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December 14, 2007

Mr. William English
Investigator-In-Charge
National Transportation Safety Board
490 L'Enfant Plaza, SW
Washington, DC 20594

Reference: Pinnacle Airlines Flight 4712, **DCA07FA037**

Dear Mr. English:

In accordance with the Board's rules, the Air Line Pilots Association, International (ALPA) submits the attached comments and conclusions concerning the runway overrun of a Canadair Regional Jet (CRJ) operating as Pinnacle Airlines (PCL) flight 4712. This accident occurred on April 12, 2007 during the landing rollout at Traverse City, Michigan.

The attached submission contains ALPA's analysis of the facts surrounding the accident based upon the information obtained from the NTSB's investigation. ALPA's suggested Safety Recommendations are included and are based upon these facts. Other safety concerns were also identified during this investigation and are also discussed in the attached report.

ALPA appreciates the opportunity to have participated as a party to the investigation, and hopes that the attached conclusions and safety recommendations will be of assistance as the NTSB concludes its investigation.

Sincerely,

Aaron Rose
ALPA Coordinator

AR:ak

Attachment

cc: Eric West, FAA
Michael Crook, Pinnacle Airlines
Kevin Klein, Northwest Regional Airport
Ken Wolski, General Electric
Brian MacDonald, TSBC
Davis Fisher, Bombardier
Jim McMenemy, Transport Canada

SUBMISSION OF THE

AIR LINE PILOTS ASSOCIATION

TO THE

NATIONAL TRANSPORTATION SAFETY BOARD

REGARDING THE ACCIDENT INVOLVING

Pinnacle Airlines Flight 4712

Traverse City, Michigan

April 12, 2007

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I. SUMMARY

On April 12, 2007, at 0043 eastern daylight time, a Bombardier Regional Jet CL600-2B19, N8905F, operated by Pinnacle Airlines Inc. as flight 4712, overran runway 28 on landing at the Cherry Capital Airport, Traverse City, Michigan. The flight had departed from Minneapolis-Saint Paul International Airport at 2144 central daylight time on a regularly scheduled flight operating under the provisions of 14 Code of Federal Regulations (CFR) Part 121. Weather observations indicated visibility was deteriorating, snow was falling, and snow and ice were reported on the runway. There were no injuries among the three crewmembers and 49 passengers (including 3 lap-held children). The airplane was substantially damaged.

The results of the Air Line Pilots Association's (ALPA) analysis revealed that the flight was dispatched with inadequate, inaccurate weather reports and forecasts, as well as out-dated field condition reports. The timeliness and accuracy of the braking action information provided by the Traverse City airport personnel is suspect, which will be addressed in Section V. There were several other safety issues identified during the course of this investigation, primarily the lack of authority given to the Pinnacle dispatchers to cancel or delay flights, the lack of adherence to Pinnacle's own company policies by System Operations Control, as well as the inability of both the dispatcher and Air Traffic Control to provide the crew with updated weather once the crew had begun their descent. One of the most insidious contributing factors to this accident was the fatigue of the crew. Not only had this crew been on duty for over fourteen hours, but for the entire day the Captain had been conducting Initial Operating Experience (IOE) with the First Officer all of this while operating in winter weather conditions. Although the flight was operated in accordance with the Federal Aviation Administration's Flight Time/ Duty Time regulations, this crew was physiologically fatigued.

II. HISTORY OF FLIGHT

The crew started their duty day at 0940 CDT for a five leg day of Initial Operating Experience (IOE) for the First Officer with the Captain providing the instruction. The crew flew four uneventful flights: MSP-CLE, CLE-MSP, MSP-DSM, and DSM-MSP in winter weather conditions all while conducting IOE.

At 2015 CDT the crew arrived at the gate for Flight 4712 and was told by the gate agent that the flight release paperwork was not available and that the flight might be cancelled. The Captain contacted Dispatch and was informed that the tailwind component at Traverse City exceeded the limitations for the CRJ. The System Operations Control (SOC) Duty Manager contacted Northwest Airlines (NWA) Meteorology and acquired a Terminal Aerodrome Forecast (TAF) for Traverse City that would make the flight legal to depart. The Dispatcher contacted the Captain and provided him with the new TAF and put the flight dispatch paperwork into the system for the flight crew to access and print.

After this delay, lasting approximately one hour, the flight departed for Traverse City. The taxi out, take-off, climb, cruise, and descent were all uneventful with the Captain continuing to instruct the First Officer. Approaching Traverse City, the crew obtained the current weather from the Automated Surface Observation System (ASOS), which reported winds 040 at 7 knots, visibility 1 ½ statute miles in light snow, sky conditions 900' broken, 1500' overcast, temperature 0°C, dewpoint -1°C, altimeter 29.54. The crew subsequently contacted the Traverse City Airport Operations to determine the runway in use and acquired a field condition report. They were advised Runway 28 was in use, the Mu (μ) report for the runway was 40+/40+/40+[1], and there was equipment on Runway 28[2]. The crew asked for and was given delaying vectors while the runway was vacated. At 0438Z, the crew was cleared for ILS Runway 28 at Traverse City and subsequently switched by Minneapolis Center to the Traverse City Common Traffic Advisory Frequency (CTAF).

The crew reported their position over CTAF and was told by Airport Operations that the runway was beginning to fill in and he is unsure of the runway conditions so he initially referred to it as "nil". When questioned by the crew, Airport Operations responds "(oh I) haven't been out there to do a field report and it's been ah five ten minutes so I don't know what it's doin' now[3]." The Captain queries Airport Operations as to the amount of snow that has accumulated and is told approximately one-half inch. The crew discussed the limitations of the CRJ with respect to the amount of snow that had accumulated and determined they were within the limitations of the aircraft.

The aircraft crossed the threshold, fully configured, on glideslope, and at 148 knots. The main gear touched town 2300' from the threshold and the ground spoilers and thrust reversers were deployed. The crew stowed the thrust reversers and continued the braking until becoming aware of the lack of deceleration and then re-deployed the thrust reversers 7 seconds later. The aircraft departed the end of the runway and came to rest approximately 100' from the end of the pavement.

[1] "40+" refers to μ (Mu) friction reading for the runway and can be translated into braking action considered good, the three values represent touchdown, midpoint, and rollout reports, respectively
[2] Reference Cockpit Voice Recorder Group Factual 376849, page 12-105/106
[3] Reference Cockpit Voice Recorder Group Factual 376849, page 12-130

The crew evaluated the situation and based on the aircraft being intact with no fire or apparent fuel leak the crew elected to keep the passengers safe onboard the aircraft. The crew contacted Airport Operations and Minneapolis Center to advise them of the situation. Aircraft Rescue and Fire Fighting (ARFF) equipment was dispatched to the scene and the passengers and crew exited through the main cabin door and were transported to the terminal.

III. PINNACLE DISPATCH AND OPERATIONAL PRESSURE

A primary function of a dispatcher is to provide flight crews with current and accurate information regarding the conduct of the flight and each dispatcher has a joint responsibility for the preflight planning, delay, and dispatch release of a flight in conjunction with the pilot in command (PIC)[4]. In the case of Flight 4712, the dispatcher himself stated in a phone conversation with the Captain, "I'm not really comfortable with this.[5]" The dispatcher further clarified his concerns and the pressure he felt to dispatch this flight during his post-accident interviews with the Operations and Meteorology Groups. The dispatcher stated, "…he indicated that he had strongly urged the duty manager to cancel flights in the past but there had been conflicts.[6]" The dispatcher also said that he told the System Operations Control (SOC) Duty Manager, "he was not comfortable with releasing this flight and there were concerns with the forecast other than winds, such as snow.[7]" In response to the dispatcher's concern the SOC Duty Manager contacted Northwest Airlines Meteorology to acquire a TAF that would allow the flight to depart, which according to the dispatcher "…was not common.[8]" Pinnacle's Operations Specifications A010 did not allow Pinnacle to utilize weather products created by the Northwest Airlines Meteorology department[9], making the flight an illegal dispatch.

According to the dispatcher, Pinnacle also has a policy not to dispatch an aircraft that will be landing on a contaminated surface with a tailwind[10]. Based on the METAR reports, as well as the TAF acquired from Northwest Airlines Meteorology the dispatcher should have been aware of the very strong possibility of having a contaminated runway when Flight 4712 arrived at Traverse City. Snow had begun prior to the 2353Z METAR report[11] and was in the forecast to continue throughout the entire valid period of the NWA TAF[12]. Although the SOC Manager received a field condition report[13] from the Traverse City Air Traffic Control Tower prior to its closing, that report from the previous air carrier arrival would have been four and a half hours old and not accurate based on the dynamic meteorological conditions of that night.

The secondary failure of Pinnacle dispatch was the lack of flight following for Flight 4712. When the dispatcher was asked about the weather during the course of the flight, he had no recollection of looking at any of the weather products, including a change in the TAF at Detroit Metro (DTW), the flight's alternate[14,15]. If the dispatcher had been monitoring the situation, including the rapidly deteriorating weather[16] at Traverse City, he should have been able to send an ACARS message to the crew with the updated weather, including the updated TAF at DTW and the decreasing visibility at Traverse City.

