Module 9A - HUMAN FACTORS

Vortex Tech Training Manual

Vortex Tech

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Sub Module 9.1 – GENERAL
Sub Module 9.2 – HUMAN PERFORMANCE AND LIMITATIONS
Sub Module 9.3 – SOCIAL PSYCHOLOGY
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1 SECTION 1: INTRODUCTION

Many people in the aviation industry wonder why Human Factors training is seen as being a vital element in their overall training syllabus. The answer is very simple. We kill people. Anybody who has any connection with the aviation industry – whether it be flight crew, engineers, baggage handlers, stores people, admin staff - all play a vital part in flight safety. We all have the potential to make mistakes which can ultimately lead to an aircraft accident.

By understanding how mistakes are made and how they can be avoided, we can go a long way to reducing the number of accidents.

To gain this understanding, we must know a little of how the human body works, how the brain processes information received, a little psychology, how we interact with others through effective communication and then learn the types of human error and ways of avoiding these errors.

All elements within aviation must work together to achieve the ultimate goal – safe and efficient flight operations, to minimise accidents and incidents and when these do happen, to investigate the causes (including the underlying hidden causes) and put in place Procedures to minimise the risk of the accident or incident happening again.

An understanding of the importance of human factors to aircraft maintenance engineering is essential to anyone considering a career in aircraft maintenance. Human factors impinges on everything maintenance personnel do in the course of their job in one way or another, from communicating effectively with colleagues to ensuring they have adequate lighting to carry out their tasks. Knowledge of this subject has a significant impact on the safety standards expected of the aircraft maintenance personnel.

Whilst this text has been prepared for those who are working in aircraft maintenance engineering environment, it is also relevant to all staff who are wishing to qualify as certifying staff under PCAA-ANO-66. Thus, whilst the term 'engineer' has been used throughout the document, it is generally used in a generic sense to include all aircraft maintenance technicians, fitters, licensed engineers, inspectors and supervisors and in some cases, it also includes managers, planners, etc.

Human Factors and Error Management is a combination of common sense and proven scientific knowledge about the way daily work is done. The information received in this course centres around the actions and inactions of the individual in the work place and considers systems that are designed to discover and correct errors before they have any negative impact on safety.

The principles associated with this subject area reflect the facts that as human errors are subjected to be made. If it is accepted that errors are subjected to be made, then a policy of zero error tolerance is unlikely to be an effective safeguard against any errors eventually having harmful effects on operations. Therefore, a policy of error management is much more likely to result in safe operations. This subject, then, is concerned about recognizing the variety of factors that affect humans, both positively and negatively, when daily work is done and about picking up any errors that might be made and managing them such that both the frequency and impact of incidents and accidents in the workplace are reduced.

Aircraft maintenance is an essential component of the aviation system which supports the global aviation industry. As air traffic grows and the stringent requirements of commercial schedules impose increased demands upon aircraft utilization, the pressures on maintenance operations for on-time performance will also continue to escalate. This will open further windows of opportunity for human error and subsequent breakdowns in the system's safety net. There is no question that human error in aircraft maintenance has been a causal factor in several air carrier accidents. It is also beyond question that unless the aviation industry learns from these occurrences, maintenance-related safety breakdowns will continue to occur.

From a Human Factors perspective, important truths have been uncovered during the investigation of these occurrences.

