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The 10th day of March, 1989 had been an extremely frustrating day for Air Ontario Captain George C. Morwood, a 24,000 hour veteran pilot, known for his commitment to on-time performance. Early morning engine problems at Winnipeg; extremely bad weather all along his Winnipeg–Dryden-Thunder Bay and return route; last minute heavier than forecasted passenger bookings at Thunder Bay requiring deloading of fuel; and the less than optimum operational status of his snag-plagued Fokker F-28 jet had allied to produce numerous and frustrating flight delays.

More than an hour behind schedule, at the button of Runway 29, the end of the day, and of the frustrations, seemed to be just around the corner, a mere forty-five minutes away, in Winnipeg, Manitoba. After a further delay, waiting in a driving snowstorm for a small plane in distress to land, his jet's wings covered with a lethal accumulation of heavy wet snow and ice, of which he could not have been unaware, Captain Morwood, at 12:09PM, advanced the throttles, initiating the take-off roll on the slush covered runway. After two attempts at rotation, it mushed into the air at a height of about fifteen feet. One minute and five seconds from commencement of the takeoff roll, unable to gain altitude, it plunged into a wooded area less than one kilometer from the end of Runway 29, killing 21 passengers, plus the cockpit crew and the senior flight attendant.

Because there was no evidence that Captain Morwood was suicidal, I concluded that he mistakenly believed that the accumulated snow and ice on the wings would slide off during the take-off roll. It was a fatal error on his part. He obviously did not consider, or was unaware of, the phenomenon of cold-soaking of fuel in the wing tanks in extreme freezing temperatures at high altitude, which causes invisible black ice to form on the upper wing surfaces after landing. Falling snow then adheres to the black ice, destroying the wing's lifting capability. The cold-soaking phenomenon was not well known at the time, and was virtually unmentioned in pilot manuals and Transport Canada literature.

The Canadian Aviation Safety Board (CASB) initiated an investigation immediately after the Dryden crash. However, the Government of Canada, in order to address widespread public outrage then existing over CASB's perceived mishandling of the Arrow Air DC-8 crash at Gander, Newfoundland, in which 278 USA military personnel and air crew died, legislated that body out of existence on March 29, 1989. Concurrently, on that date, my commission of inquiry was established under the Inquiries Act to take over the investigation of the Dryden crash from the now defunct CASB. No less than the restoration of credibility to the aviation accident investigative process in Canada was involved.

The three year Dryden Inquiry presented a rare opportunity for an independent body to examine the entire Canadian aviation system for organizational failures, both latent and active, which might have contributed to the Captain's faulty decision, and to make recommendations for necessary change. It was an opportunity not to be squandered. In order to assure credibility for the Inquiry, a multi-disciplinary team of highly reputable Canadian and International accident investigators, pilots, aeronautical engineers, aviation safety experts, human factors experts, de-icing experts and legal counsel, was assembled. A four volume Final Report and two Interim Reports, totaling some 2000 pages, were produced, based on the evidence of 166 witnesses and over 1300 exhibits. 191 recommendations were made for major changes to the Canadian Aviation system, including the complete re-writing of the then decades old and archaic Air Regulations and their harmonization with the U.S. FAR's, and the European JAR's. Unquestionably, the use of various experts was key to the success of the Inquiry.

At first blush, the cause of the Dryden crash appeared self-evident. Very heavy wet snow was falling during the one-half hour that the aircraft sat on the ground after landing at Dryden in freezing temperatures, conditions ideal for wing icing. Although offered de-icing, the Captain declined and elected to take off without de-icing the aircraft. Conventional accident investigation in vogue at that time would have quickly come to the simplistic conclusion that the crash was solely caused by pilot error and the investigation might have been closed within a week of my appointment, with a finding of pilot error. However, there was a troubling and obvious question that begged an answer. Why would such an experienced crew ignore the tell-tale danger indicators which were presented to them before takeoff? I suspected that there was a lot more to it than simply pilot error. Therefore, the mandate that I insisted upon, and obtained, from the government, as a term of my accepting its request to head the Commission of Inquiry, was not only to investigate the specific air crash, but also to investigate corollary safety-related matters within the entire Canadian aviation system. This turned out to be a fortuitous decision.