[4] Reference FAR 121.533 (b) (c)
[5] Reference Meteorology Factual Report 376049, page 29
[6] Reference Attachment 1 Operations Group Factual Report- Interview Summaries 374223, page 45
[7] Reference Attachment 2 Meteorology Factual Report- Interviews 376051, page 7
[8] Reference Attachment 1 Operations Group Factual Report- Interview Summaries 374223, page 44
[9] Reference Meteorology Factual Report 376049, page 25
[10] Reference Attachment 2 Meteorology Factual Report- Interviews 376051, page 7
[11] Reference Attachment 1 Meteorology Factual Report- Dispatch Release and weather document, page 10
[12] Reference Attachment 1 Meteorology Factual Report- Dispatch Release and weather document, page 10
[13] Reference Attachment 1 Operations Group Factual Report- Interview Summaries 374223, page 29
[14] Reference Meteorology Factual Report 376049, page 31-32
[15] Reference Attachment 2 Meteorology Factual Report- Interviews 376051, page 2
[16] Reference Meteorology Factual Report 376049, page 36

The pressures placed on this crew and dispatchers are not unique. Regional airlines, specifically, are dependent on on-time and completion factor as part of their compensation package with their mainline carrier. Clive Seal, Vice-President of Flight Operations was "[a]sked whether there was a completion clause in the company's contract with Northwest Airlines, under which the company received money based on the number of scheduled trips completed, he indicated that this was part of a complex payment formula. The company was paid for many factors that included percent of completed trips, on-time departures, fuel burn rates, and APU usage.[17]" These pressures are so prevalent that even the Principle Operations Inspector (POI) was concerned and said, "[h]e believed that in the past, until about 1.5 years ago, pilots experienced pressure from dispatchers to complete trips. Dispatchers would tell pilots they were legal. This led the company to establish a duty officer, available to deal directly with schedulers as a representative of flight operations.[18]" These operational pressures are part of a company culture and while difficult to quantify were present in ensuring this flight would be completed.

[17] Reference Attachment 1 Operations Group Factual Report- Interview Summaries 374223, page 56
[18] Reference Attachment 1 Operations Group Factual Report- Interview Summaries 374223, page 67

IV. METEOROLOGY AND WEATHER REPORTS

The Meteorology Group Factual Report provides through various sources, a clear picture of the dynamic weather conditions in the Traverse City area the night of April 12, 2007. While all the information available to the Meteorology group was available that evening, most of the weather products do not appear to have been considered by the dispatcher or the Northwest Meteorological department. The NWS Hydrometeorological Prediction Center (HPC) Heavy Snow Discussion issued an advisory describing in detail that the Traverse City area should expect heavy, wet snow throughout the evening, which would be aided by the cool air flow across the upper Great Lakes[19].

The TAF issued by the National Weather Service (NWS) forecasted moderate snow and blowing snow at the time of the aircraft's arrival at Traverse City, that in combination with the forecast surface winds exceeded the limitations of the aircraft. As discussed in the Pinnacle Dispatch and Operational Pressure section, the SOC Duty Manager contacted Northwest Meteorology to provide them with a TAF in an effort to legally dispatch Flight 4712. The Northwest Meteorology TAF forecasted light snow and winds that were within the tailwind limitations of the CRJ. While the wind forecast proved to be more accurate, the precipitation aspect of the TAF was inaccurate. The majority of the weather products available indicated that the Traverse City area should expect moderate to heavy snow based on the enhanced snow bands that were propagating North[20] through the Michigan area. Dispatch's use of this errant TAF, which was not an approved source of weather by Pinnacle's Operations Specifications[21], allowed a flight that should have been cancelled to depart.

The weather at Traverse City was acquired via an ASOS and augmented by a National Weather Service (NWS) certified weather observer[22] and disseminated via METAR reports and radio broadcasts over the normal ATIS frequency. Throughout the course of this flight the weather observer on-duty twice inaccurately amended the precipitation intensity. The METAR at 0430Z should have shown moderate snow with the ½ statue mile visibility and again on the 0453Z METAR the report should have been amended to heavy snow with the ¼ statute mile visibility being reported. While the last errant METAR occurred after Flight 4712 landed, the previous one if disseminated correctly may have been passed on via ACARS to the crew from the Pinnacle dispatcher.

Crews typically acquire the weather information prior to the beginning of their initial descent, as this crew did[23]. This allowed the crew to brief and set-up the approach prior to descending below 10,000 MSL. Crews then rely on Air Traffic Control for weather updates, typically through the Air Traffic Control Tower or in this case any updates should have come from the Center controller. This crew had to communicate with both Air Traffic Control on one radio and Traverse City Airport Operations on the other, making it impossible for the crew to obtain any updated ASOS weather. Minneapolis Center did not switch Flight 4712 over to CTAF until 0439Z, nine minutes after the 0430Z Special Weather Observation was disseminated, which included the visibility dropping to one-half mile. Air Traffic Control is required to provide updated weather to aircraft prior to approach when the ceiling is less than 1,000 and/ or visibility is less than 3 statute miles[24].

[19] Reference Meteorology Group Factual 376049, page 9
[20] Reference Meteorology Group Factual 376049, page 27
[21] Reference Meteorology Group Factual 376049, page 25
[22] Reference Meteorology Group Factual 376049, page 11
[23] Reference Cockpit Voice Recorder Group Factual 376849, page 12-78
[24] Reference FAAO7110.65R 4-7-7 Weather Information

V. TRAVERSE CITY AIRPORT OPERATIONS AND FIELD CONDITIONS REPORTING

Airport Operations performs the critical role of maintaining the airport and the airport surfaces. This responsibility becomes even more critical during adverse weather conditions and even more so when the Air Traffic Control Tower is non-operational. It is incumbent upon the airport personnel to ensure the airport surfaces are maintained and if any contamination exists on these surfaces that the information be accurately disseminated via Field Condition Reports and via CTAF. Providing misleading or inaccurate information can and did contribute to an accident. As discussed in the previous section, it had been snowing in Traverse City for hours. Airport personnel were in the process of clearing the runway when Flight 4712 initially called CTAF.

The initial field condition report at 0426Z was forty plus[25] on Runway 28 with thin wet snow or patchy thin ice[26]. At 0435Z airport operations advised Flight 4712 "…it's comin' down pretty good[27]…" and again at 0437Z he states "…its fillin' n pretty quick down here[28]…" The next comment from operations at 0438Z "yeah I'm gonna I don't know what the ah conditions like * down the runway but I'm gonna call braking action NIL now. cause' it's fillin in real hard[29]." He begins to provide misleading communications using non-standard phraseology with Flight 4712, just twelve minutes earlier he said that the braking action was good and now just a few minutes later is providing more of a commentary than factual data. Unfortunately the crew probably did not even hear this report due to a radio transmission from Minneapolis Center on the other radio one second[30] after Airport Operations started their commentary. In the FAA Safety Alert for Operators (SAFO) 06012[31], the FAA states and defines reliable braking action reports. Based on the definition given in the SAFO a vehicle braking action report would NOT be considered reliable. Airport operations has a responsibility to ensure that the runway environment is safe, if they are unable to do that then they must close down the unsafe portion of the airport.

The FAA in a letter to the Traverse City Airport Manager dated November 2, 2007 reminded them of their responsibility during winter weather conditions. "The airport *must* implement a standard operating procedure to *close any pavement* available to air carriers when *braking action/friction values* reach an *equivalent level of nil* braking based on the air carrier aircraft utilizing the airport.[32]" The letter went on to say that following snow removal an updated field condition report must be issued before allowing aircraft operations on the runway[33] and these "[b]raking action reports generated by a vehicle operator are subjective in nature and should not be used if other means are available.[34]" Traverse City was in the process of snow removal during the arrival of Flight 4712 and had just removed the equipment prior to Flight 4712's arrival. Airport Operations did have the capability of taking a friction report and should have done so prior to Flight 4712 arriving at Traverse City, based on the quickly changing conditions. If indeed

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[25] "40 plus" refers to μ (Mu) friction reading for the runway and can be translated into braking action considered good
[26] Reference Cockpit Voice Recorder Factual Report 376849, page 12-105
[27] Reference Cockpit Voice Recorder Factual Report 376849, page 12-120
[28] Reference Cockpit Voice Recorder Factual Report 376849, page 12-123
[29] Reference Cockpit Voice Recorder Factual Report 376849, page 12-124
[30] Reference Cockpit Voice Recorder Factual Report 376849, page 12-124
[31] Reference Safety Alert for Operators (SAFO) 06012 dated 8/31/2006, FAA Document not part of docket http://www.faa.gov/other_visit/aviation_industry/airline_operators/airline_safety/safo/all_safos/media/2006/safo06012.pdf
[32] Reference Survival Factors Factual Report 376710, page 7-8 *Emphasis added*
[33] Reference Survival Factors Factual Report- Attachment 3, page 3
[34] Reference Survival Factors Factual Report- Attachment 3, page 3

the μ (Mu) reading was below .20, then as stated previously the airport had a responsibility to close Runway 28.

