Blue Tuna's

Human Factors Introduction

Student Guide

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This **Human Factors Introduction** is a fundamental course for understanding human factors within the context of the aviation maintenance environment. This handout serves as a guide for reviewing the course including the theory and basic models used to develop our thinking and understanding of the subject. You will need access to this guide to answer some of the questions in the quiz.

Course Overview: *Human Factors Introduction*

This course layouts the basic theory and models for understanding Human Factors and provides case studies to frame human factors within the context of the Aviation Industry. Designed to meet the FAA & EASA requirements for Human Factors Training, the course focuses on the foundations of the Shell Model, the Swiss Cheese Model and Contributing Links in the Chain of Events. The Swiss Cheese Model examines the difference between latent and active errors and their relationship to the local maintenance organization. MEDA represents a basic understanding of the mechanic in the maintenance setting. The Heinrich Ratio emphasizes the need to look for accident data at a much lower level. Using the Dryden Disaster as a case study the student will learn how human factors impacts maintenance and service personnel.

Course Outline:

I. What is Man? Understanding the components

1. Fallibility man's leaning
2. MEDA components
3. United Flight 171 case study
4. Air Florida Flight 90

II. Historical Development of Human Factors

1. Crew Resourced Management (History of Development)
2. Human Factors Defined
3. The Development of the SHELL Model
4. Historical Demographics
5. Leading Causes of Error

III. The Heinrich Ratio as a means of capturing accident data

IV. Contributing Links in the Chain of Events

1. Latent and Active events

V. Dryden the Case Study

VI. Preventing Accidents

1. Link Busters
2. James Reason's Swiss Cheese Model

VII. The Goal of Training

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Lexicon

Accident	An occurrence associated with the operation of an aircraft (AC) which, in the case of a manned aircraft, takes place between the time any person boards the aircraft with the intention of flight until such time as all such persons have disembarked, or in the case of an unmanned aircraft, takes place between the time the aircraft is ready to move with the purpose of flight until such time as it comes to rest at the end of the flight and the primary propulsion system is shut down, in which: A person is fatally or seriously injured as a result of being in the AC or direct contact with the AC or with any part of the AC which have become detached from the AC or direct exposure to jet blast. Or the AC sustains damage or structural failure which adversely affects the AC. *See exceptions at skybrary.aero*
Active Failure	A type of human error whose effects are felt immediately in a system.
Crew Resource Management (CRM)	Crew Resource Management (CRM)Team-based human factors (HF) training focusing on effective use of all available resources: human resources, hardware, and information. At one time CRM stood for Cockpit Resource Management. Over time it was broadened to encompass the entire crew.
Domino Theory	A linear causation model stating all accidents are the result of a chain of events.
Human Factors (HF)	Human Factors (HF). HF is a multidisciplinary field that generates and compiles information about human capabilities and limitations, and applies it to design, development, and evaluation of equipment, systems, facilities, procedures, jobs, environments, staffing, organizations, and personnel management for safe, efficient, and effective human performance.
Incident	An occurrence, other than an accident, associated with the operation of an aircraft which affects or could affect the safety of operation.

	Serious Incident involving circumstances indicating that there was a high probability of an accident and associated with the operation of an aircraft which, in the case of a manned aircraft, takes place between the time any person boards the aircraft with the intention of flight until such time as all such persons have disembarked, or in the case of an unmanned aircraft, takes place between the time the aircraft is ready to move with the purpose of flight until such time as it comes to rest at the end of the flight and the primary propulsion system is shut down. The difference between an accident and a serious incident lies only in the result. *Definition per FAA SKYbrary.aero
Latent Conditions	Deficiencies, faulty conditions that lie dormant with a system. Latent conditions have two kinds of adverse effect: they can translate into error provoking conditions with active failures and local triggers to create an accident. Or they lie dormant within the system that can create long-lasting holes or weakness in the defences.
MEDA	**M**aintenance **E**rror **D**ecision **A**id is a structured process used to investigate events caused by maintenance technician or inspector performance.
SHELL Model	The **SHELL** model is a conceptual model of human factors that clarifies the scope of aviation human factors and assists in understanding the human factor relationships between aviation system resources/environment (the flying subsystem) and the human component in the aviation system (the human subsystem). SHEL(L) is an acronym **S**oftware; **H**ardware ; **E**nvironment; **L**iveware & **L**iveware on Liveware
Swiss Cheese Model	An accident causation model comparing swiss cheese as layers of defence within a system, each layer is a barrier. The holes within each slice of cheese are deficiencies within the system.

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.]