I elected to interpret my mandate broadly. This made it possible for my Commission to not only investigate the Dryden crash but also, for example, to undertake the investigation of peripheral safety concerns such as the very serious winter weather departure lineups and delays, and aircraft de-icing concerns, which were personally drawn to my attention by the Chief of Air Traffic Control at Pearson International Airport in Toronto, after a severe winter storm shut down the airport in January 1990. He described that airport as an accident looking for a place to happen. He had been begging Transport Canada to do something about the situation for a long time. As my Commission was the only aviation safety and accident investigative body in existence in Canada at the time, we immediately launched six months of Commission hearings focused on Pearson International. My investigators uncovered major problems at that airport, including the use of very primitive deicing technology. We found that aircraft wings were being deiced with hot water which immediately refroze in the form of invisible ice, or with a primitive Type 1 deicing fluid which provided a hold-over time against refreezing of about 1

minute or less. These aircraft then joined a departure lineup in freezing precipitation for up to one hour and were taking off with contaminated wings and a drastically reduced margin of safety. My Commission investigators observed one Boeing 747 stagger into the air at Pearson International, with a foot of snow and ice on it's wings. Clearly it had no margin of safety left. Even a slight loss of power in one engine on takeoff would have almost certainly caused it to crash. Needless to say, numerous urgent and specific recommendations to Transport Canada for change were promptly made by way of my Second Interim Report. This resulted in speedy regulatory enactment by Transport Canada of the 'clean wing' concept and the prohibition of takeoff with contaminated wings, the introduction of revolutionary new ground deicing procedures including provision of runway departure–end deicing bays, gate holds, mandatory runway departure-end inspections of aircraft surfaces before takeoff in bad winter conditions, new deicing equipment and the development of new, advanced deicing fluids, to name a few. These major changes were adopted not only at Pearson, but also at all other major Canadian airports, as well as internationally. These changes, which are regarded as the crown jewel of the Dryden Commission, moved Canada from an aircraft ground de-icing backwater to the leading edge of aircraft ground de-icing technology internationally. I do not have time to elaborate further on them here.

Preliminary evidence uncovered by my commission investigators pointed compellingly to the possibility of a widespread systems failure contributing to the Dryden crash, A decision was made, over the objections of counsel for the regulator and the carrier, to conduct, for the first time in aviation accident investigation history, an in-depth, structured investigation of the entire aviation system within which flight 1363 functioned, including the role of all the primary components of the aviation system, i.e. the regulator, the carrier, the aircrew, and the operating environment. This involved a search for all contributing factors leading to the crash, with an emphasis on the impact of human factors throughout the aviation system upon the events at Dryden. Today, because of time limitations, I will focus primarily on the role of the carrier. Captain Morwood's flawed decision to take off, which clearly constituted pilot error, became only the starting point of the Dryden Inquiry. It led to the ultimate determination that the entire aviation system had let him down.

During twenty months of intensive public hearings, my Commission literally tore apart the Canadian aviation system and exposed a plethora of negligence, miscues, omissions, commissions, deficiencies, bad management and regulatory policies, human factors, and active and latent failures within every aspect of the aviation system, which all came together at Dryden. Contributing factors to the Dryden crash manifested themselves not only in the cockpit but also in the carrier's System Operations Centre, in its dispatch, maintenance and training departments, in the boardrooms of the carrier and of those of the regulator, and in two simultaneous and mutually inconsistent policies of the government itself, namely the policies of fiscal responsibility and the deregulation of the airline industry. I can cite only a few examples out of hundreds because of time limitation, and I propose to

make some comments on the subjects of human factors, system failures and the management of risk in high technology systems, all of which were involved in the events at Dryden.