This crew was presented with many conflicting pieces of information. They had the runway friction assessment (40+) that implied braking performance had not yet deteriorated, but then received a “nil” report from an operator using a ground vehicle (not a pilot braking action report), a field condition report that would indicate poor braking action (1/2 inch wet snow), and finally a report of heavy snowfall (no information on how that affects the braking performance). These issues point to a need for a common and uniform runway condition reporting standards.

VI. AIRCRAFT PERFORMANCE

At the time of the accident it was Pinnacle Airlines procedure to add 5 knots to the V_{ref} speed published by Bombardier (FIGURE 1). Due to several incidents with the aircraft entering an unrecoverable deep stall condition during the flight certification process and a reference in the manufacturers AFM to fly an additional five knots during approach to increase the level of safety, Pinnacle airlines made the five additional knots mandatory to all phases of the approach. When flaps were selected to 45 the aircraft was slowed to V_{ref} plus 5 plus half the gust factor to a maximum of V_{ref}(45°) plus 10KTS. The Pinnacle Airlines manuals called for slowing the aircraft to V_{ref} when crossing the threshold but never specified at what point the speed reduction was to occur. If this reduction in speed were delayed by a crew who was task saturated by flying a difficult approach, this could result in the aircraft crossing the threshold with five additional knots of airspeed and a longer flare to touchdown than specified in the performance data.

PINNACLE
AIRLINES, INC.
CRJ Company Flight Manual

Revision: 01
Date: 15 Dec 2006

When operationally necessary, it is permissible for Crews to use speeds between minimum maneuvering speed and V_{FE} (ATC requests, spacing, etc.).

V_{REF} Bugging Procedure

The Pilot Flying flies a minimum approach speed of V_{REF} (45°) +5 during approach. However, V_{REF} (45°) +1/2 the gust will be flown if greater, not to exceed V_{REF} (45°) +10. For this reason, we are able to reference three speeds at one time. After final flap selection, V_{REF} +5 is always "bugged." When this is accomplished, the top of the bug represents V_{REF} +10 (maximum approach speed), the middle of the bug represents V_{REF} +5 (normal approach speed), and the bottom of the bug represents V_{REF}.

FIGURE 1 – PRE-ACCIDENT

In the months following the accident, Pinnacle Airlines has changed its procedures and manuals to remove the additional five knots from the flown V_{ref} speed. The new procedure requires the crew to bug and fly the published Bombardier V_{ref} speed plus ½ the gust factor, not to exceed 10 kts (FIGURE 2). By reducing the V_{ref} to published speeds Pinnacle Airlines has brought the operation of the aircraft in line with the manufacturer's performance data and reduced possible "long landings" during difficult conditions.

PINNACLE AIRLINES, INC.
CRJ Company Flight Manual

Revision: 02
Date: 07 Jun 2007

When operationally necessary, it is permissible for Crews to use speeds between minimum maneuvering speed and V_{FE} (ATC requests, spacing, etc.).

V_{REF} Bugging Procedure

The Pilot Flying flies a minimum approach speed of V_{REF} (45°) during approach. However, V_{REF} (45°) +1/2 the gust will be flown, not to exceed V_{REF} (45°) +10. After final flap selection, V_{REF} is always "bugged." The gust factor is not bugged. It is compensated for and flown accordingly during the approach while slowing to cross 50' AGL at Vref.

FIGURE 2 – POST-ACCIDENT

On landing, Flight 4712 crossed runway 28 threshold at 148 knots (kts) airspeed and the main landing gear (MLG) touched down at 121 kts, about 2,300 ft from threshold. Immediately after touchdown the spoilers were deployed and brake pressure was applied. There was a brake pressure reading of zero for the left outboard brake at one point during the stop. Immediately preceding this, the left inboard brake pressure spiked upwards. Per the NTSB Structures Group Chairman for the accident investigation:

> "The drop in the brake pressure that's seen in the FDR most likely comes from the antiskid system. It looks like the system detected a skid in one of the wheels, and dumped the brake pressure (as designed) to prevent the tire from skidding. Once the skid characteristics are no longer seen, the system will restore the pressure to continue braking. Without having the actual wheel speeds instrumented, it's hard to know for sure, but the characteristics are consistent with a sensed/prevented skid."

The thrust reversers were twice deployed and stowed during the landing roll. The thrust reversers were first deployed at 108 kts and stowed at 90.5 kts. The crew felt the aircraft was not slowing adequately and deployed the thrust reversers a second time at 71 kts and stowed them again at 38 kts. Per Bombardier's response to the NTSB's query on rudder blanking (Response to NTSB Question re: Rudder Blanking), the manufacturer stated:

> *"The techniques used by the pilot during the landing are broadly consistent with the advice in the FCOM for landing on possibly contaminated runways (FIGURE 3); specifically, the pilot did restrict the use of the thrust reversers at higher speeds to prioritize maintaining directional control (per the fifth bullet), and maintained the use of the thrust reversers on the second deployment below the normal stow speed of 60knots as advised for an emergency situation (per the fourth bullet).[35]"*

[35] Reference Bombardier Memo to the NTSB Performance Group (FS/07/601R/034/AP)

The following is taken from the Flight Crew Operating Manual, CSP A-013, Volume 2, Supplementary Procedures (Chapter 7), Cold Weather Operations (Section 12), page 07-12-29 at temporary revision TR RJ/167 dated Nov 02, 2005.

G. Landing

Considerations:

- Carry out a positive touchdown to ensure initial wheel spin up and breakout of frozen brakes if icing has occurred
- Lower the nosewheel immediately.
- Anticipate skidding and hydroplaning to occur, and be prepared to make the necessary corrections.
- Use maximum reverse thrust as soon as possible after touchdown. Thrust reversers are most effective at high speed. Maximum reverse thrust may be used to a complete stop in case of an emergency situation.
- If a loss of directional control occurs, reduce reverse thrust to idle reverse and if necessary, return the engines to forward idle thrust to return to the centerline. Regain the centerline with nosewheel steering, rudder and/or differential braking.
- DO NOT pump the brakes as this will only diminish braking effectiveness. Apply brakes normally with steadily increasing pressure, allowing the anti-skid system to modulate brake pressures to obtain maximum braking.

FIGURE 3

The airplane continued to roll down the runway and departed the 200 ft long overrun at about 45 kts ground speed. The NTSB conducted a simulation to estimate the airplane braking coefficient, and the results indicated on average the coefficient was approximately 0.10. The crew had received a report from Traverse City Airport Operations at 04:26:56.5 (approximately 18 minutes prior to touchdown) advising Runway 28 was in use and that the Mu (μ) report for the runway was 40+/40+/40+.

As part of its work, the NTSB looked at simulated landing distance scenarios, which were tested for three separate thrust reverser schedules at four different speeds. The results showed that an airplane similarly configured and in similar conditions as the accident flight, could not have stopped on the runway, requiring an additional 1,146 ft of unobstructed runway. Similarly, at lower V_{ref} speeds of 145, 143, and 140 kts, the airplane could not have stopped on the runway. The manufacturers recommended procedure of stowing the reversers at 80 kts to achieve idle reverse by 60 kts would have allowed the airplane to stop at V_{ref} 140 kts, but not for the three other tested speeds. Maintaining thrust reversers at max N1 until the airplane came to a complete stop would have provided for positive stopping margins for all tested speeds.

The Company Flight Manual (CFM) contaminated landing runway length charts were used to compute the required landing distances for various contaminants, and the results showed the compact snow contaminant with the SAFO margins was the only condition in which the flight had stopping distance on runway 28.

During the Performance Group’s work, the Contaminated Runway Landing Distance Charts were discussed. These charts were incorporated into the Pinnacle Airlines operating handbook in December 2006 and Pinnacle was not sure if there was an Operations Bulletin released to address this change. There was no specific training involved with their addition, just “read and do” which translates that crews would not receive any official training until their next recurrent training. The contaminated runway charts used by Pinnacle Airlines are calculated from tabular data in the

QRH provided by the manufacturer (Bombardier) with an additional 15% safety margin. The 15% was added by Pinnacle as recommended in FAA SAFO (Safety Alert for Operators) 06012 which was published on August 31, 2006. The purpose of the SAFO is:

> *"This SAFO urgently recommends that operators of turbojet airplanes develop procedures for flightcrews to assess landing performance based on conditions actually existing at time of arrival, as distinct from conditions presumed at time of dispatch. Those conditions include weather, runway conditions, the airplane's weight, and braking systems to be used. Once the actual landing distance is determined an additional safety margin of at least 15% should be added to that distance. Except under emergency conditions flightcrews should not attempt to land on runways that do not meet the assessment criteria and safety margins as specified in this SAFO.*[36]*"*

Pinnacle performed the interpretation/translation of manufacturer data to SAFO standards.

