft
Adjusted MDA
Actual MDA 740
Actual MDA 277
0.3 nm
ZHZ to centre of TDZ=29600ft Google Earth
ZHZ- Threshold 28300ft Google Earth (4.6 DME nm = 27950', 0.057 nm less)
"Conversation" about seeing approach lights
Landing lights on
Autopilot disconnected
Auto "100"
F/O pull up instruction
Capt G/A actions
"Lighted facility"
Approach light at 861' from threshold struck by wheel
TDZ 463'
Threshold 449'
ZHZ
Split Crow
Lake
seconds at 120kt ground speed
Distance to threshold
ft x100

	Report reference and text		Comments and supplementary information
1.	Section 1.1 - History of the flight		
2.	**Issue**	**Report text**	
3.	INFORMATION OMITTED - Approach and go-around briefing details.	At about 2256, Air Canada dispatch provided the flight crew with weather updates .....The flight crew performed the go-around briefing and repeatedly reviewed the weather conditions at CYHZ..... At 2321, about 2 minutes after the flight was cleared to descend to flight level 290, the flight crew carried out the approach briefing for a non-precision LOC approach to Runway 05, followed by the pre-descent checklist. These briefings included the corrected altitudes and amended FPA. The approach was to be coupled–selected with a manual landing.	A "go-around (G-A) briefing" evidently occurred between 2256 and 2311 when the 2300 METAR was received; an "approach briefing" was about 20 minutes later. While the discussion of conditions and consequent options is exactly what would be expected, normally these two briefings would form part of a single briefing on a connected sequence of events (descent > approach > go-around / landing). Without a CVR transcript it is not evident whether there was any discussion in either of these briefings of the likely sequence of visual cues and possible illusions due to the "black hole" environment, the very basic runway lighting, and runway's initial slope, or even whether the crew were aware of the latter. It is also not evident whether either briefing included rehearsal of specific Go-Around actions including autopilot usage and modes (the eventual go-around attempt was manual whereas normally an autopilot one might be expected), or whether it was confined to routing and altitudes.
4.	Cold temp. correction	It was determined that the FAF crossing altitude would be 2200 feet above sea level (ASL), based on the published altitude of 2000 feet plus a cold temperature correction of 200 feet.	An approximate low temperature correction is 4 per cent height increase for every 10°C below standard temperature as measured at the altimeter setting source. Halifax airfield elevation is approx 500ft with temp -6C. Standard lapse rate is 2deg/1000ft so MSL temp = approx -5C. In ISA, MSL temp is +15C, so cold temp correction is for ISA-20 and equals 8%. Airbus' Flight Crew Training Manual (FCTM) gives 160ft altitude correction at 2000ft for airfields at sea level, and states it is conservative (i.e. on the safe side) for airfields higher than sea level. Rounding up to nearest 100' is also conservative. The author's calculation is that the 2200' indicated altitude used was a true altitude of approx 2080'.
5.	MDA correction	The MDA was calculated at 813 feet ASL, based on the published MDA of 740 feet ASL plus a cold temperature correction of 23 feet, plus 50 feet added to the corrected MDA, as required by Air Canada's *Flight Operations Manual* (FOM).	The 50ft FOM addition is applied to a Continuous Descent Final Approach (CDFA) which is recommended as safer than a "Dive and Drive" non-precision approach. Adding 50ft to the cold-weather adjusted MDA allows a decision to go-around to be implemented without the aircraft infringing the actual MDA, which assures obstacle clearance. The 50 ft height loss allowance accepts that the aircraft will descend somewhat after the decision is made, as it takes time before the aircraft can respond when the go-around is initiated. With a "Dive

			and drive" approach there is no height loss as the aircraft is not descending when the go-around is initiated. 
6.	INFORMATION OMITTED - MDA setting in MCDU	No record of whether the pilots set either the corrected Minimum Descent Altitude, or the corrected MDA+50ft, being used an equivalent to a Decision Height in the MCDU, which would affect whether a number of alerts and warnings occurred. The report's Airbus-supplied illustration PFD image shows the correct localiser frequency IGK 109.9, track 053, and MDA 813'. It shows approx. 8 deg. of right drift. An altitude of 800 ft is in GREEN below the adjusted MDA being used by the crew and shown in the FMA. It is my understanding that below MDA the altitude indication is AMBER not green. A radio altitude of 400ft is also shown in green though again according to my copy of the FCOM, "If no DH has been entered, or if both FMGCs fail, the radio height appears in amber, when RA ≤ 400 ft". A radio altitude of 400ft is consistent with 800ft baro. although the actual height above the TDZ at this point was only 300' on this approach due to the sloping terrain. Flying a constant descent angle approach with no level segment, the crew would use the corrected MDA+50 as a Decision Altitude. In a precision approach the Radio Altimeter would be used to provide automatic callouts and other instrument indications of reaching DA. In an non-precision approach (NPA), the PM should call at "100 above" and "minimums". The availability of automatic calls when using a barometric reference (MDA) depends on operator choice and aircraft modification state, which is not stated.	
7.	Flight Path angle temperature corrections	The flight crew calculated a flight path angle (FPA) based on the temperature-corrected FAF. The calculation was based on the published vertical descent angle of −3.08° obtained from the Jeppesen approach chart (Appendix A) and Air Canada's *Airbus A320 Quick Reference Handbook* for a final calculated FPA of −3.5°.	Airbus FCTM information: "*Note: The ADIRS computes the FPA from inertial data and barometric altitude.* When the temperature is lower than ISA, the FPA that the aircraft actually flies is less steep than the FPA that the ADIRS (ISA referenced) computes". The FPA calculation should take the aircraft to the touchdown zone which is about 1000 ft beyond the threshold. In this case the TDZ is 14 ft higher than the threshold so crossing height at the threshold should be about 64 ft .

			Example **EXAMPLE** Airport outside temperature -20 °C ; Delta ISA = -35 °C. Approach: FAF at 3 000 ft ; Final descent slope 3 °.  The process reported seems valid BUT the FCTM illustration of this for ISA-35 shows an altitude correction of 420 ft at 3000ft (equivalent to the 160ft calculated above), and the associated FPA change shown is from 3° to 3.3°. (i.e. **-0.3°**). For AC624, at ISA-20 the cold temp correction would be expected to be significantly LESS than for ISA-35, but is calculated here at 0.42° degrees to give a FPA of -3.5°. Thus, the angle in the Airbus drawing appears to be wrong, the horizontal distance for 3000ft at 3.0° is 57,234'. 3420ft altitude produces an apparent VDA of angle of 3.42° degrees not 3.3° as shown, i.e. **-0.42°** correction.
8.	Altitude references	Throughout the report altitudes are referred to as "ASL" which the glossary gives as "Above Sea Level". E.g. at 00:26 " The aircraft levelled off at 2200 feet ASL, the landing gear was extended, and the missed approach altitude was set."	It is not clear whether these refer to ACTUAL altitudes or INDICATED altitudes. The author assumes they are INDICATED since these are what is shown on the only data chart, on report page 5. If so, heights such as the 2200' stated here would have actually been lower, and the aircraft did NOT level off 2200 "feet above Sea Level": the "Feet" referred to are actually only 11.1 inches due to temperature error.
9.	Approaching FAF	At 0.3 nm from the FAF, the PF rotated the V/S-FPA knob to select −3.5°..... the PM indicated that ground lighting was noted.	A second reference to early sight of the ground contributing to plan continuation bias, an earlier one being when 11 nm out.
10.	INFORMATION OMITTED - Horizontal position Data	No record of how these distances were determined: were the ILS DME I-HZ and NDB ZHZ tuned? What navigation display was selected to show horizontal position?	
11.	Final approach started	The aircraft started to descend about 0.2 nm from the FAF. The aircraft crossed the FAF at	Although this was already slightly low (30ft) on the intended flight path, it was above the required approach profile in ISA.