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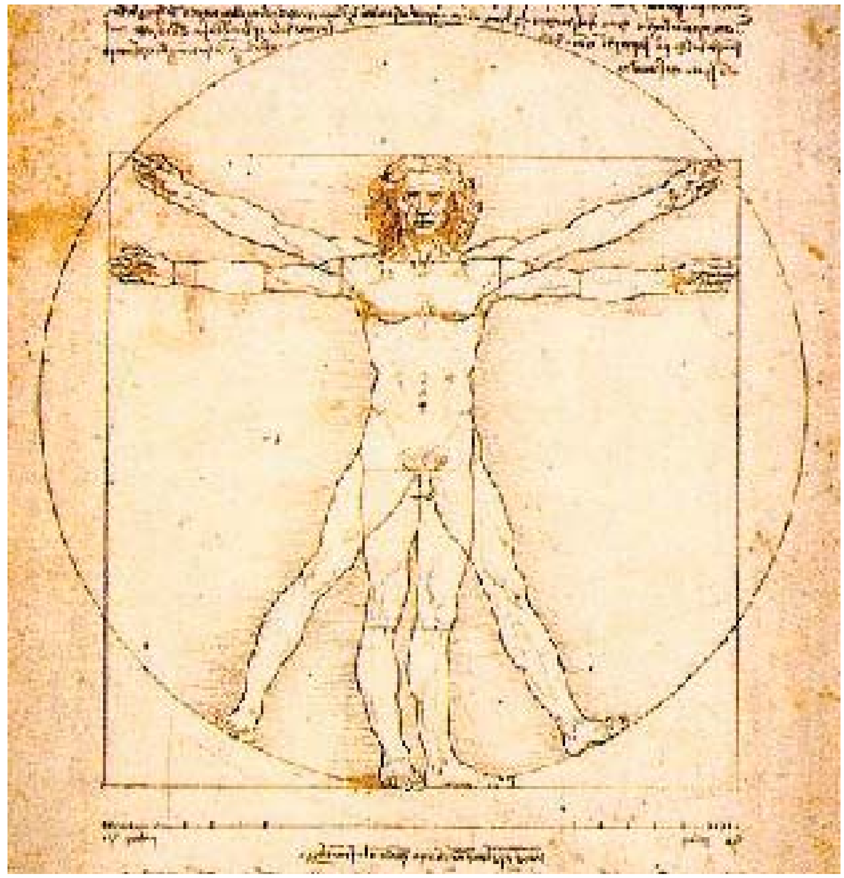
falli·bili·ty or falli·ble·ness n.
falli·bly adv.

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.

Maintenance Error Decision Aid

M.E.D.A. acknowledges man's leaning towards fallibility. One of the earliest Aircraft Accident Investigation Tools was developed by Boeing. It is called MEDA, which stands for Maintenance Error Decision Aid.

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, **S**oftware, **H**ardware, **E**nvironment, **L**iveware, and Liveware on **L**iveware. 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, Enivronment and Liveware.

History

Approximately 25 years ago, one major airline took notice and began implementing people skills training as part of technical flight training. It became known as Crew Resource Management or C R M. Formerly known as Cockpit Resource Management, CRM has its roots at United Airlines. The reason for the change from cockpit to crew resource management training was because the training eventually branched out, to include not only the pilots, but also flight attendants, mechanics, dispatchers, and management personnel.

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!

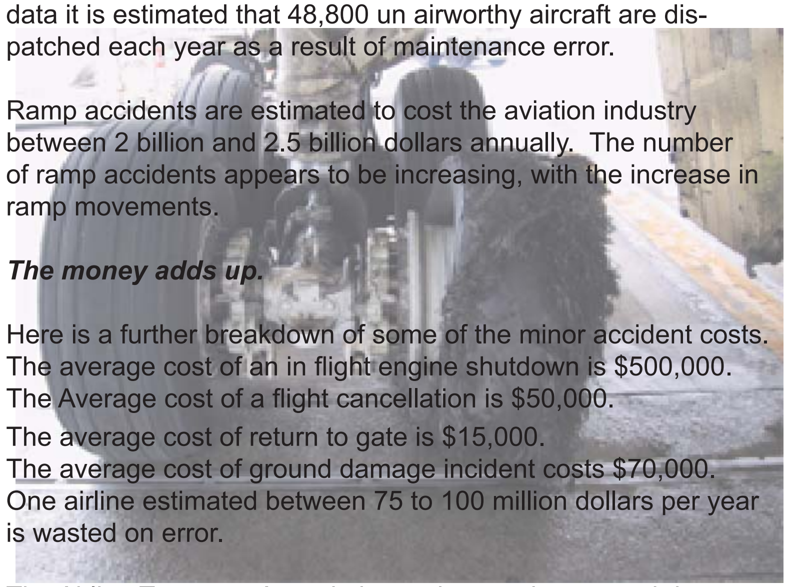
Of those 39 maintenance accidents.
23% were removal, installation errors.
28% involved manufacturer, vendor maintenance or inspection program.
49% were airline maintenance or inspection related program policies.
49% was attributed to design.
21% was manufacturer, vendor service bulletins and in-service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

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.
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.

