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FOCUS is a quarterly subscription journal devoted to the promotion of best practises in aviation safety. It includes articles, either original or reprinted from other sources, related to safety issues throughout all areas of air transport operations. Besides providing information on safety related matters, **FOCUS** aims to promote debate and improve networking within the industry. It must be emphasised that **FOCUS** is not intended as a substitute for regulatory information or company publications and procedures.

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Front Cover Picture: British Airways A380 over White Cliffs of Dover

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Certification and Trust

by Dai Whittingham, Chief Executive UKFSC

In the last edition of FOCUS, we touched on the possible lessons arising from the loss of the Lion Air B737 MAX 8 and the questions that might subsequently be raised about certification and training. Sadly, the ink was barely dry on the print run when on 10 March ET302 crashed shortly after take-off from Addis Ababa, bringing the death toll from both accidents to 346. Beyond the personal tragedies and the impact on families and friends, two fatal accidents involving a new aircraft in less than 5 months has been a shattering blow to Boeing. The accidents will also have caused a great deal of soul-searching by other manufacturers seeking to know whether they are equally vulnerable.

National aviation authorities, especially those with State of Manufacture responsibilities, have similarly been challenged by the B737 MAX accidents. The decision to ground an entire fleet is fraught with difficulties but will only become fully effective if taken by the original certifying authority – the FAA in the case of the MAX – as the original certification forms the basis of the validation exercise undertaken by 3rd-country regulators.

For some regulators, the validation is largely a paper exercise, where the assurances provided by the original certifying authority are accepted as proof that the aircraft meets the required standards (the Certification Basis). Others may have a more rigorous process, but there is seldom a need to demonstrate (eg) handling qualities if these have already been checked elsewhere. Occasionally, a manufacturer may be required to demonstrate additional compliance with a particular national requirement but, in the main, the systems are based on the ICAO requirements and are mirrored across the globe.

Central to the certification process is the concept of trust between all parties. The certifying authority must be confident that the evidence being presented by the manufacturer is complete and that all reasonable steps have been taken to ensure the airworthiness of the aircraft under consideration. And when passed to 3rd countries, those countries have in turn to be confident that they can rely on the proof offered by the certification itself. A bona fide type certificate should meet the test. We apply a similar test, consciously or otherwise, when we buy a new car – it is built by company X, it has been approved for use on the road by authority Y, and it comes with a warranty to that effect, so you can use it without fear of being prosecuted for having an unsafe vehicle. You just trust what you are told.

With formal investigations ongoing into the design, testing and certification processes at Boeing and the role of the FAA in that, it would be wholly inappropriate to speculate about likely conclusions or to suggest corporate or individual wrong-doing (as some commentators have done). Let the appropriate authorities do that work. Whatever the outcome of a forensic examination into the development of the MAX, national aviation authorities and airlines must now struggle with a system in which implicit trust has been leavened with a few seeds of doubt. The market does not like breaches of trust, as the recent car emissions scandal has shown – shortcomings we can deal with, falsified data we can not.

On that note, the FAA's decision to delay grounding the MAX pending receipt of more data was understandable because of the likely economic impact on multiple entities, but it added fuel to the fire of mistrust. Instead, we witnessed a creeping vote of no confidence as more and more NAAs decided they could no longer wait. As has often been said: "If there's doubt, there's no doubt." Some commentators suggested regulatory capture as a reason for the delay; doubt in this area and the consequent reduction in levels of trust may make the MAX return to service a little more difficult if countries take a different view of the FAA's eventual decision to lift the grounding and the conditions under which this will be achieved. The old order is perhaps not as orderly as it used to be.

There are some other implications for the wider aviation system thrown up by the 2 MAX accidents. The first relates to Performance Based Oversight (PBO). For the sake of argument, if it eventually transpires that the manufacturer has been allowed to mark its own homework during the certification process, and that this led to mistakes and inadvertent compromises in the airworthiness chain, what does this say for the PBO regime that was applied? And for wider aviation, to what depth should a regulator explore an entity before being satisfied that its PBO provisions are adequate? Beyond PBO, the whistle-blower arrangements in many nations are there as a back-stop against the unscrupulous, who tend to be individual rather than corporate. However, organisational culture can have a key role in preventing bad behaviour, from the shop floor to the boardroom; ignore it at your peril.

