What is man?

An ancient prophet commented on man’s propensity to get in trouble. He said. Man that is born of woman is of few days, and full of trouble.

So theologians would say, man is inclined towards trouble.

Psychologists study the way man thinks and behaves. Some would say he is shaped by his environment, others would say, the emphasis should be on genetics, while another would claim his experiences defines him. Or perhaps it is a combination of all of this.

Some scientist claim man is improving, others would say the condition of man is one of decay and degradation.

Physiologists can measure the physical parameters of man, break down his constructions into compounds and chemicals. They can measure his eyesight, his ability to hear, speak, walk and interact with the physical world.

But in the end all would say, man is complex, fearfully and wonderfully made, but flawed and fallible.

Webster:

fal·li·ble    ( P ) Pronunciation Key (fl-bl)
adj.
Capable of making an error: Humans are only fallible. Tending or likely to be erroneous: fallible hypotheses.

[Middle English, from Medieval Latin fallibilis, from Latin fallere, to deceive.]

falli·bil·i·ty or falli·ble·ness n.
falli·bly adv.

Webster defines fallible as, Capable of making an error. Tending or likely to be erroneous. As humans we lean towards making errors.

Leonardo Di Vinci captured the beauty, form and function of man in the famous drawing entitled Vitruvian Man.

The MEDA process is used by aircraft maintenance organizations to investigate the causes of maintenance errors that lead to safety-related or costly maintenance events, such as flight cancellations, in-flight engine shutdowns, and equipment damage.

The MEDA philosophy is that:
• Mechanics do not make errors on purpose.
• Errors are due to contributing factors in the workplace (like poorly written manuals, poor lighting for visual inspection, and not having the correct tool for the job).
• Most of these contributing factors are under management control and can therefore be improved so that future errors are less likely (e.g., rewrite the manual, fix the lighting, and provide the correct tool).

So our understanding of man as it relates to maintenance and service may be softened just a little.

Mechanics do not make errors on purpose (Man may be inclined towards error, but his intent is not to produce error.)

Errors are due to contributing factors in the workplace, but they can be managed and controlled.
What is Human Factors?

Human factors is the interactions between human and machine, human and environment, human and procedures and human and human.

This interaction is best defined by a model of Human Factors called SHELL. Shell is an acronym for, Software, Hardware, Environment, Liveware, and Liveware on Liveware. We are the core of this model.

First, consider *liveware*. In the center of the model is a person, the most critical as well as the most flexible component in the system. Yet people are subject to considerable variations in performance and suffer many limitations, most of which are now predictable in general terms. In design of the workplace, tools and equipment that match up with the human body is vital. We come in all shapes and sizes so design must take these types of variations into consideration. We all require the same basics like food water oxygen and rest. But we experience variation in our output or performance. In fact many factors influence our behavior and performance. We vary in the way we sense and process information and the capacity for short and long term memory. We are the most flexible part of the model, but the criticality of our performance underscores the need for recognition of the variances.

*Hardware* includes, tools, equipment, workspaces, facilities and aircraft. The interface between live ware and hardware is the one most commonly considered in human machine systems. Design of seats to fit the sitting characteristic of the human body, displays to match the sensory and information processing characteristics of the user of controls with proper movement, and tools with the proper bend and fit are vitally important. Studies show that many times *a user may never be aware of a liveware hardware mismatch*. Even where it finally leads to disaster the natural human characteristic of adapting to such mismatches will mask such a deficiency but will not remove its existence. This constitutes a potential hazard to which designers should be alert.

The interface between liveware and *software* while less tangible is nevertheless a reality. This encompasses humans and the non-physical aspects of the system such as procedures, policy, manuals, checklists and computer programs. The problems are often less tangible in this interface and are consequently more difficult to resolve.

The human-environment interface is one of the most obvious, and was one of the earliest recognized in flying. Initially, the measures taken all aimed at adapting the human to the environment, like helmets, flying suits, and oxygen masks. Later the trend was to reverse this process, by adapting the environment to match human requirements, like pressurization and air-conditioning systems.

The most interesting interface is, *liveware on liveware*, people interacting with one-another. Most of us work with others on a daily basis. In the maintenance environment this is especially true. In this interface we are concerned with leadership, co-operation, teamwork, and personality interactions.

**NOTE**: SHELL is also referred to as SHEL in some instances, meaning, Software, Hardware, Environment and Liveware.

FACTS

Commercial Aviation

There has been a significant reduction in commercial jet aviation accident rates since 1965. FAA initiatives, technology improvements, the industry-wide qualification, certification, and licensing process, as well as, Crew Resource Management have brought the accident rates to the low levels. Although the accident rate per million departures has stabilized, the number of annual departures continues to grow. This translates to a greater NUMBER of accidents each year, even if the RATE remains stabilized at its present low level.