Air Ontario F-28 pilots operated in a very taxing operational environment. The conflict between Aviation Safety and the corporate bottom line manifested itself very vividly in the case of the Air Ontario F-28 crash at Dryden. Air carriers obviously are not in the business to lose money. Like every business they seek to generate a profit. All of them are confronted with a dilemma. Pro-active steps to advance safety cost money. It is in the area of safety that the easiest cuts in expenditures can be made by management. Where an air carrier is profit driven to the virtual exclusion of concern for safety standards, as we found was sadly the case at Air Ontario, we have an incubator for a potential accident. A myriad of examples were uncovered of a corporate management culture that was in fact profit-driven and which placed profit before safety, a few of which are as follows:

(a)As a cost cutting measure, and even though it's corporate plan and Transport Canada Regulations called for one, there was no safety officer and no safety organization in place at Air Ontario during the entire period from the introduction of the F-28 jet into service until the crash, a period of less than two years.

(b)There was inadequate pilot training and former propeller-aircraft pilots were turned loose on the sophisticated F-28 jets with absolutely minimal jet aircraft indoctrination. Low-time F-28 Captains were paired with low-time First officers, a bad combination. Both pilots on the doomed F28 at Dryden had less than 100 hours flying time on the F28. There were two different and inconsistent pilot Flight Manuals on board the aircraft. There was no Minimum Equipment list on board, even though one was required by regulation. There were no runway slush correction charts readily available in the cockpit. Pilots were left, by management, to determine their own operating standards and operational practises. Prudence and conservatism were lost in the pilot's collective enthusiasm to see their first jet operation succeed.

(c)There were grossly inadequate spare parts available for the F-28 maintenance department and very low levels of expertise among maintenance personnel. There was unbelievably lax maintenance of the F-28 aircraft, which habitually were allowed to fly with known defects. The evidence was that Air Ontario flight management policy was to keep the F-28 aircraft flying on schedule and to sort out maintenance details later. Pilots were instructed by management to record aircraft snags or defects on scraps of paper which were handed from crew to crew, instead of recording them in the aircraft log, in clear breach of Air Regulations, because recording snags in the log would have required the aircraft to be grounded. A senior F-28 Captain when questioned about this management directive stated: "As pilots we wanted this operation to be successful and I think that is why we tolerated a lot of this stuff as long as we did." Another F-28 Captain and a First Officer, who both were very concerned about the safety of their aircraft, one day decided to enter a large number of accumulated

defects into the journey log - all at one time, thus grounding their aircraft. They were both suspended and disciplined by management for doing so, when in fact they deserved to be handed medals.

(e)Air Ontario had put in place a useless policy prohibiting pilots from deicing the F-28 with engines running, a practise which had been successfully carried out in Europe and the USA for more than 25 years. The aircraft which crashed at Dryden had a non-functioning Auxilliary Power Unit (APU) which would prevent a ground start at Dryden, if the engines were shut down for deicing. The APU had been inoperative for 5 days prior to the crash. Rather than taking the aircraft out of service and repairing the APU, Air Ontario management elected to keep it flying in passenger service. The meaningless policy of prohibiting deicing of the aircraft with engines running placed Captain Morwood in an impossible dilemma. If he shut down the engines in order to deice, with no ground start unit available at the Dryden Airport, and a non-functioning APU on his aircraft, he would be stranding the aircraft at Dryden. The flight was full of impatient passengers with connecting flights at Winnipeg, and he would have to answer to management for the substantial costs of his making a decision to ground the flight at Dryden. Faced with all these pressures the Captain decided to go without deicing. Ironically, F-28 ground start equipment, for use at the Dryden Airport, was initially ordered by Air Ontario management who thought it was a regulatory requirement. However, the order was subsequently cancelled, as a cost cutting measure, when management learned that there was no mandatory regulatory requirement for such equipment. There is one now, in response to one of my recommendations. It is a virtual certainty that the Dryden crash and the loss of many lives and millions of dollars would not have occurred if ground start equipment had been available. So, one of the many lessons from Dryden is that a penny saved is not always a penny earned.