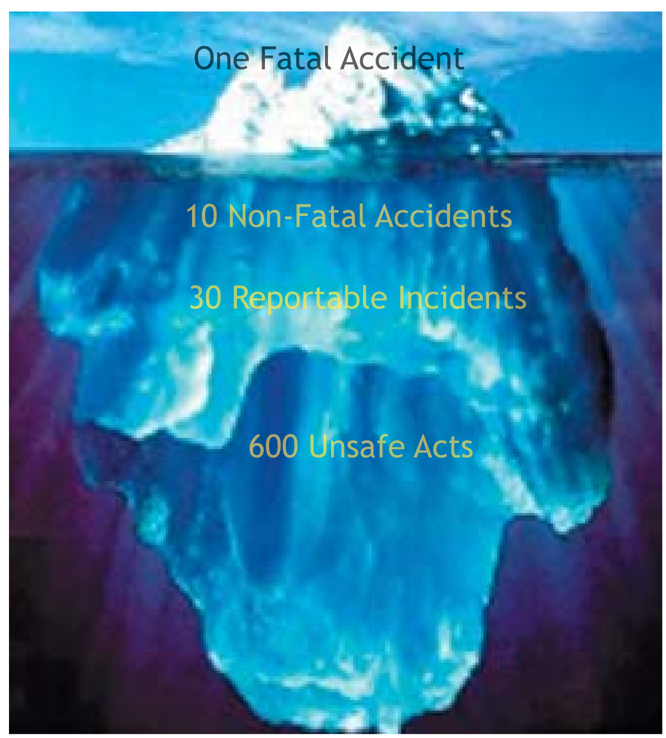
To combat this trend, regulatory agencies around the world have implemented requirements for error prevention training. The European Aviation Safety Agency, the FAA and Transport Canada, have mandated human factors training, as an error prevention strategy.

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.

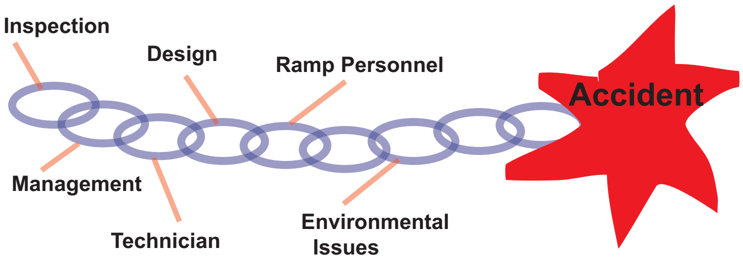
Solution: For every major accident, there are numerous, lesser accidents which have similar cause factors. So, we must investigate the minor incidents as well as the majors to discover these causes. The usual assumption is that the same causal factors are involved in both accidents and more minor incidents.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



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.

As a ways of understanding links in a chain of events that leads to an accident use the Dryden Case Study . The particular accident led to the further development of Human Factors in maintenance organizations.

The Dryden Disaster is included with this guide (pages 6-9). Begin by reading through the facts of the accident. Then take a blank sheet of paper and begin to list the different departments of the organization that contributed to the chain of events. Under the heading of each department describe in brief sentences the events that formed the links, allowing the chain of events to form.

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.

The Reason Model

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 a active failure is the pilot's decision not to de-ice.

Four factors or categories that have the potential to contribute to the links in the chain are as follows.