		2170 feet indicated altitude (Figure 1).	
12.	During final descent	As the aircraft descended, the actual flight path diverged from the desired profile as a result of wind variations. The divergence continued to increase throughout the approach. The airspeed was constant, and the vertical descent speed ranged between 700 and 800 feet per minute (fpm).	There is no indication of what the wind was or why it would cause a steadily increasing divergence. The Airbus description (Fig 15, p50) shows that individual occurrences of divergence due to wind variation cause the aircraft to PARALLEL the selected FPA, not continue to diverge from it. See also comment on 1.18.2. The flight path trace (fig 1 of the report) indicates that at Split Crow the indicated altitude was 2170' and at 1 nm from threshold it was 750'. This gives an indicated height reduction of 1420ft over 3.6nm or 21,874 ft. which computes to an average gradient of 3.7 degrees, however these distances etc. are subject to rounding errors, chart and graph interpretation etc. Using a more accurate distance from SC to the threshold of 22175 ft, the indicated angle computes at 3.66 degrees. This is of course steeper than the true angle flown. My calculation of the ACTUAL angle of descent is based on estimated corrected altitudes of 2050 ft to 720ft = 1330' height change. This computes to 3.48 deg., very close to the 3.5 degree descent angle selected.
13.	INFORMATION OMITTED - Flight Data Recorder (FDR) readout, radio communications (R/T) and Cockpit Voice Recorder (CVR) transcripts	Apart from report fig 1, no FDR data is provided, nor any verbatim transcripts of voice communications either between the pilots or between aircraft and ATC. On page 1 it is stated to be privileged as "unrelated to the causes or contributing factors of an accident or to the identification of safety deficiencies." There are multiple reasons to question this, principally that the absence of basic FDR data makes it impossible to validate many statements made in the report e.g. the impact of wind and wind changes during the approach. It is not clear what if any other procedural callouts and crosschecks were made by the crew members, whether there was any conversation, or was there 2 minutes 30 seconds silence between 00:27 and 00:29:27.	
14.	INFORMATION OMITTED- Radio Altimeter callout	At 1.5mi. a radio altimeter callout of "500 ft", would have been expected, coinciding with a callout of "100 above" (MDA), either automatic from RA if set, or by the PM. Terrain information is not shown in the report Fig. 1, but that obtained from a screen shot of the TSB Press Conference presentation video correlates with data from Google Earth.	
15.	Close to minimum	At 0029:27, a radio altimeter automated audio call (automated call) of “400” was made, indicating that the aircraft was 400 feet above	At 400' RA above terrain however it appears that the aircraft was only 320 ft above the touchdown zone due to the sloping terrain (approx. 66ft) and runway slope (14ft).

		the terrain.	
16.	Crossing minimum	Almost immediately after this call, the aircraft crossed the calculated MDA at 1.2 nm from the threshold.	This could depend on which part of the aircraft is counted at this point. Wheel height is approximately 15-20 feet less than the barometric source. The radio altimeter reference is lower the barometric reference but obviously they were very close together. The MDA is the "altitude below which descent shall not be made until the required visual reference to continue the approach to land **has been** established" (emphasis supplied). The comment re.1.18.4 notes that the Airbus FCTM includes the statement "The Decision Height (DH) is the **wheel height** above the runway elevation...."
17.		The PM observed some approach lights and called, “Minimum, lights only,” when the aircraft was about 1.0 nm from the threshold	The First Officer (PM) was head up at this point, and the "minimums" call was not made until the aircraft was below the MDA.
18.		The PF immediately called, “Landing,” and began to observe some approach lights.	This states that the Captain (PF) announced his decision to land BEFORE observing the visual cues. The Captain's decision was therefore based only on the fact that the F/O had seen some cues around the MDA, and without any knowledge of what they meant in terms of aircraft position and velocity. The legality of this situation could be dependent on whether it is the PILOT (e.g. PF) who should have adequate visual reference as defined. CARs seem to refer only to "the pilot" in this context.
19.		By this time, the aircraft had crossed the published MDA (740 feet ASL) and was 0.3 nm farther back than the published distance.	An inaccuracy in distance arising from accumulated tolerances and errors during the instrument part of an approach is to be expected, especially during a NON precision approach. This is safe provided the aircraft does not descend below the MDA without it being recognised. This is the purpose of the ICAO visual reference requirement that the pilot have **completed** assessment of the position and flight path from the visual references before leaving the DH/MDA, and must initiate a go-around at this height if they are not satisfactory. (By definition, in a "dive and drive" approach the aircraft may be flown level AT the MDA at almost any distance from the threshold).
20.		The autopilot remained engaged as the aircraft continued descending, and there was no reduction in the descent rate.	The FCOM requires that the autopilot be disconnected at MDA if the pilot considers the flight path and visual references are suitable to continue descent, and this continuation must be in manual control as the autopilot's earlier inputs no longer have valid information regarding the position of the runway. However, in this case the aircraft continued descent under autopilot control on an unsafe flight path, which the crew had not detected by either instrument or visual cues.
21.		When the aircraft was about 0.7 nm from the threshold, the flight crew had a conversation in which both confirmed they could see some approach lights. At this time, the aircraft crossed over a lighted facility.	The contents of any "conversation" about visual cues when below MDA are clearly relevant to "the causes or contributing factors of an accident or to the identification of safety deficiencies", but are not provided. Both pilots seem to be head up, while the autopilot is still taking the aircraft on an unsafe flight path. A "conversation" implies an exchange of ideas over a period of time, possibly as much as the 20 seconds between the specific times

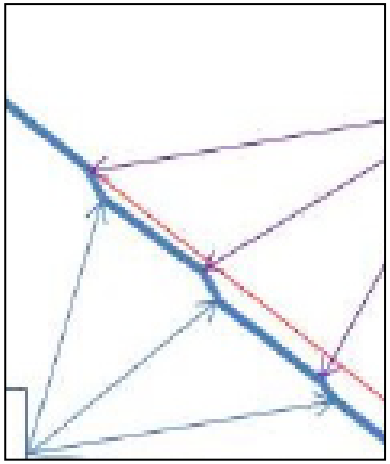
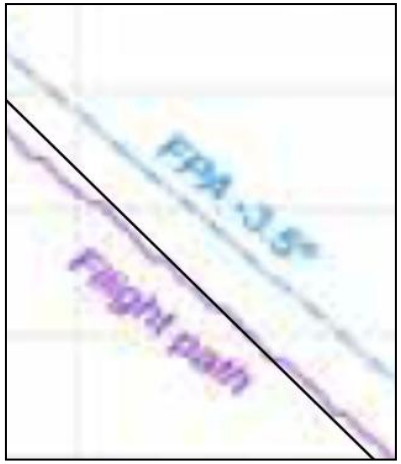
			of 0029:27 and 0029:47.
22.		At 0029:47, the landing lights were selected ON, followed in very quick succession by the PF disconnecting the autopilot, an automated call of “100,” an automated call of “50,” and the PM instructing to pull up.	The rapid succession of "100" and "50" automated calls reflect the steep rise in the terrain immediately before the threshold. The go-around was called first by the F/O (PM), implying that the Captain as PF may not yet have recognised the situation. According to footnote 17, the autopilot disconnection was at 30ft above threshold elevation and only 16 feet above the planned touchdown zone elevation.
23.		About 1 second before initial ground impact, the PF advanced the thrust levers to the takeoff go-around detent and pulled the side-stick to the full nose-up position.	The initial ground impact may be that with the approach light 861 ft from the threshold (strobe 3) but this is not clear.
24.		At 0030:00, the aircraft’s main landing gear, aft lower fuselage, and left engine cowling struck the snow-covered ground on the south side of the embankment that sloped up toward the runway surface.	Fig. 1 indicates that the lowest point in the go-around was an indicated altitude 50ft BELOW the threshold. It was only the good fortune that the ground sloped so steeply that prevented the aircraft striking the ground at its full rate of descent, which would have had totally catastrophic results and 138 fatalities. It appears that the aircraft was actually below the runway elevation for several seconds.
25.	INFORMATION OMITTED - timeframe of events	Without a time-frame transcript showing it is difficult to understand the exact sequence, for example if any seconds elapsed between the "PM instructing to pull up" ("shortly after" 00:29:47) and "ground impact" at 00:30:00 - an elapsed time of 13 seconds. However this appears unlikely if the sequence was actually as stated.	
26.	**Section 1.2 Injuries, 1.3 Aircraft Damage, 1.4 Other Damage - no comments**		
27.	**Section 1.5.1 Flight Crew**		
28.	Relation between pilots	The captain had over 9 years of experience at Air Canada and had flown as a first officer (FO) on the A320 for about 7 years before he had qualified as captain in 2013. As a captain, he had flown about 1200 hours as pilot-in-command. The FO had 15 years of experience at Air Canada and had flown as an FO on the A320 since being hired.	The two pilots had almost the same total flight and A320 experience, but had never flown together before. The Captain had been an A320 F/O for 7 years prior to promoted to Captain 2 years previously. The F/O had been on the A320 for 15 years (6 years longer) but remained as a F/O. Since in many airlines seniority/length of service is a major factor in promotion as well as personal choice and individual competence, it is unusual to find an F/O with more seniority (almost twice the time in the company) than the Captain.
29.	INFORMATION OMITTED - Training and experience.	No information provided on for example recent exposure to an approach of this type or in similar conditions, or any training in recognition of unsatisfactory aircraft trajectory in marginal visual cues. Such experience is frequently considered in accident reports, e.g. in report A96A0035, referring to an accident on the same approach in broadly similar but somewhat better conditions. A review of training records could also eliminate the possibility that a cross-cockpit authority issue could have affected the initial decision to make an approach rather than divert, or had an influence on plan continuation bias at MDA, and the non-disconnection of the autopilot when required at MDA.	