Consider the following. In 1965 there were approximately 2 million departures worldwide. In 1999 there were over 18 million departures worldwide. The increased number of departures is possible because of the greater number of aircraft and the efficiency of operations. The number of certified jet aircraft greater than 60,000 pounds (non-military) increased from below 2000 in 1965 to 14,358 in 1999.
To further reduce the accident rate, we must identify and correct the causes of accidents.

The number of accidents attributed to:

- Flight crews is 91 for a total of 67 percent
- Airplane problems with a number of 15 for 11 percent
- Weather accounts for 10 accidents or 7 percent
- Maintenance is attributed with 8 accidents or 6 percent
- Airport and ATC account for 5 accidents or 4 percent

As you can see from this chart, flight crew errors comprised the largest percentage of primary cause factors, but maintenance factors were 6 percent.

Maintenance factors are not only primary, but also contributing cause factors in accidents.

**Maintenance was involved in 15% of accidents (39 of 264) during 1982-1991, and ranks second in contributing factors to onboard fatalities!**

Of those 39 maintenance accidents:
- 23% were removal, installation errors.
- 28% involved manufacturer, vendor maintenance or inspection program.
- 49% were airline maintenance or inspection related program policies.
- 49% was attributed to design.
- 21% was manufacturer, vendor service bulletins and in-service communications.
- 21% were attributed to airline SB incorporation.
- And 15% was missed discrepancy.

**The Tip of the Iceberg**

Major accidents are only the tip of the iceberg. To make significant improvements in aviation maintenance error we must thoroughly analyze the major accidents. Fortunately, major accidents are extremely rare events. However, this low accident rate poses a new problem. There is not enough information available from major accidents to conduct an effective trend analysis.

**Solution:** For every major accident, there are numerous, lesser accidents which have similar cause factors. So, we must investigate the minor incidents as well as the majors to discover these causes. The usual assumption is that the same causal factors are involved in both accidents and more minor incidents. We conclude that prevention of the more common incidents, will help prevent the extremely rare accidents.

**Heinrich Ratio:** The relatively few number of catastrophic accidents are only the tip of the iceberg. For every major accident, there are 10 less serious accidents, 30 incidents, and 600 hazardous acts. The circumstances or cause factors which raise the severity of the accident are identifiable in all levels of accidents through careful investigation. Incidents, therefore become an excellent source for trend analysis.

We should not minimize incidents. **MINOR MAINTENANCE ACCIDENTS CAUSE MORE THAN MINOR PROBLEMS.**

When we examine the minor accidents and incidents we find that maintenance and ramp issues are both hazardous and costly!

One study of commercial jet accidents found that 20-30% of engine in-flight shutdowns and 50% of engine-related flight delays, and cancellations are caused by maintenance error.

General Electric calculated that 50 percent of engine related flight delays and cancellations are caused by improper maintenance.

Based upon Boeing and the National Transportation Safety Board data it is estimated that 48,800 un airworthy aircraft are dispatched each year as a result of maintenance error.

Ramp accidents are estimated to cost the aviation industry between 2 billion and 2.5 billion dollars annually. The number of ramp accidents appears to be increasing, with the increase in ramp movements.

**The money adds up.**

Here is a further breakdown of some of the minor accident costs. The average cost of an in-flight engine shutdown is $500,000. The average cost of a flight cancellation is $50,000. The average cost of return to gate is $15,000. The average cost of ground damage incident costs $70,000. One airline estimated between 75 to 100 million dollars per year is wasted on error.

The Airline Transport Association estimates that ground damage costs 850 million dollars per year.

To combat this trend, regulatory agencies around the world have implemented requirements for error prevention training. The European Aviation Safety Agency, the FAA and Transport Canada, have mandated human factors training, as an error prevention strategy.
Understanding An Accident

CHAIN OF EVENTS

Chain of Events
Multiple contributing causes that can lead to an accident.

Accident reports often refer to aircraft maintenance departments as contributing links in the chain of events that lead to an aviation accident. The contributing links may include inspection, technicians, management, aircraft design, environmental issues, ramp personnel and so on.

An in-depth review of accident reports reveals that a series of human errors also known as a chain of events, was allowed to form until the accident occurred. In some cases a specific maintenance error itself was the primary cause of the accident, whereas in others the maintenance oversight was just one link in the chain of events that led to the accident.