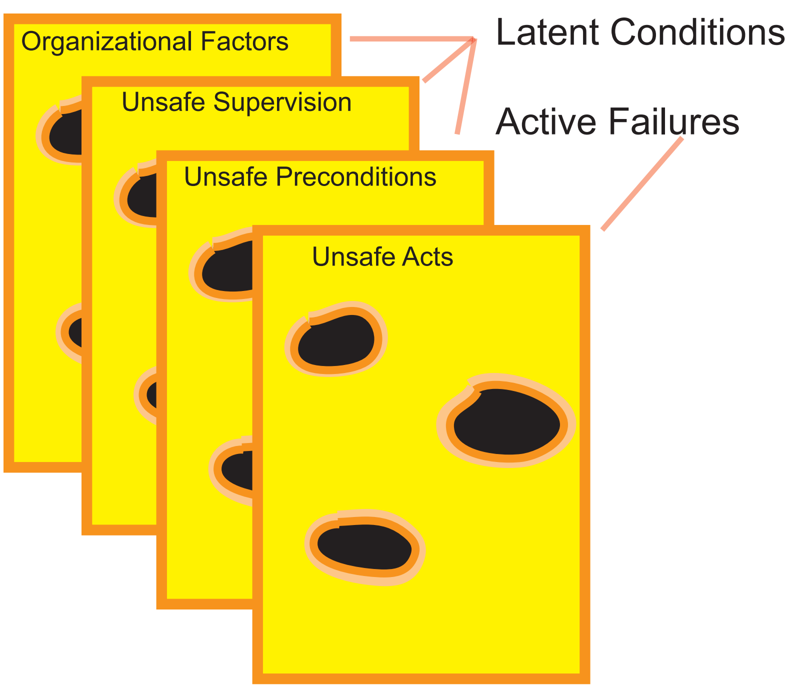
Organizational Factors, which contain latent conditions usually consist of decision makers and management personnel responsible for policy, procedures and upper level decisions. At Dryden factors to consider were a lack of clarification on critical policy and airworthiness issues and deregulation.

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.



This 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.

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

About the Aircraft *continued . . .*

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 deiced; 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.

Eyewitness Accounts

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.

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.

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 rebuke for unsolicited advice; fear of embarrassment if the concern proved groundless; and a reluctance to interfere in the busy flight deck workload.

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.

The pilot died in the accident and in times gone by the accident would have been dismissed as "pilot error". Now, because aircraft accidents are so horrendously expensive for society, society asks what led the pilot to make his mistake.

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.

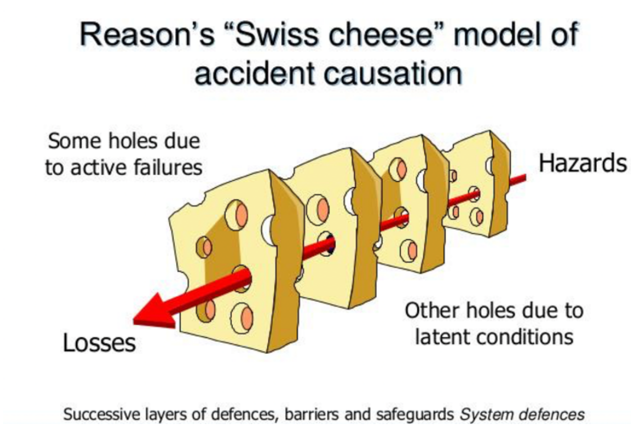
Digging Deeper
The Swiss Cheese Model of Accident Causation

There is a lot to learn by slowing down to review what we know and then dig deeper into some Basic 101 Human Factors Theory & Models, *lets start with Swiss Cheese!*

The James Reason Swiss Cheese Failure Model in 300 Seconds

Credit for parts of this section to WHATSTHEPONT

Causation Model



The Swiss Cheese Causation Model

Causation (to give it the full name), was developed by Professor James T. Reason at the University of Manchester about 30 years ago. The original 1990 paper, "The Contribution of Latent Human Failures to the Breakdown of Complex Systems", published in the transactions of The Royal Society of London, clearly identifies these are complex human systems, which is important. Well worth reading is the British Medical Journal (BMJ), March 2000 paper, 'Human Error: models and management'. This paper gives an excellent explanation of the model, along with the graphic I've used here.

The Swiss Cheese Model:

JT Reason compares Human Systems to Layers of Swiss Cheese (see image above), Each layer is a defence against something going wrong (mistakes & failure). There are 'holes' in the defence – no human system is perfect (we aren't machines). Something breaking through a hole isn't a huge problem – things go wrong occasionally. As humans we have developed to cope with minor failures/mistakes as a routine part of life (something small goes wrong, we fix it and move on). Within our 'systems' there are often several 'layers of defence' (more slices of Swiss Cheese). You can see where this is going…. Things become a major problem when failures follow a path through all of the holes in the Swiss Cheese – all of the defence layers have been broken because the holes have 'lined up'.

Digging Deeper
The Swiss Cheese Model of Accident Causation

Person vs System

Who uses it? The Swiss Cheese Model has been used extensively in Health Care, Risk Management, Aviation, and Engineering. It is very useful as a method to explaining the concept of cumulative effects.

The idea of successive layers of defence being broken down, helps us to understand that things are linked within the system, and intervention at any stage (particularly early on) could stop a disaster unfolding. Think of all the layers of defence that were penetrated in the Dryden Disaster beginning the company culture at Air Canada, Air Ontario and Austin Airways.