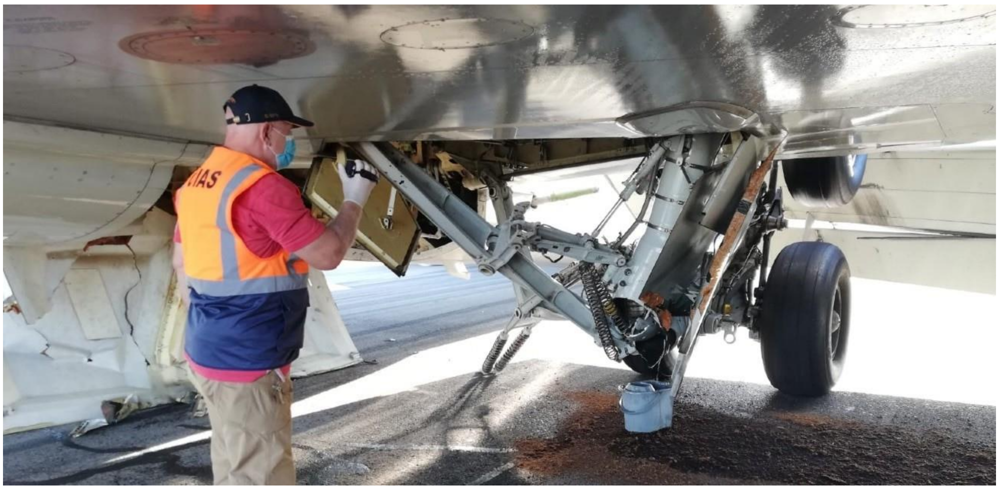

图 1 The Role Mechanics Play in Airplane Accidents

According to the FAA National Plan for Aviation Human Factors and other data analyses, human error has been identified as a causal factor in 70-80% of aviation accidents and incidents.

图 2 Maintenance Human Factors: Beyond Error to Performance

2 SECTION 2: THE NEED TO TAKE HUMAN FACTORS INTO ACCOUNT

Where human beings are involved in work the possibility of error is always present. This factor must be recognised and dealt with in aircraft operation and maintenance by every person who contributes to airworthiness and safety.

The early pioneers in aviation were motivated by the challenge of flight and were prepared to take the risks with perhaps little regard to the safety of others. Flying was seen as a sport. However, as aircraft designs improved and transport services and routes grew the owners and customers wanted a successful outcome to the venture. So we started the philosophy of flight safety. It was soon discovered that after mechanical problems, the human error problem was the next biggest factor in flight safety. The better understanding of design has given us reliability and the air transport industry has a very good safety record today compared to other modes of transport. The human problem has been more difficult to solve. Recent statistics show that about 70-80% of aviation accidents are caused by human error, the pilot error problem having a higher profile. However, maintenance induced accidents are growing in number year on year and are causing concern.

图 3 Aviation Human Factors

2.1 2.1 FUTURE PREDICTIONS

The worldwide commercial aviation major accident rate has been nearly constant over the past two decades. While the rate is low, increasing traffic over the years has resulted in the absolute number of accidents also to increase. It is expected for air travel to increase over the coming decades, doubling by 2017. Without improvement in the accident rate such volume in traffic would lead to 50 or more major accidents a year. One a week would have an unacceptable impact upon the public's confidence in the aviation industry.

2.2 2.2 AIRCRAFT MAINTENANCE

The Human Factor course and notes cover in the ANO-66 Module 9 contains requirements to make Aircraft Maintenance Engineers aware of the possible dangers in aircraft maintenance due to their own performance and others. To be aware of conditions that increase the possibility of human error and identifying ways of reducing errors, develop a positive, professional approach in the training of ab-initio aircraft engineers and perhaps develop a new awareness and culture change in the mature student. It is a requirement of PCAA-ANO-145:35 that human factors are part of continuation training whilst working in an approved maintenance organisation.