So Human Factors is an attempt to understand maintenance as a whole, or as a system.

Contributing Links

For a few moments, we will consider the events leading up to the Dryden accident, in order to identify the contributing links in the chain of events, that resulted in the loss of life, on board flight 1363.

We will examine the contributing links of:

- Equipment
- Environmental Issues
- Cultural Issues
- Pilot Error
- and finally, Management.

Equipment The auxiliary power unit was inoperative, and there was no ground power unit available at Dryden. The lack of a Minimum Equipment List may be traced back to inadequate documentation and planning.

Environmental issues simply made the entire situation much more complex.

If cultural boundaries had not existed then the flight attendant may have approached the pilot about snow on the wings. Also, the passenger pilots may have overcome their professional courtesy by approaching the pilot in charge.

Certainly pilot error played a role. There is no doubt the crew should have been aware of the snow and ice forming on the wings.

Management is responsible for distancing itself from the airworthiness issues surrounding Air Ontario. Management was ultimately responsible for ensuring proper equipment and procedures were established and in place.

Link Busters

Breaking a link in the chain of events will lessen the chance of an accident.

Take a few moments to consider link busters that may have prevented the accident at Dryden.

- Repair or replace the inoperative auxiliary power unit.
- Flight Attendant reporting the accumulation of snow on the wings to the crew.
- Management providing clear cut procedures for refueling and de-icing.

Any one of these link busters may have resulted in avoidance of the disaster at Dryden.
A widely accepted model of human error is the classification of unsafe acts developed by J.T. Reason. This classification distinguishes between two types of errors.

**Active failures** are usually the result of actions taken or not taken by frontline operators such as pilots, air traffic controllers, mechanics or anyone else with direct access to the dynamics of a system. Effects of active failures are experienced immediately.

**Latent failures** on the other hand are caused by those separated by time and space from the consequences of their actions. Personnel working in vocations such as architectural design, hardware design, and equipment maintenance are more prone to cause latent failures than active failures. Effects from latent failures lie dormant in a system until they are triggered.

Both active and latent failures may interact to create a window for accidents to occur. Latent failures set the stage for the accident while active failures tend to be the catalyst for the accident to finally occur.

A good example of a latent failure at Dryden was a lack of a minimum equipment list. An example of an active failure is the pilot’s decision not to de-ice.

### Organizational Factors

Unsafe Supervision

Unsafe Preconditions

Unsafe Acts

### Latent Conditions

The reason model of accident creation is like Swiss Cheese. Each slice may be thought of as a defense against an accident. Each hole in the cheese is like a hole in the defense. The last slice is an active failure that serves results in the accident. If the system of defenses allows for a sufficient number of holes in the defense and they line up and accident will occur. The key is to identify the holes in advance of failure and move to repair them before failure occurs.

Organizational Factors, which contain latent conditions usually consist of decision makers and management personnel responsible for policy, procedures and upper level decisions. At Dryden factors to consider were a lack of clarification on critical policy and airworthiness issues and deregulation.

Unsafe Supervision is composed of front line supervisors, leaders and managers. This category contains latent conditions. At Dryden factors to consider were insufficient training for ground personnel and lack of supervision as realized in poor planning of flight schedule.

Unsafe Preconditions involve mechanics, inspectors, working supervisors and any others who worked on the floors. This category contains latent conditions and the introduction of active failures. At Dryden the inop APU, non-existent GPU and lack of clarity concerning de-icing and refueling were problems.

Unsafe Acts is the final factor that leads to an accident and contains active failures. Hot fueling, lack of ground checks and the most obvious - the pilot did not de-ice.

These categories allows us to analyze latent and active failures and in turn build safety nets (links busters) as defense mechanisms.

### Conclusion

The goal of training is to:

- Reduce maintenance errors, and their associated costs.
- And to improve aviation safety and awareness.
- Human factors defines the way maintenance personnel, interacts with the environment, equipment, tools, procedures and other people in the task of maintenance. Human factors training raises our awareness of maintenance errors and how to avoid them.