30.	**Section 1.6 Aircraft information.**		
31.	INFORMATION OMITTED - Navigation displays	No reference to the navigation displays which show aircraft position in relation to the runway.	
32.	**Section 1.7 Weather.**		The weather was extremely marginal for this operation with visibility forecasts and reports as low as 1/4mile and vertical visibility as low as 200ft. Surface wind was generally direction 340DegT with a minimum of 19kts, and credible wind gusts of 40kts at surface level which were likely to be higher at approach altitude. This would have led to drift angles of perhaps 7 to 15 degrees placing any visual cues well to the right of the pilot's field of view. Snow was variable from light to heavy with drifting. The nature of such snowstorms is that they vary from point to point so reports made at the airport weather station may not be at all representative of contemporaneous conditions on the approach path.
33.	**Section 1.8 Navigation Aids, 1.9 Communications - no comments**		
34.	**Section 1.10 Aerodrome information**		
35.	INFORMATION OMITTED - previous accident on same runway in similar weather.	This report cites four previous TSB accident reports (in regard to CVR power supply, child restraint systems, carry-on baggage, and floor penetration). However, no mention is made of a previous report A96A0035 on an accident in similar circumstances on the same runway, also involving crew judgment of visual cues in poor visibility.	
36.	1.10.1 Runway slope	Runway slope Runway 05 is oriented 053°M and has an upslope throughout the touchdown zone. The threshold elevation is 449 feet ASL, and the highest elevation within the touchdown zone is 463 feet ASL.	The up-slope is very close to the maximum above which it must be notified to pilots on charts. Report A96A0035 refers to this at greater length: "Runway [05] has an upslope of 0.77% in the first portion of the runway, which is close to the normal limit specified by TP312. The illusion created by the upslope is that the aircraft is higher than it should be, and a reaction to correct for this perceived problem causes the aircraft to deviate below the proper path. There was nothing on the approach chart to indicate that the first portion of the runway was sloped up. Also, there does not seem to be any way for the crew to have determined that runway 06 had an upslope in the first portion of the runway. Only average

			slope is provided if the average runway slope exceeds 0.3%. The visibility present during the landing would limit the amount of runway that could be seen, which would have made the first portion upslope more of a visual illusion problem".
37.	1.10.2	Approach and runway lighting • the prevailing visibility of ½ s.m. can be used to define the transmissivity of the atmosphere available to the pilot landing on Runway 05; • the transmissivity can also be applied to the slant visual range when the pilot is above the airport elevation	These two assumptions in the theoretical light visibility estimate amount to a single assumption that there was a uniform air mass, which was clearly not the case, so the calculations must be treated with great caution.
38.	**1.11 Flight Recorders, 1.12 Wreckage and impact - no comment**		
39.	**1.13 Medical Information**		
40.		Obstructive sleep apnea (OSA).	The report devotes 5 pages (over 6% of its total length and 2100 words) to this subject before concluding that although the Captain would have been at risk of fatigue related to chronic sleep disruption caused by this condition, there was no indication that fatigue was involved the accident.
41.	**1.14 Fire, 1.15 Survival - no comment.**		
42.	**1.16 Tests and Research**		
43.	Simulation	The accident occurred when the crew did not detect that the flight path was dangerously in error until immediately prior to ground impact after passing MDA. Given the stated problems associated with the weather conditions, and the absence of information as to what visual cues the crew actually observed, it is surprising that no simulator trials were made to determine whether it was even theoretically possible to detect the divergence from the range of cues which were estimated to have been potentially available.	
44.	**1.17 Flight crew training**		
45.	INFORMATION OMITTED - flight crew standard operating procedures	No copy of the crew coordination procedures used, specifically the allocation of crew duties and callouts for the approach and go-around. Other evidence in the report leads to the conclusion that the crew were trained only to use "traditional" duties which are known to lead to both pilots simultaneously being exposed to visual illusions, and inadequate monitoring of instrument cues.	

46.	1.17.1.2	Air Canada considers an aircraft to be on the correct vertical approach path when the flight crew has selected the correct FPA, in accordance with the SOPs. Given that the above criteria were met, AC624 was considered to be on a stable approach.	This means that there is no requirement to consider whether the FPA selection has a satisfactory result. This contradicts the principles of the AQP, which "focuses heavily on crew resource management, including threat-and-error management, in which potential hazards are analyzed and appropriate steps are taken to avoid, trap, or mitigate threats and errors before they lead to an undesired aircraft state".
47.	1.17.1.3	On a non-precision approach, once the flight crew has established visual contact with the runway environment and the autopilot has been disconnected, the PF manually flies the aircraft using visual cues to determine its lateral and vertical position relative to the runway. Air Canada training and pilot experience both reinforced the knowledge that there may be a need to make minor corrections to the flight path to ensure the aircraft maintains a stable approach and crosses the threshold at the correct height to ensure landing in the touchdown zone.	This refers to "the crew" having visual contact with the runway environment without saying which crew member. The PILOT FLYING must control the aircraft manually using the visual cues to maintain or make small corrections to the correct flight path to the runway. Since the PF must make manually make any control inputs to achieve such corrections, only he/she can determine whether the aircraft's position and rate of change of position (velocity) is such that this can achieved. Any input from the other pilot can only be advisory.
48.		During a non-precision approach, when the aircraft reaches the MDA, a PM is required to make a call of “Minimums” followed by either “No contact,” “Lights only,” or “Runway in sight.” The response by a PF is to call either “Go-around, flaps” or “Landing.” Air Canada does not provide any specific training on or definition of what “Lights only” entails. When a PM calls, “Lights only,” a PF expects that the PM has acquired visual references in order to continue with the approach. The typical response is for the PF to call, “Landing,” and to continue with the approach.	If the actual conditions are not very close to limiting this is easy. In marginal conditions it requires the PM's attention to be simultaneously outside the aircraft looking for cues, and inside looking at the altimeter. Time is needed for eyes to accommodate from exterior to interior, and this will tend to lead to inaccuracy in the callouts. In this case the aircraft had passed MDA before the callout was made. This "expectation" in the AC procedure in effect delegates the landing decision to the PM, whereas the responsibility for its consequences rests with the PF.
49.	1.17.1.4	Although the Air Canada FCOM identifies the requirement to monitor and adjust the position and flight path, pilots do not have access to this	It seems that pilots do not have access to some of the basic documents for their aircraft. TC seems to have approved a process whereby extracts from Air Canada's FCOM are converted into an Aircraft Operating Manual which is then issues to the pilots without necessarily