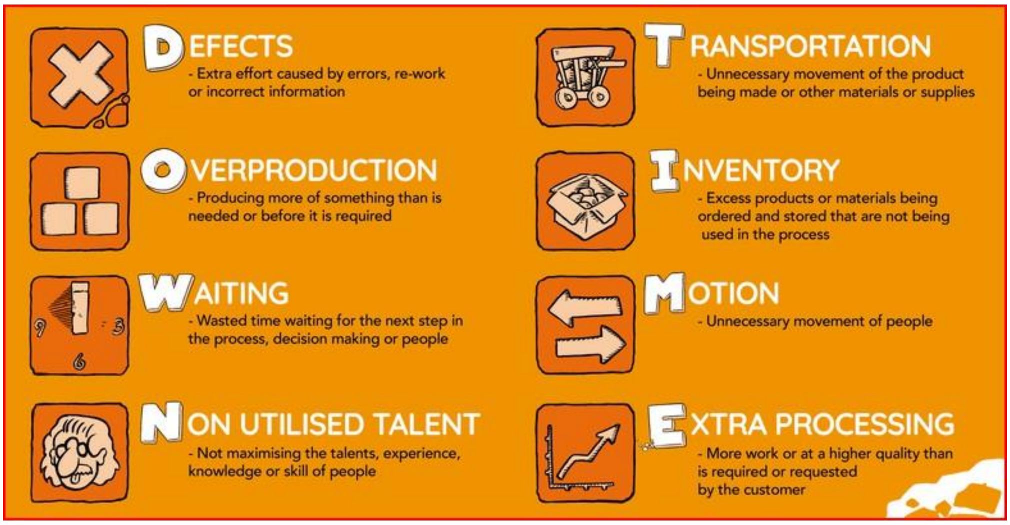

图 4 Applying DOWNTIME in Aircraft Maintenance

2.3 2.3 WHAT IS “HUMAN FACTORS”?

The term “human factors” is used in many different ways in the aviation industry. The term is, perhaps, best known in the context of aircraft cockpit design and Crew Resource Management (CRM). However, those activities constitute only a small percentage of aviation-related human factors, as broadly speaking it concerns any consideration of human involvement in aviation. The use of the term “human factors” in the context of aviation maintenance engineering is relatively new. Aircraft accidents such as that to the Aloha aircraft in the USA in 1988 and the BAC 1-11 windscreen accident in the UK in June 1990 brought the need to address human factors issues in this environment into sharp focus. This does not imply that human factors issues were not present before these dates nor that human error did not contribute to other incidents; merely that it took an accident to draw attention to human factors problems and potential solutions.

Before discussing how these accidents were related to human factors, a definition of human factors is required. There are many definitions available. Some authors refer to the subject as ‘human factors’ and some as ‘ergonomics’. Some see “human factors” as a scientific discipline and others regard it as a more general part of the human contribution to system safety. Although there are simple definitions of human factors such as: “Fitting the man to the job and the job to the man”, a good definition in the context of aviation maintenance would be:

“Human factors” refers to the study of human capabilities and limitations in the workplace. Human factors researchers study system performance. That is, they study the interaction of maintenance personnel, the equipment they use, the written and verbal procedures and rules they follow, and the environmental conditions of any system. The aim of human factors is to optimize the relationship between maintenance personnel and systems with a view to improving safety, efficiency and well-being.

Thus, human factors include such attributes as:

- Human physiology
- Psychology (including perception, cognition, memory, social interaction, error, etc.)
- Work place design
- Environmental conditions
- Anthropometrics (the scientific study of measurements of the human body)

2.4 2.4 SUBSET DEFINITIONS

The study of Anthropometrics (human measurement) is concerned with the physical sizes and shapes of humans. Of particular interest are the differences between and among different populations (men vs. women, Northern Europeans vs. Japanese). Anthropometrics literally means man (anthrop) measurements (metric). It is the measurement of the size and proportions of the human body, as well as parameters such as reach and visual range capabilities. Accurate data on height, weight, limb, and body segment sizes are needed to design items ranging from clothing, furniture, automobiles, buses, and subway cars to space shuttles and space stations. Anthropometrics enables us to properly size items, including system interfaces, to “fit” the user.

Biomechanics (bio=life + machine) is the application of the principles of mechanics and physics to measure the forces exerted by and upon living forms. Human Factors is principally concerned with occupational biomechanics which is the application of these principles to the measurement of forces exerted by and upon the human body during the performance of work. These measurements are used to determine physical work performance tolerances with the goal of maximizing work performance while protecting worker occupational health and safety.

The application of the principles of mechanics and lever systems to the human body requires the use of anthropometric data, critical data being the distance/length of body levers (bones) between joints. Human variability in physical size (static anthropometry) and physical strength (dynamic anthropometry) is also important in biomechanics with respect to the worker population in terms of gender, age, and ethnicity.