(f)The Air Ontario Flight Dispatch system epitomized risk management at it's worst. Flight 1363 was dispatched from Thunder Bay into Dryden by a young man whose previous dispatch experience consisted of dispatching trucks for a department store. He was installed as a full-fledged and unsupervised flight dispatcher of the F28 jet aircraft, after a five day, so-called, training session during which he sat and observed another flight dispatcher at work. Clearly, he would have commanded a salary which was a fraction of that required for a fully qualified and experienced flight dispatcher. He issued an error-filled flight release and dispatched Flight 1363 into Dryden in the face of forecasted conditions of freezing precipitation. An experienced flight dispatcher would have been alerted by the weather forecast to the virtual certainty that the aircraft would need to be de-iced after landing at Dryden in freezing precipitation. He would have been aware of the non-functioning APU on the F28, the lack of ground start equipment at Dryden, and of the Air Ontario policy of prohibiting de-icing with engines running, and that this would mean the automatic grounding of the flight at Dryden. Experts testified that an experienced flight dispatcher would never have dispatched the flight into Dryden in those circumstances. He would have sent it straight to Winnipeg from Thunder Bay, instead, and the Dryden crash would not have occurred.

(g) The Air Ontario Chief Pilot, a son of the owner of the airline, in a program status report urged greater utilization of the grossly under-maintained aircraft, without which, he stated, their profit projections would not be realized. To maximize profits, the F-28 aircraft were ordered by management to be flown on scheduled routes during the entire day and evening, and then throughout the night by training pilots, leaving very little or no opportunity for maintenance of the aircraft. In a bending-of-the-law operational environment, where less restrictive operational practices are promoted by management, a pilot may be encouraged to encroach upon the margin of safety and attempt takeoff with contaminated wings, as indeed occurred at Dryden. It is clear that all on board Air Ontario Flight 1363 were the victims of unacceptable risk management which showed up in all areas of operations, maintenance and personnel training. These are but a few of many examples of how human failures, deliberate risk taking and management cost-cutting measures designed to improve the corporate bottom line, impacted on the crash at Dryden.

The dicothomy between profit and safety places on pilots and maintenance engineers, and I suspect on those in the health care system, a moral or ethical dilemma. On one hand, they are concerned about losing their jobs if they refuse to carry out the orders of management, and, on the other, about the ethics of having to turn a blind eye to questionable actions or inaction. Clearly this is an area where effective whistle-blower legislation and strong professional organizations have a role to play.

Whenever human beings are involved in a complex system, there will be failures both active and latent. The concept of human factors contributing to aviation accidents has been around since the 1930's, when it was first advanced by Dr. Robert McFarland, a renowned American Psychologist. However, cynicism and a lack of understanding of the concept prevailed, with the result that aviation accident investigators generally ignored it or regarded it with skepticism, until Dryden.

Up until the time of the Dryden crash, the aviation industry, for selfish economic reasons, had generally been quite content to avoid a system-wide scrutiny of air carrier management and flight operations for causal factors contributing to an aviation accident. They gladly adopted the expedient of going along with crash investigators in the simplistic assignment of full blame for aviation accidents to pilot error, in up to 90% of air crashes. Equally significant, prior to the Dryden Inquiry, it was also virtually unthinkable for aviation accident investigators to examine the possibility of a role by the regulator in a series of human and organizational failings in the events leading to an accident. That has now changed irrevocably since Dryden. The failings of the regulator, and it's master, the government, of which there were many leading to the events at Dryden, however, will have to await telling on another day.

One of the main lessons of the Dryden crash investigation is that in the vast majority of accidents, multiple causal factors, both active and latent, within the system in which they occur

constitute the anatomy of the accident, and virtually every one of them is put in place by a human being. The elimination of even one of them likely would have prevented the tragedy at Dryden. I will now say a few things about risk management.