		document as a reference.	being comprehensive.
50.	INFORMATION OMITTED - autopilot disconnect warning	In accordance with the AOM section 1.01.22, Autoflight limitations, at the MDA, when the required visual conditions are met to continue the approach, the autopilot must be disconnected. During the occurrence flight, the autopilot was not disconnected until the aircraft reached 484 feet ASL, about 23 seconds after passing the calculated MDA of 813 ASL, which did not conform with an aircraft flight manual limitation, CARs 602.07(a), or Air Canada's SOPs.	An amber message DISCONNECT AP FOR LDG is displayed when, during a Non Precision Approach, the AP/FD remains engaged at Minimum minus 50 ft, or - 400 ft AGL (if no minimum entered). This message should therefore have been visible but there is no record of whether either crew member observed it, and if so made the required callout. During each of these 23 seconds the autopilot was causing the aircraft to deviate further from its correct flight path, at a time when only small corrections TOWARDS the correct flight path were permitted. It is not simply a technical non-conformity with a limitation or SOP.
51.		Pilots refer to Air Canada's SOPs; however, these do not provide direction on monitoring the vertical flight path when the FPA guidance mode is engaged, nor is such monitoring taught in training (Table 4).	Operators are entitled to develop different procedures to those provided by the manufacturer but the AC FCOM was identical to the Airbus one. There was therefore a major difference between internal documents the AC FCOM and the AC SOP, which had not been identified during TC inspections.
52.	**I.18**	**Additional information**	
53.	1.18.2	Flight Path Angle guidance mode When flying with the FPA guidance mode, external perturbations, such as wind variations or turbulence, can cause the aircraft to move away from the selected FPA initial approach path. If these perturbations result in momentary changes to the aircraft's vertical trajectory, then the autopilot will recover the selected FPA, effectively paralleling the initial trajectory	It is understood that Airbus uses the calculation FPA = arc tan(Vzbi/GS), where Vzbi = baro-inertial Vertical Speed (inertial for accuracy in dynamic manoeuvres & barometric for stability in time) and GS = Groundspeed. Vzbi is computed from Vacc (Vertical acceleration from IR), Hi (Inertial altitude from IR) and Hb (Baro altitude from ADR). Report Fig.15 (below left) illustrates the "perturbations" as described by Airbus, showing downward steps away from the initial selected FPA, followed by longer sections returning parallel to it. The printed trace in report Fig 1 (below right) is poor quality but shows the perturbations recorded, which has long sections where the "best fit" lines for the actual flight consistently DIVERGE from the selected FPA, with short horizontal steps back towards it. Without a full FDR readout and knowledge of the FPA algorithm which includes both barometric and inertial inputs, it is impossible to tell what was happening. However, given that no information whatever is provided on the winds experienced during the descent, "external perturbations such as wind variations or turbulence" does not explain the actual

			flight path.  Airbus (Fig 15)  Report (Fig 1)
54.	I.18.3	Cold temperature correction	*The FCTM section reads* "Note: The ADIRS computes the FPA from inertial data and barometric altitude. When the temperature is lower than ISA: - The true altitude of the aircraft is lower than the altitude that the ADIRS computes. - The FPA that the aircraft actually flies, is less steep than the FPA that the ADIRS computes. If appropriate, the flight crew should therefore apply corrections on the altitudes and on the FPA (in vertical selected FPA mode), and they should be vigilant on the parameters that are displayed. FPA Correction When the temperature is lower than ISA, the FPA that the aircraft actually flies is less steep than the FPA that the ADIRS (ISA referenced) computes. In vertical selected mode FPA, to correct the FPA for this ISA deviation effect, the flight crew should select on the FCU a FPA slightly different from the FPA that the aircraft needs to fly. In any case, the check "altitude (corrected in temperature) versus distance" remains the reference.
55.	INFORMATION OMITTED - Canadian non-compliance	In the report's discussion of "Required Visual Reference" definitions which follows, there is no mention of ICAO Standards and Recommended Practices. The quoted Canadian legislation negates the entire basis of ICAO SARPS regarding weather minima, which is also emphasised in Airbus documentation.	

	with ICAO Standards	DH is the lowest altitude at which reliance on instrument information alone can ensure safe flight and avoidance of obstacles. In ICAO Annex 6, "required visual reference" means that AT DH/MDA visual cues "should **have been** in view for sufficient time for the pilot to **have made** an assessment of the aircraft position and rate of change of position in relation to the desired flight path". The Decision required at DH is that the visual cues **currently show** that the aircraft's position and velocity are satisfactory to continue. If this is not the case a go-around must be initiated immediately.	
56.	1.18.4	Required visual references. Section 100.01(1) of the CARs defines required visual reference as follows: In respect of an aircraft on an approach to a runway, means that portion of the approach area of the runway or those visual aids that, when viewed by the pilot of the aircraft, enable the pilot to make an assessment of the aircraft position and rate of change of position, in order to continue the approach and complete a landing. This information is also found in the TC AIM (section GEN 5.1), and in the CAP GEN. The TC AIM, the CAP GEN, and the Air Canada FOM all list the following 10 items, of which pilots should see at least 1 in order to continue an approach to a safe landing and to meet the requirements for required visual reference*: [list given, not repeated here]*. The Air Canada FOM did not identify that the required visual reference should enable the pilot to assess aircraft position and rate of change of position in order to continue the approach to a landing.	Canada's FARs only require that the visual cues at DH "**enable"** the pilot to make an assessment of the aircraft position and rate of change of position, in order to continue the approach and complete a landing. It places no limit on how long the assessment can take. This assessment can have 2 outcomes: that position and velocity are satisfactory, or that they are not. If the answer is "NOT" then by definition the aircraft has been in an unsafe position throughout the assessment period, during which time the pilot has not had adequate information to avoid obstacles. The Airbus FCTM includes the statement "The Decision Height (DH) is the wheel height above the runway elevation by which a go around must be initiated unless appropriate visual reference has been established and the aircraft position and the approach path **have been assessed as satisfactory** to continue the automatic approach and landing safely." Later it states that "It should be stressed that the **DH is the lower limit of the decision zone**." Canada's version of required visual reference requires only that at DH/MDA a decision is announced that at least one of number of cues is visible. At that moment these may not in themselves have ANY implications about the aircraft's actual position and velocity relative to the correct flight path. Time is needed to make any such assessment, as was evident in this accident. **In effect, under Canada's CARs it is legal to fly the aircraft in conditions in which its safety is not assured. Below DH the pilot has ceased to have sufficiently accurate instrument information to avoid obstacles, but it is possible that he/she either (1) may not yet have assessed from visual information whether its position and velocity are satisfactory, or (2) actually have confirmed that its position and trajectory are unsafe and that a go-around is required, but now be below the altitude at which a go-around can safely be carried out.** **While the report makes considerable play of non-compliance with ICAO and EASA rules regarding CVR power supplies, it makes no mention of the (far more serious) fact that CAR 100.01(1) is in direct conflict with both ICAO Annex 6 and EASA wording intended specifically to prevent this situation arising.**

57.	1.18.5	Visual Cues As an aircraft moves beyond the MDA, it is expected that visual cues associated with the runway environment will become increasingly visible to the flight crew and will assist with assessment of the aircraft position and rate of change of position in relation to the runway.	While the expansion of the visible cues may generally occur it is not an expectation that should be relied on. It will not necessarily occur in conditions such as shallow fog or variable obscuration by fog, rain or snow. It is for this reason among others that the ICAO Annex states that the cues "should have been in view for sufficient time" prior to descent below DH/MDA. Even in "ideal" conditions of uniform obscuration, the allowed visibility minima do not provide assurance that cues at DH will be sufficient to judge the vertical trajectory.
58.	INFORMATION OMITTED	In neither 1.1 "History of the flight" nor this section on visual cues is there any record of what the crew recalled actually seeing. This was the subject among other things of a "discussion" between the MDA and the go-around initiation, the contents of which are not stated. Given that both survived without major injuries and could be expected to have a recollection of events it is remarkable that no information on these is given and the subsequent analysis is based on only on speculative possibilities.	
59.		Approaching a runway that has even a small uphill slope can create an illusion that the aircraft is too high. When visibility is poor, runway environment visual cues become visible to the flight crew later in the approach sequence than they would under good viewing conditions. When these visual cues are eventually acquired, there is less time available to recognize and identify them as well as to understand their configuration in order to effectively judge aircraft position and movement relative to the runway.	These statements are all true and echo those made in the TSB report A96A0035 on a landing accident to a B767 on this runway, also at night and in snow, but with better visibility. The current report does not indicate whether the crew were aware of the runway slope or discussed it during the briefing so as to be better prepared for the visual illusion. The earlier accident crew were not: as that report noted, the (14 ft.) slope from the threshold to the touchdown zone was just below the maximum permitted before it was required to be specifically notified on crew charts. Appendix A is the only chart provided and shows the airport elevation (477 ft) and touchdown zone elevation (463ft). The current CHYZ aerodrome chart does show threshold elevation 449ft, but not TDZ elevation. It would have been necessary for the pilots to do a calculation to realise they were exposed to a significant visual illusion in which the PAPI indication, if seen, would conflict with the visible runway cues.
60.	1.18.7	Cultural lighting on approach to Runway 05. At the time of the occurrence, the approach to Runway 05 had few sources of cultural lighting. The most notable source was a facility located directly under the flight path, about 4000 feet from the threshold.	"Absence of cultural lighting" refers to what is more commonly known as "Black Hole" approach conditions. Such conditions are well known as a source of hazardous visual illusions that can lead to ground contact short of the runway. This report does not indicate whether the crew were discussed it during the briefing so as to be better prepared for the visual illusion. Cultural lighting may be actively misleading if it leads to a false confidence that the actual visual cues will become visible, as happened in this case with the sight of ground lights 11 miles out and at the FAF.