What does this mean for Learning from Failure? In the BMJ paper, Reason talks about the System Approach and the Person Approach:

Person Approach – failure is a result of the 'aberrant metal processes of the people at the sharp end'; such as forgetfulness, tiredness, poor motivation etc. There must be someone 'responsible', mental processes such as forgetfulness, inattention, poor motivation, carelessness, negligence, and t recklessness. Countermeasures are targeted at reducing this unwanted human behavior.

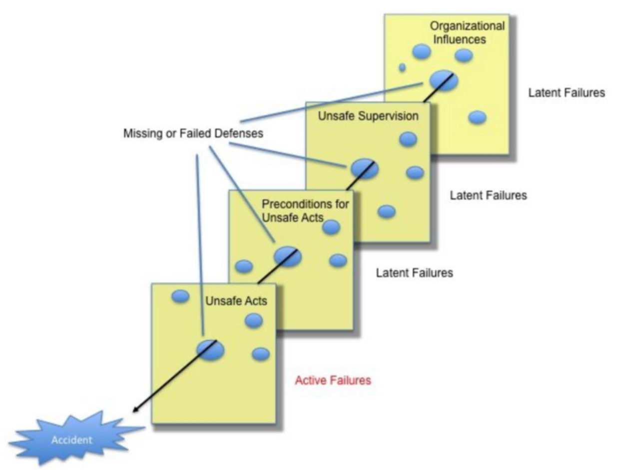
System Approach – failure is an inevitable result of human systems – we are all fallible. Countermeasures are based on the idea that ***"we cannot change the human condition, but we can change the conditions under which humans work"***. So, failure is seen as a system issue, not a person issue. When a adverse event occurs, the important issue is not who blundered, but how and why the defence(s) failed.

The Systems Approach allows us to shift the focus away from the 'Person' to the 'System'. In these circumstances, failure can become 'blameless' and (in theory) people are more likely to talk about it, and consequently learn from it.

Digging Deeper
The Swiss Cheese Model of Accident Causation

Layers of Defence

Other users of the model have gone as far as naming each of the slices of cheese in this Layers of Defence, for example:



Organizational Influences
- Poor Communication
- Aggressive Scheduling

Unsafe Supervision
- Lax enforcement using PPE
- Too many employees to surveil

Preconditions
- Employee Fatigue
- Rush Job

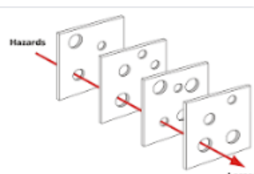
Unsafe Acts
- Pencil Whipped Inspection
- Failure to follow shift handoff procedures

Professor Reason traced accidents to one or more of four levels for failure. Reason's theory also referred to the four levels as Four Failure Domains: Organization Influences; Unsafe Supervision, Preconditions and Unsafe Acts.

Holes in the Cheese……

In an ideal world each defensive layer would be intact. In reality, however, they are more like slices of Swiss cheese, having many holes—though unlike in the cheese, these holes are continually opening, shutting, and shifting their location. The presence of holes on any one "slice" does not normally cause a bad outcome. (That is because these holes are latent conditions. More on this next.) Usually, this can happen only when the holes in many layers momentarily line up to permit a trajectory of accident opportunity—bringing hazards into damaging contact with victims (Active Failure). The holes in the defence(s) arise for two reasons: active failures and latent conditions. Nearly all adverse events involve a combination of these two sets of factors.

A more correct version of the combined theories is shown with the Active Failures (now called immediate causes) Precondition and **Latent** Failure (now called underlying causes) shown as the reason each barrier (slice of **cheese**) has a **hole** in it and the slices of **cheese** as the barriers.