We obtain the goals of training by:

- Working together to create a culture conducive to error prevention.
- Providing a frame work for better communication.
- Developing realistic and immediate safety nets or link busters.
Dryden Disaster
A Look Back on the Crash of Air Ontario Fokker F28

The Event
On March 10, 1989, at 11:55 EST, an Air Ontario Fokker F28 departed Thunder Bay about one hour behind schedule. The aircraft landed at Dryden at 11:39 CST. The aircraft was being refuelled with one engine running, because of an unserviceable APU [auxiliary power unit]. Although a layer of 1/8–1/4 in. of snow had accumulated on the wings, no de-icing was done because de-icing with either engine running was prohibited by both Fokker and the operator. Since no external power unit was available at Dryden, the engines couldn’t be restarted in case of engine shutdown on the ground. At 12:09 CST, the aircraft started its take-off roll using the slush-covered Runway 29. The Fokker settled back after the first rotation and lifted off for the second time at the 5 700 ft point of the 6 000-ft runway. No altitude was gained and the aircraft mushed in a nose-high attitude, striking trees. The aircraft crashed and came to rest in a wooded area, 3 156 ft past the runway end and caught fire. Twenty-four of the 69 people on board died as a result of the accident.

Eyewitness Account

The Blender Effect
“The aircraft was hitting trees, hitting trees, and at that point the aircraft I guess was decelerating and we were inside the blender effect... you take a blender, throw in some metal, some trees, people and turn it on.”

Technical Analysis
A routine accident investigation soon found that the aircraft had been unable to gain height because its wings were covered in ice and snow.

Background
The accident was all the more tragic because just seven weeks earlier, warnings within the regulatory authority Transport Canada had been leaked to the press. In part the leaked memo said, “Air carrier inspection is no longer capable of meeting even minimum requirements necessary to ensure safety. In fact, it is no longer able to assure the Minister of the safety of large air carrier commercial air services in Canada”. It went on with the ominous warning, “The situation is to the point where every ACI (Air Carrier Inspector) and an increasing number of industry pilots are convinced that a major accident is inevitable”.

Judicial Inquiry
The routine accident investigation was subsumed into a judicial inquiry under the Honourable Virgil P. Moshansky. His report clearly shows that competitive pressures caused by commercial deregulation cut into safety standards. Moreover the regulatory authority was aware of this but could not counter it because the government was cutting regulatory resources.

When investigators looked at why the pilot had attempted a take off, it became apparent that the real causes of the accident lay at the heart of deregulation and that because of deregulation, traditional air safety standards had been cut.

So ended Air Ontario flight 1363 in March 1989. So ended Canada’s delusion that the country could have cheap, deregulated air fares without the need for extra air safety surveillance.
About the Company
Air Ontario Inc. was formed by the merger of Air Ontario Limited and Austin Airways. Under the impetus of deregulation it changed from being mainly a charter and cargo operation with a mix of generally small aircraft, to become a feeder airline for the large national carrier Air Canada. Air Canada effectively owned Air Ontario and wanted to project its corporate image through its subsidiary by way of marketing, logo and decor. Unbeknown to passengers Air Canada deliberately distanced itself from operational and airworthiness aspects of Air Ontario.

The judicial inquiry found that Air Ontario had rushed the introduction of its relatively large and complicated jet powered F28. Some personnel were not properly trained and some manuals and procedures were neither correct nor consistent. These deficiencies were not fully detected nor were they countered by a regulatory authority which was hopelessly under resourced.

About the Aircraft
On the day of the accident the aircraft was flying shuttle services from Thunder Bay to Winnipeg via Dryden. It was a Friday at the start of school holidays so the aircraft was full. This limited the amount of fuel which could be carried on any one leg of the journey without exceeding the maximum allowable weight of the aircraft. Also the weather was inclement and getting worse, so the aircraft needed to carry enough fuel for a longer than normal diversion. These factors combined to force the airline to schedule refueling during the aircraft’s second stop at Dryden.

The aircraft had many unrectified defects. The one which became critical to the accident was an unserviceable Auxiliary Power Unit (APU). This is a small extra engine in the rear of the aircraft which among other functions provides compressed air to start the main engines. The main engines can also be started by an external power supply. The airline put the pilot in a very difficult predicament when he landed at Dryden. It was not normal to refuel at Dryden.

At Dryden there were no ground start facilities so the aircraft was dependent on its APU but the APU was not working. If the pilot stopped the engines he could not start them again. He needed to load fuel but this should never be done with engines running and certainly not with passengers on board. Snow was falling gently.

Off-loading and reloading passengers took time and the longer the aircraft stayed on the ground the greater was the need for the wings to be sprayed with deicing fluid. On the Fokker F28 aircraft deicing fluid must not be applied while the engines are running.

The pilot had the aircraft fueled while the engines were running and with passengers on board. Although this is a very dubious procedure it was not then prohibited by Transport Canada and airline instructions were inconsistent. The pilot did not have the wings de-iced; again airline instructions were unclear on this point.