			Lights on the "facility" at 4000ft out were apparently seen, but any vertical position information the crew might have gained would have been seriously misleading as the terrain at this point is approximately 70ft below the TDZ, giving the impression the aircraft was higher than it actually was. Report A96A0035 above noted "In the fall of 1994, Transport Canada (TC) received several complaints from pilots regarding poor vertical reference on runway 06 at Halifax with the ODALS in operation. ..... Transport Canada..... solicited comments from pilots who used the airport frequently. ..... The pilot comments ranged from "comparable to any other ODALS system" to "the worst black hole approach in Canada." TC established that when visible, the PAPI did provide good guidance, but the current report indicates that the PAPI was never visible to the crew, so any runway lighting seen would have been deceptive.
61.	1.18.8	Information processing. Expectation bias describes the fact that, when people expect one situation, they are less likely to notice cues indicating that the situation is not quite what it seems. Expectation bias is worsened when people are required to integrate new information that arrives piecemeal over time in incomplete, sometimes ambiguous, fragments. Plan continuation, a form of confirmation bias, is a “deep-rooted tendency of individuals to continue their original plan of action even when changing circumstances require a new plan.” Once a plan is made and committed to, it becomes more difficult for stimuli or conditions in the environment to be recognized as indicating change than if a plan had not been made. For a pilot to recognize and act on a reason to change the plan in a timely manner, a condition or stimulus needs to be perceived as sufficiently salient to require immediate action.	The crew coordination procedures used by Air Canada and most other airlines are very vulnerable to hazardous Plan Continuation bias, because the pilot flying the approach is planning and expecting to make the landing, as has happened on the vast majority of occasions. Plan continuation errors (where the need to change the plan because conditions are not as anticipated) then result in the pilot continuing descent into dangerous conditions. Early sight of the ground can increase the expectation of seeing further cues even in variable conditions when they may not occur, a primary reason why a US NTSB Special Study on approach accidents (AAS 76-5) recommended that callouts of early ground contact be prohibited. The danger from Plan Continuation errors will be mitigated if the pilot flying the approach always plans to make a go-around as in the PicMA procedure. In that case a plan continuation error will result in a go-around which may be unnecessary but is safe. Two other accidents within a few weeks of AC624 (at Kathmandu and Hiroshima) both showed similar characteristics where the crew flew through the Decision Height, one under autopilot control, without adequate visual references but in the expectation of improvements which did not materialise.
62.	1.18.9	Automation.	The safe use of automation relies on recognition of and compliance with its associated limitations. In the context of non-precision approaches and altitudes, the Airbus FCTM

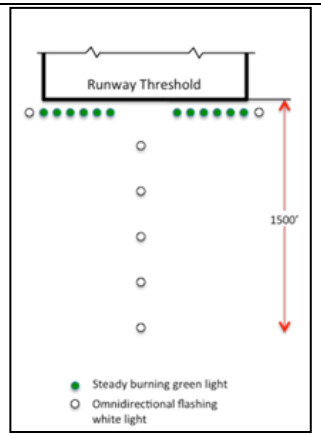
		Autopilot systems reduce pilot operational workload by freeing the PF from routine handling tasks, allowing more time and resources to assess the overall operational situation. Air Canada's AOM states: "as a matter of routine the automation should be engaged as soon as possible after take-off and, circumstances permitting, remain engaged to a late stage on the approach." The A320's autopilot system can be used during most phases of flight, including an autoland, a system that fully automates the landing procedure of an aircraft's flight, with the flight crew supervising the process. Autoland is capable of putting the aircraft in the touchdown zone on an ILS/precision approach without control input from the flight crew.	states: "Reaching MDA, "MINIMUM" is either monitored or called by the crew. The current altitude value becomes amber. If the required conditions are not met by MDA, a missed approach must be initiated. When the required visual conditions are met to continue the approach, **the AP must be disconnected**, the FDs selected off, Bird ON and continue for visual approach." A/P disconnection at MDA is essential as otherwise the aircraft's flight path remains under the control of the autopilot, which no longer has appropriate inputs for guidance, and as in this case can take the aircraft into an increasingly hazardous position. The report does not indicate whether: • the PF made any reference to an intention to leave the AP engaged during the briefing; • whether the PM became aware that the A/P was still engaged during the 23 seconds between passing MDA and its disconnection to initiate a go-around; • whether the PM made any warning callouts in this regard in this period. Normally a go-around from an approach made using the autopilot would also be conducted using the autopilot. There is no indication of whether this was discussed in the briefing.
63.	1.18.10	Reported visibility. TC AC 100-001 Glossary 5 June 2016: RVR is the maximum horizontal distance […], measured by an automated visual landing distance system […], at which the runway, or the lights or markers delineating it, can be seen from a point above its centreline at a height corresponding to the average eye level of pilots at touchdown.	Specific values reported for visibility do not necessarily bear any relation to what will be encountered by an aircraft on the approach. High values will generally do so but as visibility decreases, they become increasingly less likely to be representative of visibility from the cockpit, except in the rare condition of homogenous atmospheric conditions. These did not exist at the time of this accident. Automated RVR values reported to crews are not necessarily actual distances at which lighting may be visible, as is implied by the definition. They are localised measurements of obscuration that are converted into estimates. In variable conditions they may be contradictory and irrational: two different RVR values could apply at the same physical location between two RVR "measuring" points.
64.		1.18.11 Visibility limitations and approach differences	The approach ban concept visibility limit was created to avoid unnecessary missed approaches which are potentially hazardous and commercially undesirable. The fact that values are reported as being at or above approach ban minima conveys no implications whatever about what will be visible at the DH or MDA on any given approach. While Canada has allowed RVR minima to be set without taking account of the type of

			approach lighting, the combination of minimum visibility and DH/MDA generally in use will not permit a runway to be visible at DH/MDA for most types of approach. Accurate assessment of the aircraft's vertical path requires that cues at the point of intended touchdown should be visible, but sophisticated approach light systems can provide a good substitute during the initial part of a visual descent from DH/MDA. An Omni-Directional Approach Light System (ODALS) such as that in use in this accident is the most primitive type of approach lighting permitted. It had no such benefits and provided the pilots with a little lateral guidance but no vertical guidance whatever.
65.	INFORMATION OMITTED - Transport Canada Advisory Circular 0239 and Pilot Monitored Approach procedure	Report footnote 100 refers to Advisory Circular 0237 published by Transport Canada in 2006 on the concept and application of the approach ban. It does not mention that this was **directly associated with publication on the same date of Advisory Circular 0239** describing an alternative crew coordination procedure called the Pilot Monitored Approach (PicMA). The connection between them is that the safety advantages of using the [PicMA] procedure are such that "Operators... whose operation ..... include PMA procedures, may conduct an approach in lower visibility conditions [than those who do not]." AC 0239 recognises that this procedure improves safety in the very circumstances of this accident, i.e. making the transition from instrument conditions to visual conditions for landing in poor visibility. **"The pilot landing has significantly more "heads-up" time for visual scanning outside the flight deck which permits him or her to determine whether sufficient visual references exist to judge the position and rate of change of position of the aeroplane in order to decide to continue the approach visually to a safe landing. In addition, once the decision to continue visually has been made, the other pilot continues to monitor the aeroplane performance by remaining "heads down" on instruments during the landing phase."** This has also been recognised in for example the FAA/ICAO/FSF CFIT Training Aid, which recommends that operators "consider using [PicMA] for all approaches **in IMC and at night"** [i.e. in the conditions of this accident]. Safety benefits from use PMA procedures were extensively discussed in the report A97H0011 when another Air Canada aircraft was destroyed in an accident which has a number of common factors with AC624. Both cases involved: • Ground navigation and landing aids serviceable and operating normally. • Aircraft on an authorized flight with a qualified crew. • Aircraft flown in accordance with applicable regulations and procedures • Very poor visibility • Snow coverage • Minimal but legal lighting • Delayed assessment of visual cues by PF • Initial decision to land by PF	

		• Undesirable timing of autopilot disconnection
		• Subsequent recognition by pilot monitoring of unsatisfactory aircraft position and trajectory, prior to PF recognition of same
		• Call by PM for go-around
		• Ground contact shortly after GA initiation, with loss of aircraft.
		