2.5 2.5 ORIGINS OF HUMAN FACTORS

2.5.1 GENESIS

Many people would argue that the development of human Factors is necessarily as old as the development of aviation. This is because human factors are part and parcel of any development on aviation and, therefore, their development would be considered parallel. This is however, a fairly simplistic view and it would be fair to say that human factors as a discipline is a reasonably modern initiative. That is not to say that elements of human factors such as those coming under the headings of Anthropometrics or biomechanics have not been taken into account well before the term “human factors” was associated with them.

2.5.2 WORLD WAR II

World war two probably provided the genesis of subject areas that now considered being part of human factors. What was meant is that specific research was conducted on aeroplane operations and maintenance with the prime intension reducing accident and Incident rates. In 1939, Sir Frederic Bartlett in his Cambridge University laboratories was the first to build aircraft Cockpit Mock-Ups and simulators for the prime purpose of conducting Experiments that would reduce pilot error during training as well As war operations. Early researchers made significant safety advances through Human factor applications, though these were primarily in the Fields of anthropometrics, biomechanics and bio- physiology.

2.5.3 POST WAR DEVELOPMENTS

Shortly after the war, in 1949, the ergonomics research society was founded in England. This society was the foundation of what later became the ergonomic society and the prime Repository of human factors research from all over Europe. Meanwhile, a similar body was undertaking work in United States. This body first took on the name “human factors Society” in 1957 and the centre of research for human factors throughout North America. In many respects, these two Organizations developed in parallel and even

replicated each Other's work. It was not until recently that they joined into a Single entity that is now known as "the human factors and Ergonomics society".
Human factors really started to get the attention of decision Makers in aviation following the major disaster at Tenerife in 1977 when a KLM 747 ran into a pan American 747 during takeoff at los rodeos airport. This accident was the catalyst for KLM to engage a number of academics under the direction of Captain Frank Hawkins to put together the first course ("KHUFAC" standing for KLM human factors) aimed at Educating flight crew on reducing and managing errors through Knowledge of human factor concepts. Also in the late 70's, there were a number of accidents and incidents to us carriers that resulted in insurance companies asking for the airlines to rethink their educational strategies of flight crew. Cockpit Resource management (CRM) courses were the result of these Deliberations and they were actively taken up by most airlines in the world who could see a tangible benefit in educating their Flight crew in human factor concepts.

2.6 2.6 MODERN FOCUS

Following two significant mishaps in England, Cockpit Resource Management had transformed into Crew Resource Management. The two specific incidents involved scenarios in which the cabin crew had information that could well have prevented the disaster but it was not passed on to the captain in time to do so. Cabin crew then became an integral part of the safety equation on modern airliners and they too were required to attend Human Factors courses with the express intention of reducing and managing human error.
It did not long for senior management personnel in airlines to realize that these Human Factors elements played a significant role in the success or failure of the entire organization. The term "Corporate Resource Management" or "Company Resource Management" was coined by some to reflect the fact that these Human Factors skills should be thought to everyone in the organization. This is in effect what have become Human Factors and Error Management today. Many Regulatory authorities have also gone so far to require such courses to be taken for licensing purposes.
In the maintenance engineering discipline, Human Factors and Error Management have evolved into Maintenance Error Management (MRM). MRM can be defined as: "Maintenance Resource Management is a general process for improving communication, effectiveness, and safety in airline maintenance operations. MRM improves safety by increasing the coordination and exchange of information between team members, between teams of airline maintenance crews. MRM programs link and integrate traditional human factor topics, such as equipment design, human physiology, workload, and work place safety. Likewise, the goal of any MRM program is to improve work performance and safety. They do this by reducing maintenance errors through improved coordination and communication."

2.7 2.7 HUMAN-MACHINE COMPARISON

Early in the development of Human Factors as a discipline, Paul Fitts proposed the following comparison of human and machine abilities. Although rapid advances in technology promise to significantly increase "machine" abilities, this summary remains valid and a "classic" in the Human Factors field.
Humans surpass Machines in ability to:

1. Detect small amount of visual and acoustic energy
2. Perceive patterns of light or sound
3. Improvise and use flexible procedures
4. Store very large amounts of information for long periods and to recall relevant facts at the appropriate time

5. Reason inductively
6. Exercise judgment

Machines surpass Humans in ability to:

1. Respond quickly to control signals, and to apply great force smoothly and precisely
2. Perform repetitive, routine tasks
3. Store information briefly and then to erase it completely
4. Reason deductively, including computational ability
5. Ability to simultaneously control highly complex operations (i.e. to do many tasks at the same time).