With ice on the wings, the wings did not lift properly during take off. The aircraft staggered into the air and crashed just beyond the end of the runway. 24 of the 69 people on board were killed.
Moments before takeoff, the F28 was taxiing out for the final takeoff with significant amounts of snow visible on the wings, and while a flight attendant and two airline captains traveling as passengers noticed, this was never communicated to the pilots. The flight attendant, who was the only crew member to survive, testified later that she had concerns over the snow, but because she had been rebuffed by company pilots over a similar situation in the past, it influenced her decision not to go to the cockpit. This cultural barrier between cockpit and cabin crew should never happen today, given how we train and conduct proper Crew Resource Management.

While the silence of the flight attendant was disturbing for the Commission of Inquiry, the Air Disasters synopsis spells out the thoughts on the two airline pilots:

In the case of the two airline captains traveling as passengers, their lack of affirmative action was unfortunate — to say the least. As professional pilots, they had a clear understanding of the danger, and their indication of concern would at least have been considered by the usually meticulous Captain Morwood.

The reason why they did not raise their concerns differ, but there are two points on which they agree — both assumed the crew was aware of the condition of the wings, and both believed the aircraft was going to be de-iced.

While taxiing away from the terminal and backtracking on the runway, the DC-9 captain thought they were proceeding to the more remote de-icing area on the airport. This was a reasonable assumption as Air Canada often de-iced its DC-9 aircraft at locations remote from the gate. There was no doubt in his mind, he recalled, that the aircraft had to be de-iced before takeoff.

The Dash 8 captain knew the de-icing equipment at Dryden was on the apron near the terminal, and expected they were going to return there. If the aircraft was not de-iced, he believed the takeoff would be aborted should the snow not come off the wings during the take-off run [a highly dangerous practice in itself]. He also indicated that “professional courtesy” precluded an off-duty airline pilot from drawing the attention of the flightcrew to a safety concern.

Other factors could influence an off-duty airline pilot not to make known his concerns: faith in the professionalism of the duty crew; fear of offending and possible re-buke for unsolicited advice; fear of embarrassment if the concern proved groundless; and a reluctance to interfere in the busy flight deck workload.

The inference was that “professional courtesy” among pilots was more important than safety, suggesting an unwritten code that militated against such communications, even when a potentially life-threatening concern was involved.
Conclusions

Economic deregulation of the airlines started in the USA in 1978, Canada followed in 1984. In December 1985 the Canadian House of Commons Transport Committee was warned that competitive pressures would erode self policing by the industry of its safety standards. At the same time Transport Canada arranged a number of visits to the USA to learn from their experience of deregulation.

To counter safety problems arising from deregulation the US authority eventually had to double its safety surveillance staff. Some of the Canadians knew that they too needed more resources but their pleas fell on deaf ears.

A report by the Director of Licensing and Certification outlined the problems confronting US authorities. It listed more than 50 areas of concern including:
- rapid expansion of airlines into unfamiliar areas of operation
- inexperienced, unqualified and/or over extended management
- incomplete or inaccurate records
- non-compliance with approved procedures
- increased contracting out of training and maintenance
- use of unauthorized or improperly trained maintenance personnel
- improper/inaccurate control of aircraft weight and balance

The report was prophetic in predicting the factors which later contributed to the Air Ontario accident.

Commissioner Moshansky found that the aircraft was operating with an excessive number of unrectified defects, that the aircraft should not have been scheduled to refuel at an airport which did not have proper equipment and that neither training nor manuals had sufficiently warned the pilot of the dangers of ice on the wings. Moshansky blamed Transport Canada for letting Air Ontario expand into operation of bigger, more complicated aircraft without detecting the deficiencies. Most importantly Moshansky expressed concern that the Government had not appreciated the safety implications of embarking on a policy of promoting increased airline competition at the same time as it was imposing a freeze on safety regulation resources.

Nearly two hundred recommendations arose from the Air Ontario accident. But two capture the tenor of the report. (1) “Transport Canada (should) put in place a policy directive that if resource levels are insufficient to support a regulatory or other program having a direct bearing on aviation safety, the resource shortfall and its impact be communicated without delay to successively higher levels of Transport Canada management until the problem is resolved or until it is communicated to the Minister of Transport”. (2) “Transport Canada establish a mandatory education program to ensure that senior managers and officials of the department who are responsible for or associated with aviation programs are aware of the basis for and the requirement to support policies that affect aviation safety”.

The Last Word

After a 20-month investigation, it was concluded “Captain Morwood, as the pilot-in-command, must bear responsibility for the decision to land and take off in Dryden on the day in question. However, it is equally clear that the air transportation system failed him by allowing him to be placed in a situation where he did not have all the necessary tools that should have supported him in making the proper decision.