		Air Canada does not use PMA procedures. Report A97H001 states "The procedures used by Air Canada create a higher workload for the pilot landing the aircraft than is the case for pilots of airlines that use PMA methods. Also, while there may be other factors at play, the TSB review of the landing occurrences shows that airlines using PMA techniques have few landing occurrences related to low visibility. The difficulty stems from the requirement (when using the traditional non-PMA techniques) for the landing pilot to scan in and out of the cockpit as the aircraft nears decision height. In this occurrence, the decision to land was made approximately three seconds after the runway-in-sight call. The verbalized decision to continue for the landing was made when the aircraft was about 165 feet agl, not at 200 feet [the Decision Height in this accident]. This situation is almost inevitable when the weather is at limits and the landing pilot must fly with reference to the instruments until reaching decision height."
		
		If the PMA procedure had been used on this approach it would have mandated
		• The F/O to conduct the instrument approach under the Captain's supervision, with the Captain communicating with the tower regarding visibility and light settings etc.
		• The F/O to have made a call of "100 above" at 100ft above MDA, at which point the Captain would have started seeking visual references.
		• The F/O to call "Decide" at the MDA, requiring an immediate announcement of decision by the Captain of
		  ▪ "Landing" if he had confirmed from the available visual cues the aircraft position and trajectory were satisfactory, followed by
		  ▪ assumption of control and disconnection of the autopilot by the Captain,
		  ▪ continued monitoring of instruments including FMA autopilot engagement status by the F/O
		  ▪ "Go-around" in all other circumstances
		  ▪ immediately initiation of a go-around procedure with the autopilot remaining engaged, by the F/O and
		  ▪ the Captain returning to instrument monitoring of the go-around by the F/O, and communicating his intentions to ATC.

66.	INFORMATION OMITTED - Airbus FCTM	In the Airbus FCTM, the current procedure is understood to be that at the "100 above" call the Captain starts seeking visual references. The F/O continues instrument monitoring throughout. This was not the procedure apparently used by Air Canada .
67.	**Section 2 Analysis**	
68.	2.0 Analysis	In an effort to understand why the accident happened, this analysis will focus on the events, conditions, and underlying factors that caused or contributed to the accident. Since significant information is omitted from the factual information in Section 1, the analysis contains flaws which prevent the causes and underlying factors being fully described or understood.

69.	2.1 Approach visibility limits	If the type of approach lighting system on a runway is not factored into the minimum visibility required to carry out an approach, in conditions of reduced visibility, the lighting available risks being less than adequate for flight crews to assess the aircraft's position and decide whether or not to continue the approach to a safe landing.	Even if the type of approach lighting is factored in, the fact that reported visibility is at or above limits at the commencement of the approach provides no guarantee whatever that adequate cues will be visible on arrival at DH/MDA. It only means that the risk that they will not be adequate and/or the aircraft position and velocity will not be suitable to continue, is such that unsuccessful approaches will be kept at an acceptable rate for safety and regularity. Research since the 1960s shows that while sight of approach lighting gives adequate information for assessment of lateral position and velocity, vertical path judgement requires sight of the point of intended touchdown. None of the current rules linking approach lighting and minimum visibility achieve this, but this situation has been generally accepted by authorities.
70.	2.2 Air Canada FPA training	Although TC reviewed and approved Air Canada's AOM and the SOPs, it had not identified the discrepancy between the Air Canada SOPs and the Airbus FCOM regarding the requirement to monitor the aircraft's vertical flight path beyond the final approach fix when the FPA guidance mode is engaged.	The processes in Air Canada that could have led to such a major difference between the A320 fleet SOPs and the airline's own FCOM for the same aircraft type are not addressed. Radical differences had also developed between AC internal documents (the FCOM and the SOP) without this being identified during TC inspections.
71.		However, in the FPA guidance mode, the aircraft is susceptible to perturbations which, if not compensated for by manual corrections to the FPA, could alter the flight profile.	There is no analysis of the mechanism whereby these perturbations occur, and the **supplied trace of altitude does not correspond to the description provided by Airbus**. Consequently there is no assurance that the subsequent warning to crews - "FPA [flight path angle] is not a vertical navigation system. It is an angle in space. The aircraft may drift above or below the vertical profile." (Report 4.1.1 (c)) - will be effective.
72.	2.3 Approach	INFORMATION OMITTED - GPWS	The approach was on an unsafe trajectory which resulted in a CFIT accident, against which GPWS equipment is mandatory precautionary equipment and was presumably fitted and serviceable. However, it would probably not have been effective as the approach met stable approach criteria. Nevertheless one might expect this to be mentioned in the report.
73.	2.4 Visibility	INFORMATION OMITTED - Pilots' recollection of actual cues.	While there are theoretical calculations of what visual cues MAY have been visible, no information whatever is given as to what the pilots actually recalled seeing, other than that reported by the callout of "Minimum, lights only", and there was a subsequent "conversation" while below MDA about whether each crew member could see approach lights.

74.	2.4.1	Even in clear weather, judging an aircraft's position relative to the desired vertical flight path can be challenging during a night landing, particularly if there is minimal cultural lighting on the approach path to a runway. During this occurrence, the visual cues that would have been available to the flight crew included the ODALS, the runway lights, and the precision approach path indicators. The reduced visibility would have diminished the ability of the flight crew to make use of these cues, either by obscuring them or by reducing the time that they were available. The blowing snow likely exacerbated this situation by momentarily or continuously obscuring some or all of the visual cues.	 Research carried out in the US, UK, France and Australia during development of operating minima (DH/MDA and visibility/RVR) demonstrated that while sight of approach lights is usually adequate for judgement of an aircraft's lateral position, judgement of vertical path requires a point of low or zero relative movement, i.e. the intended touchdown point. Typical operating minima ratios of height to visibility will not provide sufficient visibility for this purpose when the aircraft is at DH/MDA. The less visual information is available, the longer the assessment can be expected to take. The ODALS system (left) available on this approach consisted of 2 threshold lights plus only 5 flashing strobe lights which provide no vertical guidance whatever. Because the strobes flash in sequence, they cannot all be visible simultaneously and unlike more sophisticated systems cannot be shown in a photograph. A full approach light systems in good visibility is illustrated below. 
75.	2.4.2 Visibility estimates		The visibility estimates given indicate that at the MDA, the lighting visible may have ranged from the light at the off-airport facility to the first 3 ODALS lights. These estimates are based on a homogenous air mass, and not the blowing snow conditions actually experienced which may have increased or decreased the cues. In a normal approach the threshold lights when visible will move down the pilot's field of view. If they are stationary or moving up they provide a strong cue that the aircraft is going to touch down short . However if the threshold lights may not even be visible (as the

			calculation shows), no such cues are available.
76.	2.5 Decision to continue the approach	In understanding why the flight crew continued the approach and did not consider a go-around, it is important to consider that the flight crew was interpreting the available visual cues in the context in which they were presented.	"The context in which [the visual cues] were presented" includes the crew's training and procedures, and regulatory requirements , which should have but failed to protect the aircraft and its occupants from coming to harm in these conditions. From here on the report's analysis refers consistently to "the crew" as a discrete unit (akin to a committee), where CARs (and ICAO SARPs) always refer to "the pilot" as responsible for assessment and decision-making. The "flight crew" consists of two individual pilots whose assigned duties and responsibilities should safeguard against individual human errors by redundancy, crosschecking and the provision of fail-safe procedures. The references only to "the crew" show that these safeguards had in fact been removed by the procedures in use by Air Canada - both pilots were exposed to the same inadequate cues and subject to the same potential illusions, while valid alternative information was being ignored.
77.		Both flight crew members had detected ground lighting between the final approach fix and the MDA, which likely reinforced their expectation that they would acquire the required visual reference at the MDA and that a landing could be carried out successfully.	This paragraph describes the known risk that early recognition of visual cues can prejudice the decision DH at in favour of continuation even when it is not justified. The US NTSB recommended as long ago as 1976 that crew procedures should guard against this known risk, and specifically should limit sighting callouts to those visual cues which are associated with the runway environment, and prohibit un-required callouts which can result in the premature abandonment of instrument procedures.
78.		As the aircraft reached the calculated MDA, both crew members observed some approach lights.	**This does not reflect the stated sequence of events.** "As the aircraft reached the calculated MDA" implies that each pilot's observation of some approach lights was simultaneous with passing the MDA. This time is in itself hard to define - which part of the aircraft? By which altimeter reference? With what degree of accuracy? However, according to report 1.1, when the F/O called "minimums, lights only", the aircraft was 0.2 n.m. closer to the threshold than when it crossed the MDA, following which "The PF immediately called, “Landing,” and **began** to observe some approach lights" (emphasis added). The aircraft covers 0.2 miles in approximately 5 - 6 seconds and the descent rate was approximately 11 ft /sec, so the Captain at least could not have acquired sight of the approach lights as stated here.
79.		These cues meet the criteria for required visual reference per the Air Canada Flight Operations Manual, the Transport Canada Aeronautical Information Manual, and the Canada Air Pilot general pages.	**But not the criteria in Annex 6, EASA etc. and the Airbus FCTM. The pilot had not completed an assessment of the aircraft's position and rate of rate of change of position by DH.**