2.8 2.8 HUMAN-MACHINE DIFFERENCES

Other major differences between humans and machines are:

- Machines can be modified, redesigned, and retrofit - humans cannot. Humans are born with innate, genetically determined differences that are shaped by the environment. Innate aptitudes or abilities are developed through education and training.
- Machines can be manufactured to be identical - with identical, or nearly identical, output or performance. Humans are not identical and vary across all sensory, cognitive, physical and performance characteristics. Specific aspects of human performance can be made more equal through education and training.

2.9 2.9 THE IMPORTANCE OF AN EFFECTIVE HUMAN FACTORS PROGRAMME IN A MAINTENANCE ORGANIZATION

Humans have performance limitations:

- Therefore, they make errors

Effective Human Factors programs train employees and put systems in place to pick up those errors:

- Therefore, those errors do not result in delays, incidents or accidents

Fewer errors by engineers’ means reduced delays, incidents and accidents:

- Therefore, the company is safer and more cost efficient

A safer, more cost efficient, company means:

- Fewer delays
- Fewer injuries to employees
- Better company performance
- And therefore, better work place for its workers

2.10 2.10 THE COST EFFECTIVENESS OF IMPLEMENTING HF PROGRAMS IN ORGANIZATIONS

There are two primary reasons for including HF programs in organizations. They are:

1. Safety
2. Cost

Safety has two aspects to it.

- First and foremost is public safety. Organizations that are better trained and present fewer errors in their routine and emergency work present a safer option to the travelling public. Passengers prefer to travel with a safer airline.
- And second is on-the-job safety for maintenance workers. Reduced error rates are reflected in the injury rates amongst staff and less down time for workers. It is worth noting here that those injuries aren’t always physical.

Cost savings are a bit more tangible than safety as a reason to implement HF programs and therefore easier to identify with. It is very difficult to prove to an accountant that an accident is saved from occurring but it is easier to show book figures that show definitive cost savings. Ironically, the biggest cost savings are in reduced accident rates. It is just that in ultra-safe systems such as aviation, the accident rates are so small that they become statistically insignificant.

In summary, implementing HF programs in organizations reduces the overall cost of maintenance. Organizations are known to have run many HF programs within the different branches of the organization.

2.11 2.11 DEFINITION - HUMAN FACTORS PRINCIPLES

"Principles which apply to aeronautical design, certification, training and operations and which seek safe interface between the human and other system components by proper consideration to human performance."

3 SECTION 3: INCIDENTS ATTRIBUTABLE TO HUMAN FACTORS / HUMAN ERROR

Maintenance errors are not some new phenomenon, but with the advent of more reliable aircraft, and human factor training for aircrew, the maintenance component as the cause of an aircraft accident has become more noticeable.

3.1 3.1 CCC → HPIM → MRM

Continental airlines first came up with the term "crew coordination concept" (CCC) to include engineers in their crew resource management workshops. An air Ontario accident at Dryden in Ontario led to a specific course called "human performance in maintenance" (HPIM) and the current evolution of these programmers has become "maintenance resource management (MRM) which is organization specific rather than generic. It has the added advantage of just targeting those issues that relate to maintenance engineers rather than flight crew and cabin crew as well.

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THE HUMAN FACTORS ELEMENTS THAT CAN EVIDENT WHEN CARRYING OUT SPECIFIC AIRCRAFT MAINTENANCE TASKS SUCH AS INSPEECTION OF AGING AIRCRAFT AND OTHER REPETITIVE AND BORING ACTIVES.