[36] Reference Safety Alert for Operators (SAFO) 06012 dated 8/31/2006, FAA Document not part of docket http://www.faa.gov/other_visit/aviation_industry/airline_operators/airline_safety/safo/all_safos/media/2006/safo06012.pdf

VII. HUMAN PERFORMANCE

Introduction

Accidents that occur in tightly coupled complex systems such as aviation are the result of separate but interrelated components of the system failing to function as designed. These accidents result from individual system component failures and their failed interactions. Due to the catastrophic potential of aviation accidents, multiple layers of redundancy built into the system serve as protection against these failures. Despite this, when aviation accidents do occur, this indicates a failure of the system as a whole to function as designed. Not as a single component failure, but rather a failure that involves the many facets and layers of any complex system. This is referred to as a systems accident. The focus of any accident investigation should be the determination of why the system failed. Why did the individual components of the system fail to operate as designed and why was human error not attenuated despite the multiple layers of protection?

The goal of any human performance analysis is to understand the role that humans played in a failed system. In order to understand the human role and influence we must focus on the decisions and their context that were made by the operators involved. We need to appreciate what the crew knew and perceived at the time they were making their decisions. Essentially, we need to understand their local rationality. If not careful, the investigator may allow outcome bias to label crew decisions made prior to an accident as human error just because of the resulting accident outcome. The discovery of human error is not the end of the human performance investigation but rather the beginning. As the goal of any accident investigation is the prevention of the next accident. The goal of any human performance investigation is to understand why the crew made the decisions they made in the context at the time they were made.

The investigation should strive to seek out the crew's previous experience, training and information that was available or missing which shaped their decision-making. What was their mental model? What was their local rationality? The knowledge that they possessed combined with information (data-centric or perceptual) they received while operating the aircraft develops their understanding of their environment. It is this understanding that will shape their decision making process. This is their unique local rationality. The investigation should capture why the crew thought that their choices seemed reasonable at the time they were made. To examine these decisions as errors and out of context is pointless and potentially misleading.

Pilots, like all other professionals, want to perform to the highest standard possible. However, the degradation of human performance by external or internal factors can result in what has historically and myopically labeled as human error. This section of this report will examine the factors surrounding the crew's decision to land in Traverse City the early morning of April 12, 2007. Specifically we will examine the role that fatigue played in this decision making process.

The Accident Flight Crew

The investigation revealed that during this flight the Captain was administering IOE to the First Officer. Interviews with numerous individuals that knew both pilots indicate that they were both well trained and liked by fellow employees. A review of records for both pilots showed no aviation accidents or violations and the National Driver Register also revealed no driver's license suspensions or revocations.

The Captain
The Captain lived in Pensacola, Florida with his wife and infant child and was based in Memphis, Tennessee. From numerous interviews it appears he is family oriented and enjoys his time at home with his family. He reported that his personal and financial situation had recently changed due to the birth of his six month old son. He discussed that his wife had quit working outside of the home to care for their child. When home, he appears to be an active member of their household. He typically goes to bed around 2130 hrs and awakes around 0730 hrs. However, when home his sleep may be disrupted since he tries to respond to his son's awakenings before his wife giving her a break from these disruptions.

Interviews with other pilots that knew him and had flown with him described him as *"courteous", "competent" and "professional"*. One pilot interviewed made the statement the he *"immediately liked him"*. One check airman that flew with him a day before the accident reported the flight as *"by the book"* and *"uneventful"*. Interviews also revealed that the Captain provided a comfortable flight deck environment and was very knowledgeable. By all accounts it appears that the Captain was a well experienced and likable pilot.

The Captain was a check airman and was providing IOE to the First Officer on the accident flight. It was reported that he enjoyed teaching and had the ability to "read people and step up to the level of each person to get a point across." His time thus far as a check airman appears to have been successful. Outside of their professional relationship during the flight both crew members had known each other prior to working for Pinnacle airlines. Both crewmembers described each other as "*personal friends*". The Captain was concerned that due to their friendship, performing IOE with the First Officer may hurt their future relationship. He reported that he was unsuccessful in getting another check airman to operate the trip and planned on operating IOE with the same strictness that he would for any other candidate.

The First Officer
The First Officer is single and lived in Memphis, Tennessee where he was based. He reported that his personal situation had recently changed with the death of his mother the previous November. Additionally, he was having trouble paying his bills due to his low income during training. He described his schedule as crazy but typically went to bed around 2200 hrs and awoke around 0800. However, on occasion he may sleep until noon.

He was receiving IOE from the Captain on the accident flight. During simulator training, an instructor characterized the First Officer as *"average"* and that he had no concerns about him going out on line. A simulator check airman that administered his proficiency check after simulator training reported that he had no problems and that he *"sailed right through it"*.

NTSB Study
In 1994, the National Transportation Safety Board issued the study *A review of flightcrew-involved, major accidents of U.S. Carriers, 1978 through 1990.* In an attempt to better understand deficiencies in the aviation system that may adversely affect crew member performance they examined the operating environments and the crew errors that were made in these accidents. Thirty seven accidents were identified and reviewed resulting in a total of 302 flight crew errors that were classified by type. Several of these classifications and frequency were; procedural (73), tactical decisions (51), aircraft handling (46) and situational awareness (19). Numerous environmental and situational factors were examined including fatigue related issues such as time since awaking (TSA) also known as length of day.

For the purpose of the Board's report and this analysis, length of day or TSA was defined as from the time the pilot awoke from his last rest period until the time of the accident. They further separated the data and into high and low TSA crews. Those Captains and First Officers that were determined to be considered high TSA crews had an average TSA of 13.8 and 13.4 hours respectively. Further examination of the data showed that high TSA crews made an average of 40 percent more errors than their low TSA counterparts. Perhaps more revealing is that not only did high TSA crews make more errors, but they also made significantly more procedural and tactical errors. Additionally, the data also suggests that the degraded performance seen in the high TSA crews involved ineffective decision making and procedural non-compliance. This concern is consistent with NTSB findings in several accidents where fatigue was a causal factor including Korean Air Flight 801, American Airlines Flight 1420, American International Airways Flight 808 and Corporate Airlines Flight 5966. From these accidents, several recommendations have been made regarding flight time and duty time limitations. To date the FAA and aviation industry have been unable to address these recommendations.

Fatigue

Introduction
This section will examine the role of fatigue in crew member decision making. We will examine both crew members' sleep history, length of day prior to the accident and several cognitive and physiological performance markers that are related to a physiologically fatigued state.

Fatigue has been defined as a physiological state resulting in decreased wakefulness, decreased attention or performance that may or may not include sleepiness. Fatigue-related degradation of performance results from the combined effect of sleep/wake history (time awake/length of day), circadian phase (time of day), and time spent on the same task (time on task) (Wesensten, et al., 2004). This analysis will focus on time of day, length of day and chronic sleep restrictions considerations.

Circadian Rhythm: Time of day considerations
Human beings are diurnal in nature which means that we follow a natural rhythm of being awake during the day and asleep at night. This natural circadian rhythm is about 24 hours in duration and is primarily set by the brain's response to light exposure. In addition to sleep propensity, circadian rhythm also modulates core body temperature and neurobiological performance in a sine-wave shaped pattern (Kryger, Roth, and Dement, 2005). All three of these parameters are interrelated such that when our body temperature decreases our sleep propensity will increase. This results in the highest period for sleep propensity between 0400 hrs and 0600 hrs corresponding to the lowest point of body temperature. See figure 4.

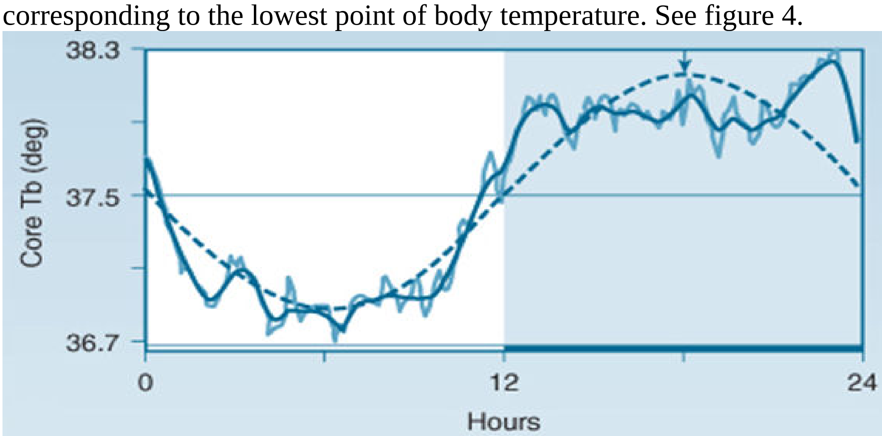

Figure 4 - The 24-hour circadian rhythm in body temperature (taken from Kryger, Roth, and Dement, 2005).

Body temperature increases and peaks in the early to mid-evening (about 1800 hours) corresponding to the point with the lowest sleep propensity. Simply put, during this time, it is very difficult for humans to sleep. In fact, this period in the circadian rhythm has been described as a forbidden zone for sleep (Lavie, 1986). Performance follows core body temperature with an approximately two-hour lag. Thus performance is lowest between 0600 and 0800 hrs and peaks at approximately 2200 hrs. Performance and sleep propensity are thus near-mirror opposites (Belenky, 2007).