80.		Having visually acquired a portion of the ALS at the MDA, the flight crew decided to continue the approach.	A more correct statement would be that the F/O (PM) had visually acquired a portion of the ALS at the MDA, as a result of which the Captain (PF) announced his decision to continue the approach and commenced seeking his own visual reference.
81.		As an aircraft moves closer to the runway, it is expected that visual cues associated with the runway environment—particularly the number and intensity of the lights—will become increasingly visible.	While this is generally true, it is not an expectation that can or should be relied upon. A basic purpose of the ICAO required visual reference definition is to minimise the risk when this does not happen, by ensuring that the pilot confirm visually that the flight path is safe BEFORE leaving the DH/MDA. If the visual cues do not expand as expected, then a baulked landing go-around can be performed from a known safe position. Despite the lack of facts in the report it seems likely that the visual cues did not expand sufficiently and when the pilots realised this it was too late to avoid collision with the ground, because the aircraft had never been suitably placed at any time below MDA.
82.		In this occurrence, the conditions for the flight crew to acquire and maintain the visual cues would have been challenging because the aircraft crossed the MDA 0.3 nm farther back than the published distance and visibility was reduced by blowing snow.	The very name "non-precision" implies that there will be variability in the position at which MDA is reached. For example , e.g. the promulgated true VDA was 3.08^0 but the nearest selectable FPA value would be 3.1^0; altitudes are rounded to the nearest 10ft or 100ft; additional margins are added, etc. The fact that the aircraft had reached MDA early should not have been critical, it should merely have increased the probability of a go-around being necessary.
83.		At the MDA, the flight crew were occupied with the need to assess the aircraft's position and its rate of change of position. The flight crew were relying on the approach and runway lights to achieve this.	The CAR requirement is that "the pilot of the aircraft" have the required visual references before descending below MDA. If this means either "pilot in command" or "pilot flying" then clearly the narrative states this was not achieved as some distance below MDA "The PF immediately called, "Landing," and **began** to observe some approach lights".
84.		Using the aircraft's autopilot system allows more time and resources to assess the overall operational situation.	This is a valid statement but to be safe relies on adherence to the autopilot's own limitations.
85.		Considering the challenging conditions to acquire and maintain the visual cues, it is likely that the flight crew delayed disconnecting the autopilot until beyond the minimum descent altitude because of their reliance on the autopilot system.	The aircraft controls were being operated by the autopilot, which in turn was under the supervision of the Captain as PF. The required disconnection of the autopilot was the responsibility of the PF alone, and would result in the PF becoming directly responsible for control manipulation to ensure a safe flight path, based on visual cues. As no information is provided regarding briefings etc, nor any record of testimony from the pilots themselves, it is not clear whether the autopilot's continued engagement (for 23 seconds below the minimum permitted usage altitude (MDA) until just before impact) was a deliberate and planned decision or an oversight. The wording here implies that it was deliberate. "The flight crew delayed disconnecting..." implies both pilots were involved when it was the Captain who should have used his side-stick disconnect button at MDA to

			continue descent. The First Officer's (PM's) duties included bringing non-compliance to the PF's attention and would have been reinforced by the existence of an amber FMA message " DISCONNECT AP FOR LDG". There is no indication that this message was noticed or acted upon. This would be expected if leaving the autopilot engaged was deliberate as discussed above. Equally it is possible that both the PF and the PM were preoccupied with attempting to interpret visual cues, which did not provide either with sufficient information to detect that the aircraft was on a near-catastrophic flight path. The autopilot continued to manipulate the controls using its earlier inputs, most significantly to maintain a vertical descent path which had already become incorrect prior to reaching the MDA. This would not have been critical had either a go-around been initiated at MDA due to it being detected by visual cues, or had the autopilot been disconnected at MDA as required following a pilot judgment from visual cues that the error was within limits that allowed for a safe further descent. Leaving it engaged while acquiring visual cues meant that the flight path became increasingly unsafe, as the VDA input was based on instrument flight parameters which would only maintain obstacle clearance down to MDA, and was not valid below the MDA. Thus, none of the "components" in the control chain - PF > autopilot > aircraft - had appropriate or sufficient information to keep the aircraft safe, nor did the monitoring and backup via the PM. Once below MDA the aircraft did not receive any control inputs that would keep it on a safe flight path**, i.e. the aircraft was actually not under meaningful control**, until the Captain disconnected the autopilot after landing lights were selected on, apparently a few seconds before impact.
86.		Flight crews can be subject to a plan continuation bias: without salient triggers, they will continue with their original plan (that is, to carry out the landing). In this occurrence, there was nothing particularly significant to cause the flight crew to re-evaluate their original plan of action. Therefore, the flight crew's recognition	Because the original plan was to carry out the landing, plan continuation bias was inherently hazardous as it would take the aircraft towards the ground. A plan for the pilot flying the approach to make a go-around at MDA will avoid this risk. Callouts that should have been made at 100' above MDA and at the MDA would provide salient triggers for evaluation of progress. There is no indication of whether the "100 above" call was made. The callout for the MDA "minimums" was actually made below the MDA and

		that the aircraft was too low at that point during the approach would have been delayed because of plan continuation bias.	was associated with the statement "lights only". The word "minimums" is an advisory one and especially if left to an automated system creates less of a salient trigger than a call of "DECIDE" voiced by the other crew member. As the report states, in the Air Canada procedure "When a PM calls, “Lights only,” a PF **expects** that the PM has acquired visual references **in order to continue** with the approach. The typical response is for the PF to call, “Landing,” and to continue with the approach." The initial responsibility for determining whether adequate visual reference exists is devolved to the PM, but actual responsibility for making the final determination and completing the landing still rests the PF, leading to a two-stage decision-making process which is incompatible with the basic concept of Decision Height. Particularly when the PM is a First Officer and not the aircraft commander (as should normally be the case in the most critical conditions) the PM will be strongly biased towards interpreting any cues at all as "sufficient", in order to give the aircraft commander the final say as to whether a go-around is needed. Any other announcement will logically lead to a go-around and disruption of the PF's plan to land, with potentially significant operational and economic consequences, which it will then be the PF's responsibility to deal with. This decision-making by committee is inherently unsound, and the procedures and callouts used here directly reinforced continuation bias. If the PicMA procedure advocated in Transport Canada AC 0239 had been in use, all the factors referred to in this paragraph would have been mitigated. The plan would have been for the F/O (flying the approach) to make a go-around; a salient trigger of a "100 above" call would have been made by the F/O and would have alerted the Captain to the need to start looking for and assessing cues. An imperative (rather than advisory) callout of "Decide" by the F/O at MDA would have provided a second salient trigger, and required a positive response from the Captain, without reinforcing any potentially hazardous bias to continue with inadequate cues in the hope and expectation that they would improve.
87.		Visibility estimates indicate that a portion of the runway lighting may have been visible to the flight crew on the approach.	In addition to the visibility estimates it would have been useful to know what if any elements of the runway lighting the crew recalled actually seeing.