en.wikipedia.org › wiki › Swiss_cheese_model ▾
Swiss cheese model - Wikipedia

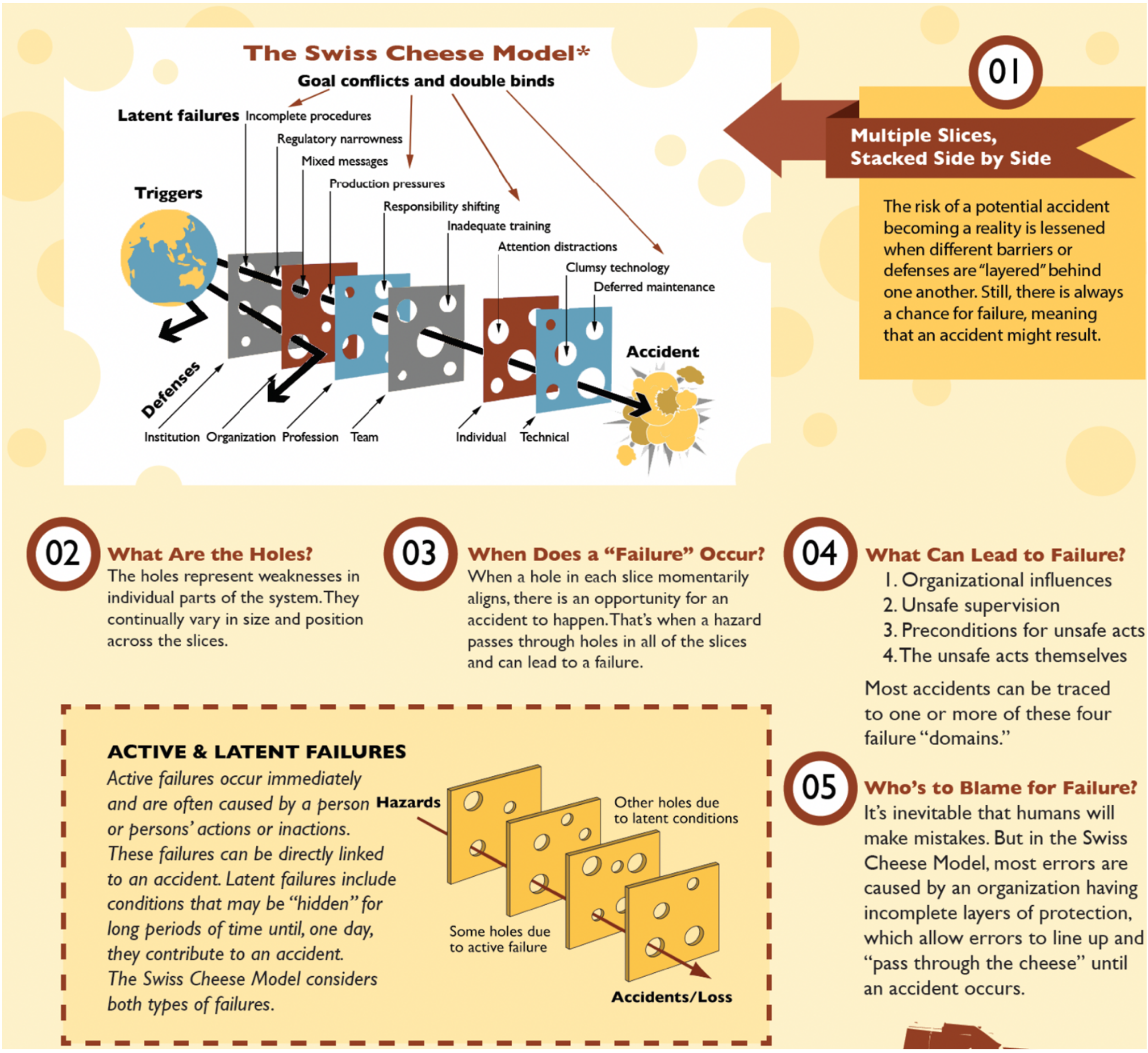
Active failures are also called immediate causes.

Latent failures are also called underlying causes.

The **Slices of Cheese** represent multiple layers of defence. The holes are latent failures. The final slice of cheese, contains a failure, an immediate cause that results in the accident.

Digging Deeper
The Swiss Cheese Model of Accident Causation

Latent Conditions & Active Failures



About the Cheese . . . The holes in the defences arise for two reasons: active failures and latent conditions. Nearly all adverse events involve a combination of these two sets of factors.

Bottom Line, the Swiss Cheese Causation Model helps us to understand how an accident occurs and identify areas we can work in to strengthen our defences.

Digging Deeper
The Swiss Cheese Model of Accident Causation

Active failures are the unsafe acts committed by people who are in direct contact with the "patient" or system. They take a variety of forms: slips, lapses, fumbles, mistakes, and procedural violations.[6] Active failures have a direct and usually short-lived impact on the integrity of the defences.

At the **Chernobyl** nuclear disaster, for example, the operators wrongly violated plant procedures and switched off successive safety systems, thus creating the immediate trigger for the catastrophic explosion in the core. Followers of the person approach often look no further for the causes of an adverse event once they have identified these proximal unsafe acts. But, as discussed below, virtually all such acts have a causal history that extends back in time and up through the levels of the system.