Technology dominates our world today. While technical solutions for controlling risk can bring order out of chaos, risk management is unfortunately also at the mercy of human failure. Stories of human failure undermining the operation of the best engineered systems abound. Yale University sociologist, Charles Perrow, in his textbook entitled “Normal accidents - living with high risk technologies”, identifies a systems failure which is due to the unforeseen interaction of multiple components which are tied together tightly in a complex system. He states that most high-risk systems have some special characteristics that make accidents in them inevitable, even normal. This has to do with the way failures can interact and the way the system is tied together. Mr. Perrow wrote: “Risk will never be eliminated from a high-risk system and we will never eliminate more than a few systems at best. At the very least, however, we might stop blaming the wrong people and the wrong factors, and stop trying to fix the systems in ways that only make them riskier.”

The subject of safety inevitably arises whenever risk and its management are discussed. In his book, “Of Acceptable Risks,” William W. Lowrance proposes that “a thing is safe it its risks are judged to be acceptable. There are two aspects to a consideration of risk. The first is the objective assessment of the number and severity of the risks facing one. The subjective aspect involves assessing how acceptable a person or society finds those risks to be.

General James Doolittle, who led the World War II Tokyo Raid, stated in 1952 that “the American public accepts the calculated risk in transportation accidents as an inescapable condition of the enjoyment of life in a mechanical age”. Today it is quite clear that not only in America, but worldwide, public attitude has dramatically shifted away from General Doolittle’s view as to the public’s docile acceptance of calculated risk in transportation accidents. Dr. Vernon Grose of Arlington, Virginia, a world authority on risk management, and a pioneer in the application of systems methodology to controlling risks, wrote in his book “Managing Risk”, that managers today are pressured by three major influences to control risks and hazards before the fact. These are morality, economics and litigation. He wrote: “The Judeo- Christian values of western civilization establish the moral imperative to protect human life. A strong moral corollary has existed for centuries to consider any loss of any type as undesirable. Economic pressure to control risk arose about thirty years ago. However, the third force, litigation, is more recent. In the early 1960’s, product liability law and it’s off-shoot, service liability, awoke from a deep sleep. It is in the courtroom that the ultimate dollar value of human life is established case by case. So managers can expect to be increasingly caught in the middle of three forces, morality, economics and litigation, in the risks which they elect to undertake. The key to resolving them is in managing risk instead of risk managing itself”.

Disasters resulting from unmanaged risks have entrapped managers of all kinds of enterprises, including factories, nuclear power plants, government services, medical services, financial institutions, air carriers, railways, shipping companies and even churches. As was demonstrated after the Dryden crash, and indeed in many other even more catastrophic events, such as in Bhopal, India, the tainted blood scandal in France, and that in Canada, in which our esteemed colleague Justice Krever was involved, the Three Island and Chernobyl nuclear disasters, the Alaska oil spill, the recent tainted drinking water scandals at Walkerton and North Battleford, and more recently the CN Rail environmental disaster at Lake Wabamun, Alberta, the public is increasingly demanding accountability for preventable accidents. Society's sanctions upon managers for flagrant mismanagement of complex systems are now progressing from mere civil liability into the criminal arena. In the past, managers were able to market their products or services first, and settle risk-related losses later, from accrued profits. This profit-risk method worked for many years, while there was a compliant public. That is no longer the case. The public is no longer compliant. Jail-time is now a very real possibility facing managers guilty of flagrant mismanagement which produces disastrous results.

Inappropriate decisions,whether they are made by the C.E.O., by management, the Regulator, or an individual at the sharp end of the system, should not be allowed to go unchallenged. All the primary component groups of a complex system can expect to be closely scrutinized during any future major accident investigation. It is incumbent on aviation and medical organizations alike, and those who are responsible for running them, to learn lessons from the events of the past.