The HPIM Initiative following the Ontario accident led to maintenance engineering focus group identifying what has been termed: "the dirty dozen" of maintenance engineering. These are all human factors. They are:

图 5 The Dirty Dozen - 12 Common Causes of Human Factors Errors

- Lack of communication
- Complacency
- Lack of knowledge
- Distraction
- Lack of teamwork
- Fatigue
- Lack of resources
- Pressure
- Lack of assertiveness
- Stress
- Lack of awareness
- Norms

With respect to lack of communication, this has been a well – established cause of error in the aviation industry and had been included on CRM courses since they first began, so it is no surprise to see this as one of the dirty dozen. Lack of communication in this context means not passing on information, written or oral, and more particular, passing on information but not being sure that it has been understood properly.

Complacency is a real danger for engineers. Following the Aloha incident, the FAA issues an airworthiness directive (AD) requiring the close visual inspection of 1300 rivets on every single Boeing 737. If ever there was an opportunity for complacency in the inspection business, it was provided by the FAA in this case.

In terms of lack of knowledge, it is impossible to know all there is to know in the maintenance engineering business. In the absence of specific knowledge, it is a human trait to fill in the gaps with “good enough” actions or nothing, hiding behind the expression” I didn’t know what to do”.

Distractions in the engineering business are common. Irrespective of whether the distraction is home life or just a friend at work interrupting when work is done, distractions have been cited on many occasions as the reason for checks or steps being missed during an engineering process.

Teamwork, or rather the lack of it will be cited a number of times in this course as a major source of error. Humans are all members of a number of teams and it is important that they play their role in each team to the best of their ability.

Fatigue has been recognized as a source of error for a long time now but aviation personal works in a 24-hour industry and their demands are high. Education would seem to be the major counter measure to this problem at the moment but more on that later.

Lack of resources is unlikely to be a problem in most organization but there will be times when the person might say ‘I wish I had just one more person to help us with this job’ or‘ where are the spare floodlights when you need them’. It is easy to improvise but it is also easy to get caught out improvising.

Pressure comes in many and varied forms. Time pressure, for example, will always be part of the aviation industry and particularly for engineers. An aircraft cannot make any money when it is on the ground and the sooner it can be turned around the better. Peer pressure could make a person work late hours at the expense of the person’s family life and the expectations of managers can lead to pressures to work harder or further their education outside the normal working day. These can all reduce attention to detail when it is most needed are prime breeding ground for errors.

Lack of assertiveness is generally a result of the hierarchy or rank structure in an organization. There are both formal and informal versions. The formal ones are normally part of the company or profession structure whiles the informal ones are related to where a person perceives oneself amongst peers and the organization. There is an inclination for individuals to react according to their status rather than to their competence or ability. This is a big issue when it comes to inspection and checking, which are two of the prime roles of maintenance engineers.

Stress is part and parcel of everyday lives. Despite urban mythology to the contrary, stress cannot be left behind from one’s personal lives. When a person goes to work, and simple things such as an argument with the person’s spouse or partner at home in the morning can result in errors at work.

Situation awareness is also a big problem in the aviation industry and there is a whole module at the end of this course devoted specifically to situation awareness.

Norms are a part of the culture of an origination and each organization has sets of norms which are positives and those which are negative. The trick is to enhance the positive and suppress the negative.

The accident involving Aloha flight 243 in April 1988 involved 18 feet of the upper cabin structure suddenly being ripped away in flight due to structural failure. The Boeing 737 involved in this accident had been examined, as required by United States regulations, by two of the engineering inspectors. One inspector had 22 years’ experience and the other, the chief inspector, had 33 years’ experience. Neither found any cracks in their inspection.

Post-accident analysis determined there were over 240 cracks in the skin of this aircraft at the time of the inspection. The ensuing investigation identified many human-factors-related problems leading to the failed inspections. As a result of the Aloha accident, the United States instigated a programme of research looking into the problems associated with human factors and aircraft maintenance, with particular emphasis upon inspection.