Latent conditions are the inevitable "resident pathogens" within the system. They arise from decisions made by designers, builders, procedure writers, and top-level management. Such decisions may be mistaken, but they need not be. All such strategic decisions have the potential for introducing pathogens into the system. Latent conditions have two kinds of adverse effect: they can translate into error provoking conditions within the local workplace (for example, time pressure, understaffing, inadequate equipment, fatigue, and inexperience) and they can create long-lasting holes or weaknesses in the defences (untrustworthy alarms and indicators, unworkable procedures, design and construction deficiencies, etc).

At **Chernobyl** a lack of training, unsafe acts, like disconnecting alarms, lack of safety culture were just a few of the existing latent conditions.

Latent conditions—as the term suggests—may lie dormant within the system for many hours, days, months or years before they combine with active failures and local triggers to create an accident opportunity. Unlike active failures, whose specific forms are often hard to foresee, latent conditions can be identified and remedied before an adverse event occurs.

Heinrich's Domino Model of Accident Causation

The **Domino Theory** of accident causation and control developed by H.W. Heinrich states that all accidents, whether in a residence or a workplace environment are the result of a chain of events. His basic theory revolved around the five dominos

1. **Domino 1** Ancestry and the worker's social environment which impacts the worker's skills, beliefs and "traits of character". Which in turn influences the way they perform tasks.
2. **Domino 2** Worker's carelessness or personal faults, which led them to pay insufficient attention the task.
3. **Domino 3** Unsafe Acts, or Mechanical/Physical Hazard, such as worker error, or not paying attention etc.
4. **Domino 4** the Accident
5. **Domino 5** Injuries or Loss, the consequences of the accident.

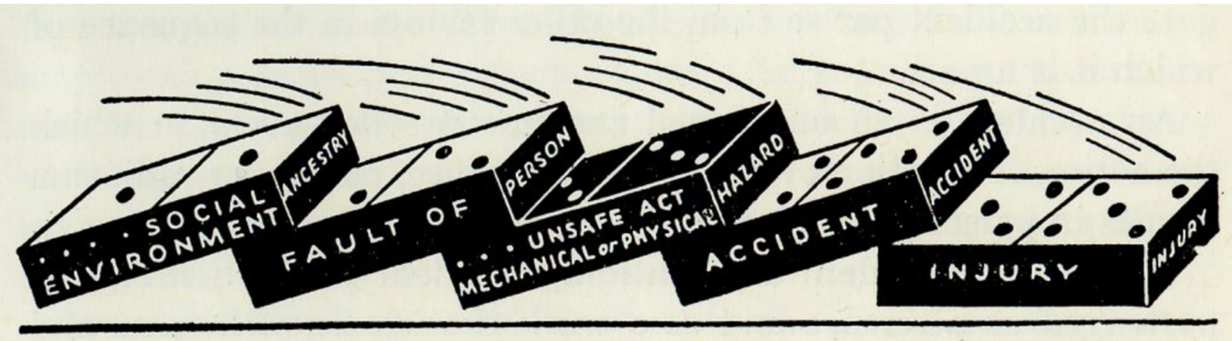
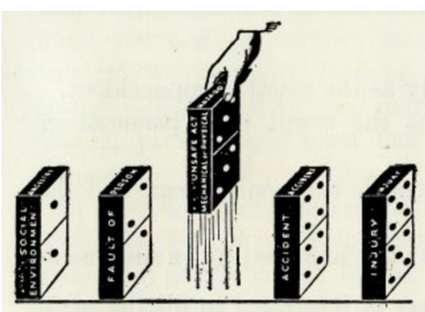
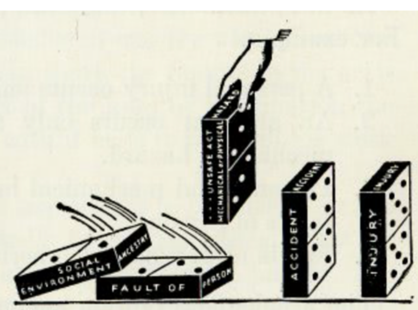


FIG. 3. The injury is caused by the action of preceding factors.

Sequential

Heinrich saw the occurrence of a "preventable injury" as the culmination of a series of events that form a sequence, similar to a row of dominos placed so that the toppling of a first domino knocks down the next, which makes the third fall down, and so on until the entire row is toppled. If this series is interrupted by the elimination of even one of the several factors that comprise it, the injury will not occur, as illustrated in the figure below:

 FIG. 4. The unsafe act and mechanical hazard constitute the central factor in the accident sequence.  FIG. 5. The removal of the central factor makes the action of preceding factors ineffective.	In the **Domino Theory** the accident is prevented by interrupting the accident sequence. The elimination of any one unsafe act or mechanical hazard possibly isolates the remaining 4th and 5th domino.