The accident occurred at 0045 EDT early the morning of April 12, 2007. By considering the time of the accident in relation to Figure 4, it is evident that the accident occurred after the point of lowest sleep propensity and maximum performance. Simply put, sleepiness was increasing and performance was decreasing. In addition to circadian rhythm considerations the crew's normal bedtime should be examined as well. The accident occurred almost two to three hours (depending on which time zone they were acclimated to) after both pilots are normally in bed and asleep. Functioning at work during a time of circadian performance decline and more than 3 hours after normal bed time represents a significant potential for developing a physiological fatigued state. The National Transportation Safety Board has identified this situation as being contributory to producing a physiological fatigued state in numerous accidents (Korean Air Flight 801 and American Airlines Flight 1420).

Length of day considerations

Examining the wake times for each crewmember and when the accident occurred gives us the length of day. The Captain's was 16 hours and 45 minutes and 17 hours and 15 minutes for the First Officer. Several researchers have shown that the cognitive impairment that occurs as the result of prolonged wakefulness can be equated to alcohol impairment. For example, Dawson and Reid (1997) showed that the cognitive impairment and performance decrement from 17 hours of wakefulness equates to a blood alcohol concentration (BAC) of 0.05%. In many countries this is the proscribed limit for vehicle operation. The relationship of cognitive impairment from fatigue compared to BAC appears to be non-linear. The same study showed that 24 hours (7 more hours) of wakefulness doubled the effective BAC to 0.10 %.

The cognitive performance impairment seen in these cases (even at a comparative BAC of less than 0.08%) include psychomotor function, learning, memory and attention (Falleti, et al., 2003) (Williamson & Feyer, 2000). The previously mentioned NTSB study on flight crew error, reported crews with high TSA (average of about 13 hours of wakefulness) made 40% more errors. Additionally, these crews made more procedural error that was more serious in nature. Both crewmembers on the accident flight had a length of day four hours in excess of the 13 hours (high TSA group) in the NTSB study. Additionally, their 17 hour length of day would have provided cognitive impairment comparable to having a BAC of 0.05% according to Dawson et al. study. Based on length of day, both crew members would be expected to exhibit some degree of fatigue related cognitive and performance decrement.

In the Corporate Airlines Flight 5966 controlled flight into terrain accident investigation report, the NTSB discussed the current British duty time regulations that consider the time of the start of the duty period and the number of legs to be flown. The Board discussed that this type of duty time chart which is based on scientific principles and current fatigue research should be considered by the FAA here in the United States. Had this been the case for the accident crew, the accident day as flown and scheduled would have been in excess of the recommended length of duty day and would not have occurred.

Chronic sleep restriction considerations

Sleep loss as defined by sleep deprivation and sleep restriction, degrades performance over time in a sleep-dose dependent manner (Belenky, et al., 2003; Van Dongen, et al., 2003). Even mild sleep restriction (decreasing time in bed from 8 to 7 hours each night for an actual loss of 40 minutes of sleep/night) degrades performance over days (Belenky, et al., 2003). This research supports the hypothesis that even after one to two hours of less rest then required, individuals will demonstrate a performance decrement. It is important to understand that despite the reduction in sleep and observable performance decrement, most subjects will not report feeling tired or fatigued. Subjects that report feeling fatigued and tired usually do so long after a significant reduction in performance occurs (Rosekind, et al., 1999).

During the Captain's interview, he reported that he typically slept for about 10 hours. The morning before the accident the Captain awoke in Minneapolis at 0700 hrs after going to bed the night before between 2200 hrs and 2230 hrs. Therefore his last rest period before the accident was 1 to 1.5 hours less than his normal required amount of sleep. A more in depth analysis (table 1) of the previous five nights shows that the Captain had a significant decrease (2.3 hours on average per night) in the normal required amount of sleep. This nightly reduction in sleep results in a chronic sleep restriction and resulting fatigue. Additionally, the Captain reported that while at home the evenings of the 7th and 8th his sleep was interrupted by his son waking at night. Although quantitatively challenging to calculate its contribution, the additional physiological burden and resulting fatigue from these interruptions would be in addition to the fatigue produced from chronic sleep restriction and other causes already discussed.

Sleep history for Captain. Five evenings prior to accident.					
Date	Evening April 6th	Evening April 7th	Evening April 8th	Evening April 9th	Evening April 10th
Time to bed	2200 CDT	2200 EDT	2130* EDT	2130* EDT	2230 CDT
Time awake (next day)	0400 CDT	0630 EDT	0730* EDT	0305 EDT	0700 CDT
Total sleep	6 hours	8.5 hours	10 hours	5.5 hours	8.5 hours
Deficient sleep per night	4 hours	1.5 hours	0 hours	4.5 hours	1.5 hours
* These times are not exact as the investigation did not report these times. To be conservative, we assumed normal bed and awake times.					

Table 1 – Nightly sleep history for Captain prior to accident.

During the First Officer's interview, he reported that he typically slept for about 10 hours. The morning before the accident he awoke in Minneapolis at 0630 hours after going to bed the night before around 2200 hours. Therefore his last rest period before the accident was 1 to 1.5 hours less than his normal required amount of sleep. Additionally, the second night before the accident his rest was about 4 hours less then his normal required amount of sleep. In the several evenings prior to these evenings, the exact rest periods are unknown. Table 2 shows the sleep history five nights prior to the accident for the First Officer. The recent sleep restriction of 5 to 5.5 hours over the two nights prior to the accident is relevant. It is important to understand that although he may have had adequate rest on the evenings prior to the restricted evenings, humans can not store-up rest for a pending sleep restriction period. You can not what some may say pay forward for a pending sleep restriction. A more in depth analysis of the previous two nights supports the idea that the First Officer had a significant decrease in the normal required amount of sleep (average of 2.75 hours per night over two nights).

Based on the chronic sleep history for both pilots, it is reasonable to postulate that chronic sleep restriction contributed to their physiologically fatigued state. Based on this data, the Captain had more of a chronic sleep restriction than the First Officer.

Sleep history for First Officer. Five evenings prior to accident.					
Date	Evening April 6th	Evening April 7th	Evening April 8th	Evening April 9th	Evening April 10th
Time to bed	2200* CDT	2200* CDT	2200* CDT	2200 PDT	2200 CDT
Time awake (next day)	0800* CDT	0800* CDT	0800* EDT	0400 PDT	00630 CDT
Total sleep	10 hours	10 hours	10 hours	6 hours	8.5 hours
Deficient sleep per night	0 hours	0 hours	0 hours	4 hours	1.5 hours
* These times are not exact as the investigation did not report these times. To be conservative, we assumed normal bed and awake times.					

Table 2 – Nightly sleep history for First Officer prior to accident

CVR indications of fatigue

Previous sections discussed the fatigue potential for each crew member regarding time of day, length of day and chronic sleep restriction. Further analysis such as the CVR transcript revealed both subjective, physiological and behavior indicators of a physiological fatigued state for both crewmembers. For ease of examination of the data, this analysis divides the flight into several segments. Each segment contains excerpts from the CVR transcript followed by discussion about the specific event. All times reported on the CVR transcript are in Coordinated Universal Time (UTC).

<u>Beginning of CVR until airborne at 03:34:06</u>

03:32:12 HOT-1	yeah just tired. too late for this #. act of & to get this airplane outta here. you know what I mean?
03:32:23 HOT-2	yeah

03:37:39 HOT-1	this is the hardest day, rest days are cake, you know, easier. tomorrow's four legs and we got two legs and three legs.

While on the ground prior to departure in MSP several comments were made regarding the length of the day and feeling fatigued. At this point in the flight only the Captain mentions this concern with the first office agreeing. Both crewmembers had already been awake in excess of 15 hours and had completed 7 hours of flying. Subjective reporting of being tired or fatigued is very unreliable (Rosekind, et al., 1999). Research has shown that even when subjects are demonstratively performance impaired due to fatigue, most will report that they feel fine. By the time people actually verbally report that they are tired and feel fatigued they have in fact been in that state for some period of time. The Captain stated in his interview that upon reaching their cruise altitude that he had realized that it had been a very long day and that he was more tired than he had realized. This observation is consistent with human behavior in that once the pace and workload decreases, subjects become more aware of their level of fatigue. This contributes to the difficulty of assessing our current fatigue state.

In order to understand the crew's decision to land after hearing the possible report of "Nil" braking action we need to examine their understanding of the runway condition prior to departure from MSP. We need to understand their unfolding mindset as it was occurring. The First Officer discussed in his interview that prior to leaving MSP, the crew discussed the dry runway conditions and fuel at Traverse City. This current understanding of reasonable runway conditions was later supported when they were 18 minutes out and they received the report of Mu values of 40. This would indicate that although there may now be snow on the runway, the depth was reasonable and the Mu value was very reasonable at a reported value of 40 (braking action good). There would be no information provided to the crew at this point that should have altered the crew's perception that this runway was unsafe to any degree. Their perception would have been that nothing of any significance had changed since their last discussion regarding runway conditions when they were in MSP.