An incident in the United Kingdom in August 1993 involved an Airbus 320 which, during its first flight after a flap change, exhibited an un-demanded roll to the right after takeoff. The aircraft returned to Gatwick and landed safely. The investigation discovered that during maintenance, in order to replace the right outboard flap, the spoilers had been placed in maintenance mode and moved using an incomplete procedure; specifically, the collars and flags were not fitted. The purpose of the collars and the way in which the spoilers functioned was not fully understood by the engineers. This misunderstanding was due, in part, to familiarity of the engineers with other aircraft (mainly 757) and contributed to a lack of adequate briefing on the status of the spoilers during the shift handover. The locked spoiler was not detected during standard pilot functional checks.

In the United Kingdom in February 1995, a Boeing 737-400 suffered a loss of oil pressure on both engines. The aircraft diverted and landed safely at Luton Airport. The investigation discovered that the aircraft had been subject to bore scope inspections on both Engines during the preceding night and the high pressure (HP) rotor drive covers had not been refitted, resulting in the loss of almost all the oil from both engines during flight. The line engineer was originally going to carry out the task, but for various reasons he swapped jobs with the base maintenance controller.

The base maintenance controller did not have the appropriate paperwork with him. The base maintenance controller and a fitter carried out the task, despite many interruptions, but failed to refit the rotor drive covers. No ground idle engine runs (which would have revealed the oil leak) were carried out. The job was signed off as complete.

In all three of these United Kingdom incidents, the engineers involved were considered by their companies to be well qualified, competent and reliable employees. All of the incidents were characterized by the following:

- There were staff shortages
- Time pressures existed
- All the errors occurred at night
- Shift or task handovers were involved
- They all involved supervisors doing long hands-on tasks
- There was an element of a “can-do” attitude
- Interruptions occurred
- There was some failure to use approved data or company procedures
- Manuals were confusing
- There was inadequate pre-planning, equipment or spares

4 SECTION 4: MURPHY’S LAW

PCAA-ANO-66 Module 9 syllabus also requires the inclusion of Murphy’s Law as a topic. There are several versions of the law. However, the most know version is the first one in the list.

- If anything can go wrong, it will.
- If there is a possibility of several things going wrong, the one that will cause the most damage will be the one to go wrong. Corollary: if there is a worse time for something to go wrong, it will happen then.
- If anything, just cannot go wrong, it will anyway.
- If an individual perceives that there are four possible ways in which something can go wrong, and circumvent these, then a fifth way, unprepared for, will promptly develop.
- Left to themselves, things tend to go from bad to worse.
- If everything seems to be going well, something obviously had been overlooked.
- Nature always sides with the hidden flaw.

There is a tendency among human beings towards complacency. The belief that an accident will never happen to “me” or to “my Company” can be a major problem when attempting to convince individuals or organizations of the need to look at human factors issues, recognize risks and to implement improvements, rather than merely to pay ‘lip-service’ to human factors.

If everyone could be persuaded to acknowledge Murphy’s Law, this might help overcome the “it will never happen to me” belief that many people hold. It is not true that accidents only happen to people who are irresponsible or ‘sloppy’. The incidents and accidents described earlier show that errors can be made by experienced, well-respected individuals and accidents can occur in organizations previously thought to be “safe”.

Consider a bolt with seven nuts and washers labelled and assembled as in the figure below.

How many times can it be assembled incorrectly? How many times can it be assembled correctly as shown?

The bolt, nuts and washers can only be assembled correctly one way. However, they can be assembled incorrectly many different ways, which shows how much more likely it is for components to be incorrectly assembled than correctly.

This exercise illustrates Murphy’s Law. One of the major causes of human error in maintenance is the incorrect installation or omission of aircraft parts and components.

Accidents can occur because of one error or may be the result of several quite unrelated errors.

In the latter case people/organisations may have contributed to the accident many years prior to it actually happening. The object of the exercise where all the work is recorded and signed for on an aircraft means that at any time records can show who has been involved – from the production of the raw metal, to the designer, to the draftsman, to the manufacturer, to the maintenance engineer.

The whole history of the aircraft and its components can be traced back to the smallest rivet. In this way if anything goes wrong then records will show the history and, hopefully, where the error lies. This is not to say we need this process for punishment purposes, but to find out what went wrong with a view to learning and putting procedures into place that will help prevent the same thing happening again.