Adaptation *Changes in the Model*

Over time some of the basic elements changed, for example attributing workplace behavior to ancestry and to ingrained personal faults was found to be inappropriate over time. The model contributed to a focus on the search for culprits or people to blame for the accident sequence. To address the problem, the labeling of the first two dominos of ancestry and personal fault was changed to make them more generalized with aspects related to planning, work organization and leadership. Variations of this basic model led people to think about and identify underlying casual factors and acting on them (by pulling out a domino) and stopping the accident.

Simple, Linear & Limited

The simplicity of the Domino Theory is also its downfall, it is linear and therefore easy to follow, but the sequential order is not sufficient to explain the systemic nature of an accident. Accidents or conditions leading up to an accident don't always occur in a simple linear order. Accidents cannot always be explained that way. Instead of viewing an accident as series of events traced back to human traits and actions, an accident is caused by multiple factors and occur due to the complex interactions of numerous working system elements, human and non-human. Those non-human, systemic based elements are latent conditions waiting on an active failure.

Lessons Learned

What Lessons can we learn from Human Factors' theories and models?

Subject	Teaches	Lesson Learned	Application
MEDA Model	Mechanics and technicians are not malicious and do not make errors on purpose.	*While man may be inclined towards error, his intent is not to produce an error.*	Don't rely on your memory, when you are required to use documentation.
SHELL (SHEL(L))	The SHELL Model states that Human Factors is the interactions between be human and machine, environment, procedures and human interacting with other humans. This interaction is best described by SHEL(L) which is an acronym for Software, Hardware, Environment, Liveware and (Liveware on Liveware). *Live is the human component, the centerpiece of this model*.	Human is the most complex, but he is also inclined towards error. *We cannot change the human condition, but we can change the conditions under which humans work.*	We don't always have to face something head on to change it.
Heinrich's Ratio	**Heinrich's Ratio** is demonstrated by the iceberg, or a pyramid and describes major accidents as the tip of the iceberg, that for every major accident, there are numerous, lesser accidents, (below the water's surface) which have similar causal factors.	Generally speaking, the prevention of more common incidents, will help prevent the extremely rare accidents.	Spend more time in following up on the more common and routine is a natural and effective way to strengthen the system at large.
Chain of Events	The Chain of Events describes events, people, procedures among others that when linked together forms a link of chain that leads to an accident. Only through removing or preventing the link from forming can we prevent the accident. The Chain of Events reveals the connectedness of elements, events, people and procedures.	The Chain of Events and the Domino theory is how many parts there are in an accident chain, and it reveals how connected all the elements are to bring forth an accident.	A good firs step towards being effective is to see how (in a system, in an organization etc.) is to comprehend the other parts and their place.
System vs People	The **Chain of Events**, and the **Domino Theory** are both linear, while the **Swiss Cheese Causation Model** is in a sense sequential, it takes on a more systemic approach. The systemic approach to the Swiss Cheese model expands the scope of investigation. Instead of seeing people at the sharp end as having created an error, the systems approach shifts the focus away from the failures of people to consider other factors at work.	*The Swiss Cheese Model (a systems model) reveals the intangibles like organizational and environmental factors and then interconnectedness of the company as a whole.*	It is not the exotic or the act of someone out of nowhere that brings us to the tipping point. At the same time don't mistake familiarity for a lack of complexity. It simple gives a more complete picture.

Lessons Learned

Case Study

What lessons can we learn from Dryden and the Accident Models learned here?

In the case study of the Dryden Disaster, the flight was in danger before it ever started its journey from Thunder Bay to Winnipeg via Dryden. While ice may have played a direct role in the crash there were organizational factors at work that set the stage for the tragic end of Air Ontario Flight 1363.

Organizational, Environmental & Cultural Forces @ Work

Air Ontario was a newly formed company by the merger of Air Ontario Limited and Austin Airways (all of which were owned by Air Canada). 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.

Set Up for Failure, all of the latent failures were pushing, waiting on some activity to occur.

This particular F28 was pushed into service with existing problems. The aircraft had existing deficiencies; the aircraft type was not well supported. Air Canada had deliberately distanced itself from operational and airworthiness aspects of Air Ontario. Organizational / Environmental factors were only the beginning of the problems for this flight. The weather accentuated the problem, there were too many holes in the Swiss Cheese Model on this fateful day. Ice, snow, lack of ground resources, a flight at full capacity, pilots who were being pushed to perform, to keep the schedule all came together for the perfect storm unfolding into an accident.

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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.

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Dryden teaches us unseen factors may be as powerful as actually throttling up to take off.

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