<u>Airborne at 03:34:06 until cruise flight at 03:50:30</u>

03:40:00 HOT-1	[sounds similar to sigh and yawn] ah #.
03:41:52 HOT-1	aw I'm tired dude, just # worn out.
03:41:57 HOT-1	(just) not in the mood to have the the # match that that coulda turned into with dispatch. ya know?

During this segment of flight we again have the Captain making a comment about being tired. The CVR also captures him yawning at 03:40:00. This is remarkable in that he continues to be aware of his fatigued state continues to make unsolicited remarks to the First Officer. He additionally makes a reference to his interaction with the dispatcher and his tolerance to the possible dynamics of that interaction. These subjective and physiological responses are strongly suggestive of a fatigued physiological state.

Cruise flight at 03:50:30 until beginning of the approach at 04:38:29

03:55:28 HOT-1	I don't know, I can't do my math. well two eight zero is only ten off of # west so hah that'd be a one hundred runway, right? so.
04:01:06 HOT-1	[sound similar to yawn] your back's gonna be sore from being in that seat leaning over to type hah shorter you are the worse it is.
04:04:51 HOT-1	good, short runway night snow tailwind heavy airplane, love it. [sound of laughter] ya know?
04:05:02 HOT-1	the public's in good hands with Allstate you know what I mean?
04:05:07 HOT-2	the way it's always is.
04:09:47 HOT-1	[sound similar to yawn] oh shyot.
04:18:43 HOT-1	'kay these are pieces of #. I * * a wet dog ready to go to sleep tonight dude. (I'm ready).
04:20:41 HOT-2	# I'm tired. approach briefing.
04:25:43 HOT-1	he's got equipment on the runway this gets better.
04:30:45 HOT-1	I don't like that #.
04:33:18 HOT-1	[sound similar to sigh].
04:33:20 HOT-1	dude * * can't win from losing today.

During this section the CVR captures three yawns/sighs (04:01:06, 04:09:47, 04:33:18) from the Captain. He also makes reference to again twice (04:18:43, 04:20:41) as to how tired he is. He also discusses how he is ready to end the day and go to bed at 04:18:43. This type of thinking contributes to plan continuation type events. Mentally he is focused on getting the aircraft on the ground and going to bed. He is recognizing his body’s developing overwhelming desire to sleep. This type of mental frame of mind as the result of fatigue will later effect critical decision making. He will be less able to incorporate and utilize new information as it becomes available and unless it is overwhelmingly different from the particular information he already has, there is less chance it will be considered.

Beginning of the approach at 04:38:29 until CVR end of recording at 04:55:44

04:38:03.2 OPS	yeah I'm gonna I don't know what the ah conditions like * down the runway but I'm gonna call braking action NIL now. cause' it's fillin in real hard.
04:38:12.7 HOT-1	three one zero. so he sayin' it's a # runway's what he's tellin' me.
04:39:08.8 HOT-1	he's saying it's fillin' in so his runway's a foot deep of snow is what's he's tellin' me. so we're gonna be very careful on the thrust reversers we're gonna keep this # straight.
04:39:21.7 HOT-1	I mean what kind of report's that it's filling in ya know doesn't tell me good bad fair poor.

At 04:38:03 the crew gets their first braking action report while airborne. The ATC tower is closed and they receive this from Traverse City Airport Operations. They received this braking action report one second before they receive their final turn for localizer intercept. At 04:38:29 (26 seconds later) they receive their approach clearance. About 30 seconds later (04:39:08) the Captain appears to have processed the information he heard from operations and tells the First Officer about the runway conditions and that they need to be careful with the thrust reversers. He never mentions the "NIL" comment and only discusses the snow depth. His comment to the First Officer at 04:38:03 and 04:39:21 indicates that he did not hear or comprehend the first braking action report from ground operations. At 04:39:21 he comments to the First Officer that the information ground operations provided him was not helpful and insinuates that it does not tell him actual braking action reports of *good bad fair poor*.

04:40:53.1 OPS	yeah we're all clear of the runway for ya and again ah brakin' actions probably NIL on the runway.
04:40:57.4 RDO-1	are you saying it's NIL?
04:40:59.3 OPS	(oh I) haven't been out there to do a field report and it's been ah five ten minutes so I don't know what it's doin' now.
04:41:07.3 HOT-1	he's not reporting it NIL he's like he's sayin' its NIL. heh.
04:41:31.3 RDO-1	about how deep of a contaminate would you say it is?
04:41:34.7 OPS	I'd ah forty seven twelve I'd say it's probably close to half inch now.

04:41:38.9 RDO-1	okay that's not bad thank you.
04:41:39.0 HOT-2	'kay.
04:41:40.8 HOT-2	good
04:41:41.2 HOT-1	* we're allowed three inches. alright. and set my missed please three thousand we might need it if it looks ugly when we're comin' in I'll go around. (you know what I mean). made this mistake before. as long as there's no shovel you know marks and # half inch is nothin'. alright our decision height's eight twenty call me at nine twenty a hundred above.

During this time frame they have configured the aircraft for landing and are beginning the landing checklist. At 04:40:53 they are two minutes and nine seconds from touchdown and they receive another braking action report that the Captain hears this time. He immediately questions back *are you saying it's NIL?* The ground operations person does not restate this concept and confesses that he has not checked in awhile and that he does not know *it's doing now*. Essentially the airport operations person is now retracting the only "nil" statement that the crew has heard and understood. This is the only vague clue the crew receives that may indicate that braking action is unacceptable for landing. The Captain comments to his First Officer that ground operations is not reporting it as NIL but rather it's *like NIL*. This is an extremely ambiguous clue in a very dynamic environment with about 2 minutes until touchdown and a crew that is suffering from both chronic and acute fatigue. Up until this moment the crew was of the mindset that runway conditions were never close to being unsafe or unreasonable. Then they receive and ambiguous clue that is then retracted a few seconds later when asked to clarify. Like all expert decision makers, they will continue with the original plan until they receive information to suggest another course of action.

At about 1,000 ft AGL (04:41:33) and with one minute and thirty-one seconds from landing the Captain calls ground operations one more time to check runway conditions. He asks them about the depth of the snow and receives an answer of about one-half inch. A few seconds later he briefs the First Officer on the current depth and discusses at 04:41:41 the aircraft limitation for snow depth and a comment about previous experiences in these conditions. There is never another discussion about braking action again prior to landing. This type of informational fixation contributing to plan continuation is commonly seen in fatigued individuals making critical decisions as seen in other accidents discussed earlier in this section. In addition, due to the fatigue of both crewmembers, they were focused on landing at this point and a diversion was probably no longer being considered. Additionally, when the Captain was discussing these comments with the First Officer, he did not mention the "NIL" comment. This ambiguous information was provided to the crew very late in the decision making process making it even harder for a fatigued individual to incorporate this knowledge into their decision making process. The Captain was extremely busy. He was the flying pilot, talking at times to airport operations and listening and repeating back ATC instructions to his First Officer. This informational fixation has been reported in other accidents (Korean Air Flight 801, American Airlines Flight 1420, American International Airways Flight 808 and Corporate Airlines Flight 5966).

Crew member decision making

There is a preponderance of fatigue research supporting the hypothesis that as length of day increases, human performance decreases. More specifically, plan continuation becomes more common and higher cognitive abilities such as those used in evaluating new data for a given situation and decision making are decreased. The Safety Board's flight crew errors study in addition to fatigue research by Rosa et al. and Goode et al. show that flight crew members that have been awake more than 12 to 13 hours demonstrate measurable degraded performance. In 1998, a study presented by NASA Ames Research Center (Orasanu, 1998) examined flight crew errors. The purpose of the study was to examine flight crew errors in an effort to discover any patterns that might enable safety improvements. The most common crew error discovered was when the crew decided to *continue with the original plan of action in the face of cues that suggested changing the course of action.* Pertaining to the Pinnacle Flight 4712, one excerpt from the report was especially revealing when examining plan continuation and new information presented to the flight crew.

> *…recurring problem is that pilots are not likely to question their interpretation of a situation even if it is in error. Ambiguous cues may permit multiple interpretations. If this ambiguity is not recognized, the crew may be confident that they have correctly interpreted the problem. Even if the ambiguity is recognized, a substantial weight of evidence may be needed to change the plan being executed.*

Research has shown that both stress and fatigue will enhance a person's selective focus on limited cues that are made available to them. This type of fixation or plan continuation has been reported in both academic literature (Caldwell, 1997) and previously mentioned accident reports. Typically it takes clear and overwhelming evidence to alter one's course of action.