88.		To detect any change in the aircraft's position relative to the runway, the flight crew would have used cues such as the aspect ratio between the runway edge lights and threshold lights, the linear perspective of the runway lights, and the amount of space between each runway edge light.	Accurate judgement of the aircraft's vertical flight path relative to the runway would have required sight of the point of zero relative motion, i.e. the current touchdown point compared to the intended touchdown point (ignoring landing flare). The planned touchdown point was at the location of the PAPI approximately 1000ft beyond and 14 ft higher than the threshold. The report indicates that the PAPI was never seen. Cues available from the ODALS approach lighting would have provided minimal lateral guidance, but no vertical guidance. As already noted, movement of the threshold lights within the pilot's field of view is a primary indication of whether the aircraft will touch down short. In the variable conditions these may not have been visible until extremely late if at all.
89.		However, the cues would have appeared late in the approach and the flight crew would not had much time to interpret and react to them. The uphill slope on the runway may also have aggravated the situation.	The report into the earlier accident on the same runway goes into the runway slope issue in some depth.
90.		Although the flight crew eventually became aware that the runway environment did not look as it should have and began a go-around, they did so too late in the approach sequence to avoid the aircraft colliding with terrain. The limited number of visual cues and the short time that they were available to the flight crew, combined with potential visual illusions and the reduced brightness of the approach and runway lights, diminished the flight crew's ability to detect that the aircraft's approach path was taking it short of the runway.	**The ICAO definition of required visual reference was developed precisely to avoid this situation, by requiring the aircraft position and flight path to HAVE BEEN assessed before descent below MDA/DH.** Under CAR 100.01(1) visual cues only need to be sufficient to "enable" such an assessment, and this is interpreted as sight of any one of the listed items. In this case, the combination of visual cues from lighting and weather was so limited that although the pilot's eventual assessment was that the flight path was not satisfactory, the aircraft crashed before it could respond to his initiation of a go-around.
91.	Information omitted - instrument monitoring below MDA/DH	At no point in the history or analysis is there any mention of instrument monitoring after the aircraft reached MDA. All references are **to the crew** (i.e. both pilots) being involved in seeking and interpreting the limited visual cues, as witness the "conversation" on the subject . As noted earlier this may explain why the autopilot limitation annunciation was not observed for 23 seconds. It seems probable that as a result of Air Canada's procedure to assigned initial responsibility for determining the adequacy of visual cues to the PM, there was no effective monitoring of the instruments below the MDA. In conditions where the cues are so limited, and especially where they do not expand as expected, human factors research has repeatedly demonstrated that assessing flight path is very demanding and the attention is focused on the visual scene to the exclusion of other cues, such as instrument information that will also require mental and optical	

		accommodation from "outside" focus to "inside". Nevertheless it is normally a fundamental statement in almost all airline SOPs that the PM (the First Officer in this case)should continue to monitor the instruments below DH/MDA. Although the report does not find that inadequate instrument monitoring was a risk factor, it notes the subsequent "Safety Action Taken" (item 4.1.1 (a) 4th item) that " Pilot monitoring duties have been modified to require a greater emphasis on instrument monitoring during all approaches after the minimum descent altitude." As far back as 1976 the US NTSB made a special study of instrument approach accidents (in that instance, with vertical guidance, which are generally less demanding than Non-Precision Approaches) and made recommendations regarding flight crew procedures. Specifically it was recommended that airlines *"Implement flightcrew coordination procedures which will insure continuous monitoring of the aircraft's instruments from the OM to landing. The wording of monitoring tasks should be specific. Fllghtcrew procedures which require a transfer or exchange of visual scanning responsibilities should require that the appropriate crew member announce that he is relinquishing previously assigned duties or responsibilities."* Although the procedures in use at Air Canada are not recorded, they appear to require an exchange of visual scanning responsibilities, but do not appear to implement this recommendation. The PicMA procedure referred to in Advisory Circular 0239 and elsewhere would have met it in full. In this case, it would have meant the F/O would have been flying the approach and remained continuously on instruments throughout, including the go-around if called for by the Captain at the MDA, and through to the landing.	
92.		Although a go-around was initiated, the aircraft stuck terrain approximately 740 feet short of the runway threshold, bounced twice, and then slid along the runway before coming to a rest approximately 1900 feet beyond the runway threshold.	The terrain where the go-around was initiated was approximately 60 feet BELOW runway level, which was the only factor that prevented the total destruction of the aircraft on impact.
93.	**Section 3 - Findings**		
94.	**3.1 Findings as to causes and contributing factors**		The "causes and contributory factors" reflect the serious limitations of the "history of the flight" and "analysis" as commented on above.
95.	**3.1 Findings as to risk**		
96.	5	If the type of approach lighting system on a runway is not factored into the minimum visibility required to carry out an approach, in conditions of reduced visibility, the lighting available risks being less than adequate for flight crews to assess the aircraft's position and	This is the sole finding as to risk that relates to the events that led directly to the accident. The analysis did not identify many of the safety issues listed above and hence the report does not recognise them as risks. **If risks are not identified, lessons cannot be learned from them and an investigation fails in one of its primary purposes, which is to prevent similar accidents in the future.**

		decide whether or not to continue the approach to a safe landing.	
97.	**Unidentified risks**	The following items are phrased in the same style as the report's own risk statements, but are the author's own and reflect the content in the comment columns and not the official report.	
98.		If regulations do not clearly identify that the pilot's visual references must have allowed him or her to complete an assessment of the aircraft position and rate of change of position before descending below an MDA or DH for a manual landing, there is a risk that the assessment will not be completed in time to avoid impact with obstacles.	
99.		If crew procedures are not based on a plan that the pilot flying the approach will execute a missed approach at DH/MDA unless the pilot landing has made a positive announcement that the aircraft's position and rate of change of position are suitable for continued approach, there is a risk that plan continuation bias will result in descent below DH/MDA without adequate visual cues to avoid obstacles or complete a safe landing.	
100.		If crew procedures involve the pilot NOT intending to make the landing making visual assessments prior to, and/or on behalf of, the pilot who IS intending to make the landing doing so, there is an increased risk of a hazardous plan continuation bias.	
101.		If crew procedures incorporate sighting callouts of any other visual cues than those associated with the runway environment, there is a risk of hazardous plan continuation bias and premature abandonment of instrument procedures.	
102.		If crew procedures do not ensure that there is continuous instrument monitoring from the FAF until landing, there is a risk that essential instrument information and warnings will go unnoticed.	
103.		If the wording of crew procedures that require an exchange of instrument monitoring obligations does not specifically require announcement of exchanged tasks, there is a risk that instrument monitoring will not be continuous and essential instrument information and warnings will go unnoticed.	
104.		If procedural callouts alerting the pilot to arrival at DH/MDA (and the end of the decision process) are phrased as advisory (e.g. "minimums") rather than imperative (e.g. "Decide!") they risk being ineffective as salient triggers, allowing inadvertent descent without adequate visual reference.	
105.	**Safety action taken**		
106.	4.1.1 Air Canada:	a) point 3: The “lights only” call has been removed from standard operating procedures.	**This action may have a negative safety effect.** It relates to the previously described Air Canada procedure: "at DH/MDA a Pilot Monitoring is required to make a call of “Minimums” followed by either “No contact,” “Lights only,” or “Runway in sight”." Even if visibility minima are increased (to take account of 1.18.11.1 Approach differences, and Risk Finding 5 quoted above), unless they are made considerably greater than those in the EASA and FAA documents referred to, **this will create an impossible situation** for Air Canada flight crews. Both sets of documents are based on setting RVR minima by a formula which theoretically allows the **nearest** approach light to be visible at DH/MDA in a homogenous atmosphere.

			For example the EASA document page 71: *"Required RVR/VIS (m) = [(DH/MDH (ft) x 0.3048)/tan α]* ***minus- length of approach lights*** *(m)"* [emphasis supplied; *α being the descent angle*]. In such conditions **neither of the two remaining calls would be true**. There would be contact with a light, but the runway would **not** be in sight. This places the PM in an impossible situation: what is the appropriate call? Either call is seriously misleading to the PF. This is a direct result of the exchange of internal / external monitoring duties inherent in the Air Canada SOP whereby the PM is required to make the initial assessment.

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The www.PiCMA.info website provides information on ways to prevent airline approach and landing accidents.

The author of this document is Captain Steve Last, a retired airline pilot. He was among the first to qualify on the Airbus A320 in 1989, and was nominated by the International Federation of Airline Pilots Associations as its first member of the ICAO Operations Panel, which developed internationally agreed requirements for All Weather Operations.