Previous fatigue related accidents

Korean Air Flight 801

In 2000, the Safety Board released their findings for the Korean Air Flight 801 accident in Guam. There were numerous findings and causal factors, one of which was the Captain's physiologically fatigued state. Several fatigue inducing factors and parallels are similar between the Captain of the Korean Air flight 801 and the Captain of Pinnacle 4712. Both had significant length of day for the accident day (Korean Air – 11 hours; Pinnacle 4712 – almost 17 hours). Both accidents occurred during a circadian decline in performance and both Captains were several hours beyond their normal and customary bedtimes. There are similar patterns of behavior between the Captain of the Korean Air flight and the Captain of Pinnacle 4712.

American Airlines Flight 1420

In 2001, the Safety Board released their findings for the American 1420 accident in Little Rock, AR. Among many identified factors, they found that fatigue and situational stress were contributing factors in this accident. They determined that both fatigue and stress affected the crew's judgment. Specifically, one conclusion was - *the flight crew's degraded performance was consistent with known effects of fatigue.* Like the Pinnacle 4712 crew, the flight 1420 crew had been awake about 16 hours at the time of the accident. Additionally, the American crew, like the Pinnacle crew was flying several hours past the time they would normally be in bed. The American crew also had length of day and time of day fatigue considerations. Although the American 1420 crew had no discussion about being fatigued captured on the CVR however there was one yawn recorded. In contrast, the Captain of the Pinnacle 4712 crew made several comments about being tired and several yawns were captured on tape. Both accident crews demonstrated impaired judgment in a rapidly dynamic environment as the result of being fatigued.

American International Airways Flight 808

In 1994, the Safety Board released their findings for the American International Airways Flight 808 accident in Cuba. In the probable cause they cited fatigue that impaired all crewmembers affecting their judgment. The NTSB discovered during their investigation that all of the crewmembers had experienced significant sleep loss as the result of extended length of day and circadian disruption. Unlike the Pinnacle 4712 Captain, there were no comments on the CVR regarding how tired they were. All three crew members testified at the NTSB hearing and remarked how tired they were prior to the accident. On the day of the accident, both accident crews had a length of day significantly more then the 13 to 17 hours of wakefulness that previously discussed research had elucidated. Both Captains also fixated on single items (Flight 808 – strobe light and Flight 4712 – snow depth) at the expense of other information that may have helped them abandon their current plan in favor of another option or seeking more information to help their decision making.

Corporate Airlines Flight 5966

In 2006, the Safety Board released their findings for the Corporate Airlines Flight 5966 in Kirksville, MO. Although several factors were cited, fatigue was reported as a contributing factor in their degraded performance. Just like the Pinnacle 4712 crew, the Corporate 5966 crew had a significant time since awake (about 15 hours) at the time of the accident. Their behavior and judgment was affected by their fatigued state as reported in the NTSB report. Once again, we see a crew that had a length of day greater than 13 hours after one or more shorter than required sleep periods. There are several similar behavioral patterns in both the Corporate and Pinnacle accident crews.

Operational considerations

Fatigue and sick call

The responsibility of safely completing each flight belongs to the operator and the pilot in command. 14 CFR Part 91.3(a) states that: *The pilot in command of an aircraft is directly responsible for, and is the final authority as to, the operation of that aircraft.* However, operational control also resides with the certificate holder. As such, there is a joint responsibility for the safe operation of the aircraft between the pilot in command and the certificate holder. In order to ensure that flights operate safely, there must be a positive interaction between these two groups. A healthy corporate culture will foster and support this type of relationship.

Airline crew members have the responsibility to report to work fit and rested. If they find themselves unable to meet this requirement (14 CFR FAR 61.53), they are clearly directed by Federal Regulations to remove themselves from duty until such time as they are able to meet the requirements of their medical certificate. One of the characteristics of a healthy corporate culture is an environment where employees, specifically pilots can call in sick or fatigued as required. Subjecting employees to disciplinary action based on these actions will undermine a healthy corporate culture and is potentially dangerous. For those pilots that do exhibit genuine unprofessional behavior a just culture supports reasonable discipline for these infractions. Disciplining a pilot for complying with a regulation is contrary to Pinnacle’s responsibility to ensure the highest level of operational safety. During several interviews, pilots felt that calling in fatigue or sick was problematic. During his interview, the Captain referred to a disciplinary process that begins once four sick calls were made. Due to the subjective and difficult nature of determining ones current level of fatigue, working in an environment where employees do not feel comfortable calling in fatigued or sick is dangerous.

Human Performance Conclusions

Thorough investigation of this accident reveals a systems accident in the truest sense. No single decision, component failure or human error produced this event. The crew of Pinnacle flight 4712 approached Traverse City Airport with the reasonable belief that a safe landing could have been accomplished. Runway conditions that were briefed prior to departure supported this assumption. Prior to beginning the approach, armed with additional information that the runway conditions were being reported as a Mu value of 40 (braking action good), they began the final moments of this flight with no reason to suspect that runway braking action was unsafe.

Close examination of sleep history for both crew members reveals that physiological fatigue was present. As seen in several previous accidents, both crew members had significant length of day, time of day and chronic sleep issues. Some or all of these values were in excess of several other accidents where crew member fatigue was cited as a contributory factor. This however, in and of itself does not guarantee a physiological fatigued state but rather these exceedances in conjunction with behaviors seen in both crew members supports the notion of cognitive impairment from a fatigued physiological state. These same behaviors are well documented in research literature and previous fatigue related accidents.

While just prior to and during the approach the crew received ambiguous clues that braking action was less than desirable. However, their preexisting knowledge of good runway conditions (Mu value of 40), the vagueness of the report and their physiologically fatigued state made it unachievable for either crew member to fully understand this newer ambiguous information. During the approach, based on the information they possessed and their limited capabilities of understanding the vague information as presented, it was understandable and reasonable for them to have continued the approach and landing. Close examination of their local rationality shows how each decision made regarding runway conditions during the flight made sense and was reasonable.

VIII. CONCLUSIONS

The accident at Traverse City on April 12, 2007, can not be attributed to one single cause, but resulted from numerous failures within the system. The flight was dispatched using weather from an unapproved source and even that forecast was inaccurate. The operational pressures for on-time flights and high completion factor created a company culture in which statistics dictate dispatching flights over utilizing a systems safety approach. The Airport Operations at Traverse City did not comply with FAA guidance material to ensure that the airport was maintained to allow for safe operations and when they deemed such unsafe conditions to exist they failed to close the runway. Airport Operations personnel instead used subjective, non-standard, conflicting information and when asked to clarify their statement the airport personnel retracted his nil report and said that he did not know what it was doing. The crew had experienced a long duty day which included five flights, all of which were conducting IOE. This in concert with sleep deprivation and circadian decline allowed a fatigued crew to fixate and exercise impaired judgment during their approach. A break in any of these sequences of events would have prevented this accident.

IX. FINDINGS

1. Pinnacle Airlines was not authorized under operations specifications A010 to use the Northwest Airlines Meteorology department to as an approved source of weather for dispatching flights.

2. The TAF obtained from Northwest Airlines Meteorology did not accurately forecast the intensity of the snow.

3. The dispatcher was uncomfortable with dispatching the flight, but by not allowing the dispatcher the ability to cancel the flight effectively forced him to dispatch the flight.

4. The relieving dispatcher failed to perform his duty of flight following the aircraft and inform the crew of the updated weather at their destination and alternate.

5. Minneapolis Center failed to provide the crew with the updated METAR for TVC prior to the approach clearance even though the weather was well below 1,000’ ceilings AND 3 statue miles.

6. Traverse City Airport Operations failed to comply with FAA guidance by not providing accurate, timely field condition reports.

7. Traverse City Airport Operations failed to comply with FAA guidance by not closing Runway 28 when Airport Operations felt that the braking action was “nil.”

8. Based on the evidentiary and scientific data this crew was fatigued and their behavior and judgment were affected.

X. SAFETY RECOMMENDATIONS

As a result of this investigation, the Air Line Pilots Association, International supports and asks that the National Transportation Safety Board would reissue these recommendations to the Federal Aviation Administration.

Open Safety Recommendations

1. A-06-010 Modify and simplify the flight crew hours-of-service regulations to take into consideration factors such as length of duty day, starting time, workload, and other factors shown by recent research, scientific evidence, and current industry experience to affect crew alertness.
2. A-07-059 Require all 14 Code of Federal Regulations Part 121 and 135 operators to provide clear guidance and training to pilots and dispatchers regarding company policy on surface condition and braking action reports and the assumptions affecting landing distance/stopping margin calculations, to include use of airplane ground deceleration devices, wind conditions and limits, air distance, and safety margins.
3. A-07-062 Develop and issue formal guidance regarding standards and guidelines for the development, delivery, and interpretation of runway surface condition reports.
4. A-07-063 Establish a minimum standard for 14 Code of Federal Regulations Part 121 and 135 operators to use in correlating an airplane's braking ability to braking action reports and runway contaminant type and depth reports for runway surface conditions worse than bare and dry.

In addition to the recommendations previously submitted by the Board, the Air Line Pilots Association suggests the following recommendations.

New Recommendations

To the Federal Aviation Administration:

1. Require manufacturers of aircraft certificated under FAR Part 25 to develop flight test data and methods necessary to utilize runway surface friction information to reliably determine landing and stopping distance requirements, and to provide the operators with these data and methods.

2. Require operators to incorporate and utilize the runway friction measurement accountability data and methods described above once it becomes available from the manufacturers.

3. Amend Advisory Circular 150/5200-30B ('Airport Winter Safety and Operations') to more specifically regiment runway surface friction measurement and reporting procedures.

4. Require Airport Operators to close runways, for the purpose of surface treatment and snow removal, that have "nil" braking action reports, whether that is determined by pilot or vehicle braking action reports.

5. Define the braking action terms using characteristics that pilots are familiar with to aid in choosing the most appropriate term. For example:

Braking Action Term	Definition*	Estimated Runway Surface Condition Correlation*	Pilot Centric Definition
Good	Braking deceleration is normal for the wheel braking effort applied. Directional control is normal.	• Water depth 1/8 inch or less • Dry snow less than ¾ inch deep • Compacted snow with OAT at or below minus 15°C	Characterized by no periods in which the anti-skid limit is reached, if equipped with an anti-skid system. The pilot is able to easily exit the runway at the planned runway exit, using normal to slightly higher brake pedal pressure (normal reverse thrust if reverse thrust is installed). Deceleration feels normal despite the runway not being dry, and no directional control problems are experienced.
Fair	Braking deceleration is noticeably reduced for the wheel braking effort applied. Directional control may be slightly reduced.	• Dry snow ¾ inch deep or greater • Sanded snow • Sanded ice • Compact snow with OAT greater than minus 15°C	Characterized by occasional (less than 1/3 of the time) periods in which the anti-skid limit is reached. The pilot is able to exit the runway at the planned runway exit, using strong brake pedal pressure (normal reverse thrust if reverse thrust is installed). Deceleration is noticeably degraded, but no directional control problems are experienced.
Poor	Braking deceleration is significantly reduced for the wheel braking effort applied. Potential for hydroplaning exists. Directional control may be significantly reduced.	• Wet snow • Slush • Water depth more than 1/8 inch • Ice (not melting)	Characterized by intermittent (1/3 to 2/3 of the time) periods in which the anti-skid limit is reached. The pilot is able to exit the runway at the planned runway exit only by using maximum manual brake pedal

			pressure and full reverse thrust, if equipped with reverse thrust. Deceleration is significantly degraded, or directional control is noticeably degraded but doesn't require discontinuing the use of reverse thrust.
Nil	Braking deceleration is minimal to nonexistent for the wheel braking effort applied. Directional control may be uncertain.	• Ice (melting) • Wet ice	Characterized by continuous (more than 2/3 of the time) period in which the anti-skid limit is reached. The pilot is unable to exit the runway at the planned runway exit, despite using maximum manual brake pedal pressure and full reverse thrust. The pilot has the sense of very little or no deceleration despite the use of maximum manual braking; the sensation may actually be that the aircraft feels as though it is accelerating. Pay particular attention to this when discontinuing reverse thrust . Directional control may be degraded to the extent that reverse thrust must be discontinued.

*Taken from the FAA Common Terms and Definitions WG

6. Use the term "contaminated" to refer to runway surface conditions that affect both the tire-to-surface friction and the acceleration/deceleration of the aircraft. Contaminated runway surfaces include any material that contributes to displacement and impingement drag and/or hydroplaning.

7. Use the term "slippery" to refer to runway surface conditions that affect only the tire-to-surface friction. Slippery runway surfaces do <u>not</u> contribute to displacement and/or impingement drag.

8. Develop standard and radio phraseology to be used by pilots, ATC, and airport personnel to describe runway surface conditions.

9. Research the development of a system that compares the operator (pilot or ground vehicle) commanded brake pressure to the brake pressure applied at the wheels by the Anti-Skid system and relating this ratio to a scale of Good, Fair, Poor, and Nil. For example:

Applied Brake Pressure / Commanded Brake Pressure	Braking Action Term
0.75 to 1.00	Good
0.50 to 0.74	Fair
0.25 to 0.49	Poor
0.00 to 0.24	Nil

In addition, pilots should be required to state what level of thrust reverse (idle, maximum, etc.) was used. For example, a pilot report might be “Braking action fair with idle reverse.”

XI. REFERECES

Belenky, G., Wesensten, N.J., Thorne, D.R., Thomas, M.L., Sing, H.C., Redmond, D.P., Russo, B.M., Balkin, T.J. (2003) Patterns of performance degradation and restoration during sleep restriction and subsequent recovery: a sleep dose-response study. *J. Sleep Res.*, 12, 1-13.

Belenky, G. (2007). Schedules, sleep, fatigue, and performance in the crash of Comair 5191. Appendix 3 in the Air Line Pilots Association submission to the National Transportation Safety Board for Comair 5191 (DCA064MA064). See the public docket at the NTSB, Washington D.C.

Caldwell, J.A. (1997). Fatigue in the Aviation Environment: An Overview of the Causes and Effect as well as Recommended Countermeasures, *Aviation, Space, and Environmental Medicine,* (68): 932-938.

Falleti, M.G., Maruff, P., Collie, A., Darby, D.G. and McStephen, M. (2003). Qualitative similarities in cognitive impairment associated with 24 h of sustained wakefulness and a blood alcohol concentration of 0.05%. *Journal of Sleep Research,* 12, 265-274.

Goode J.H., "Are Pilots at Risk of Accidents Due to Fatigue?", *Journal of Safety Research*, Vol. 34 (2003): 309-313.

Lavie, P. (1986). Ultrashort sleep-waking schedule. III. 'Gates' and 'forbidden zones' for sleep. *Electroencephalogr Clin Neurophysiol*, 63, 5, 414-25.

National Transportation Safety Board. 1993. *Uncontrolled Collision With Terrain, American International Airways Flight 808, Douglas DC-8-61, N814CK, U.S. Naval Air Station, Guantanamo Bay, Cuba, August 18, 1993*. Aircraft Accident Report NTSB/AAR-94/04. Washington, DC.

National Transportation Safety Board. 1994. *A Review of Flightcrew-Involved Major Accidents of U.S. Air Carriers, 1978 Through 1990.* Safety Study NTSB/SS-94/01. Washington, DC.

National Transportation Safety Board. 2000. *Controlled Flight Into Terrain. Korean Air Flight 801, Boeing 747-300, HL7468, Nimitz Hill, Guam, August 6, 1997.* Aircraft Accident Report NTSB/AAR-2000/01. Washington, DC.

National Transportation Safety Board. 2001. *Runway Overrun During Landing. American Airlines Flight 1420, McDonnell Douglas MD-82, N215AA, Little Rock, Arkansas, June 1, 1999.* Aircraft Accident Report NTSB/AAR-01/02. Washington, DC.

National Transportation Safety Board. 2004. *Collision with Trees and Crash Short of the Runway, Corporate Airlines Flight 5966, BAE Systems BAE-J320, N875JX Kirksville Missouri, October 19, 2004.* Aircraft Accident Report NTSB/AAR-06/01. Washington, DC.

Orasanu, J., Martin, L., and Davison, J. *Errors in Aviation Decision Making: Bad Decisions or Bad Luck?* NASA Ames Research Center, Moffett Field, California. Presented to the Fourth Conference on Naturalistic Decision Making, Warrenton, Virginia, May 29-31, 1998.

Rosa, R.R., Colligan, M.J., & Lewis, P. (1989). Extended Workdays: Effects of 8-Hour and 12-Hour Rotating Shift Schedules on Performance, Subjective Alertness, Sleep Patterns, and Psychosocial Variables. *Work and Stress,* (3) 1, 21-32.

Rosekind, M.R., Gander, P.H., Connell, L.J., & Co, E.L. (1999). Crew factors in flight operations X: Alertness management in flight operations. *National Aeronautics and Space Administration, Ames Research Center*, Moffett Field, California, Agency Report Number: NASA/TM-1999-208780.

Van Dongen, H.P.A, Maislin, G., Mullington, J.M., Dinges, D.F. (2003). The cumulative cost of additional wakefulness: Dose-response effects on neurobehavioral functions and sleep physiology from chronic sleep restriction and total sleep deprivation. *Sleep*, 26, 117–126.

Van Dongen, H.P.A, Dinges, D.F. (2005). Circadian rhythms in sleepiness, alertness, and performance. In Kryger, M.H., Roth, T., & Dement, W.C. (Eds.) The Principles and Practice of Sleep Medicine, 4th Edition (pp. 335-343) Philadelphia, PA: Elsevier Saunders.

Wesensten, N.J., Belenky, G., Thorne, D.R., Kautz, M.A., & Balkin, T.J. (2004) Modafinil versus caffeine: Effects on fatigue during sleep deprivation. *Aviation Space Environmental Medicine*, 75, 520-525.

Williamson, A.M. & Feyer, A. (2000). Moderate sleep deprivation produces impairments in cognitive and motor performance equivalent to legally prescribed levels of alcohol intoxication. *Occupational Environmental Medicine*, 57, 649-655.