The second area for concern is not MAX-specific and affects many modern types. Technology has continued to develop at a pace that usually outstrips the regulatory capacity to deal with it. With that has come more complexity and an ever-increasing need for deep specialist knowledge. That puts the modern accident investigator (or engineer) at a disadvantage when compared with earlier generations – it is no longer possible to find your way through the depths of a system that may hold the key to causation, without specialist assistance that is typically only available from the equipment or aircraft manufacturer. Is it reasonable to expect a generalist accident investigator to spot the tiny flaw in a software logic pathway that the de-bugging activity failed to find in the first place? And where will the specialist expertise come from when you need it?

It will be some time before the full MAX saga is revealed but hopefully we can get there without any more of the racist whispering campaign attempting to cast doubts on the abilities of the crews in both accidents and perhaps deflect attention from elsewhere. "3rd World = not yet ready for a modern aircraft" fails to recognise the catastrophic situation that 4 professionally-qualified pilots found themselves shortly before they lost their lives.

Continuing the theme of certification, many people will have been shocked by the videos of the unfolding tragedy at Sheremetyevo airport and the destruction of a Sukhoi Super Jet 100 in a landing accident on 5 May. A heavy touchdown led to loss of the main landing gear and a massive fuel fire that rapidly engulfed the rear of the aircraft. The Russian authorities noted that the evacuation was complete in 55 seconds; this was true but only for those who survived – 41 passengers and crew died in the fire.

The investigation will no doubt consider why the touchdown was so heavy (the aircraft was reportedly in direct law following a lightning strike), why the landing gear did not separate more cleanly and why the process of separation ruptured the fuel tanks. It should also look at why an apparently survivable accident produced so many fatalities, which means a close examination of the evacuation including the adequacy and proximity of means of escape.

Passenger behaviour during the evacuation must also form part of the investigation. There is clear video evidence of passengers bringing cabin baggage with them during their escape, and footage of the front right slide shows a significant pause in the flow of escapees before the next individual appears in the doorway with a large bag. Others followed his example. Reports on social media suggest a mid-cabin pile-up occurred while one man from row 10 was retrieving his bag; it appears only 3 people seated in the row behind him managed to escape the flames.

Whilst the above detail has yet to be confirmed, what is beyond doubt is that some passengers stopped to remove cabin baggage and that this action will have impeded the egress of others. How many will have been affected is hard to say (likely not all), but even one additional fatality is one too many. There have been plenty of instances in recent years of cabin baggage being removed during evacuations, but this is the first accident where this behaviour has been seen and not all passengers have survived. The other alarming behaviour shown during evacuations since 2010 has been the willingness of passengers to risk compromising their own escape, and that of others, in the interests of taking phone video of the event even in the most life-threatening situations.

We are not easily able to modify passenger behaviours, especially when they are stressed in an emergency, so we need to consider other forms of protection. Whether that takes the form of technology (overhead bin central locking, new slides or overheads, different seats etc) or business practices (discouraging cabin baggage) is open to question. Artificial intelligence engines may assist with better modelling of evacuation scenarios, but the first step should be an awareness campaign. There are arguments to be had about risk exposure and the allocation of resources to a remote threat, but that is where serious focus from the regulators will pay dividends.

Focus The Just Culture – how are we doing?

by Jacky Mills, Chairman UKFSC

It seems quite a long time since we first started talking about the merits of The Just Culture – around the mid 2000's I believe – prior to that we had talked about the No Blame Culture as the sensible way of conducting our safety investigations – and importantly – finding a vehicle for encouraging open reporting. The No Blame Culture was clearly a step in the right direction and replaced largely punitive cultures.

So, what was wrong with the No Blame Culture? The three words that on first glance tell people that there is a culture where you can hold your hands up and admit your 'erring' and everyone could learn, and you would not be in trouble. That encourages Open Reporting surely? Well yes, but that is not quite the message that was intended, and it did have some weaknesses.

The trouble with No Blame is that it could be interpreted as just that 'No Blame' so do whatever you want but as long as you admitted it (before you were found out) all would be well, and you could get away with the misdemeanour. Of course, this wasn't what a fair culture set out to do. What was wanted was those who made a mistake or error with the very best of intentions, those who had not meant to get it wrong, could report it and the safety investigators could find out the Why. The intention was not that those who wanted to follow their own rules could do so and get away with it.

The 'No Blame Culture' also fails to address culpability – this should not be ignored – it may be discounted as 'Not Applicable' but not ignored. It is important to know where the line should be drawn to distinguish between the culpable and non-culpable, the unacceptable behaviour and the blameless unsafe act.

No decent and right-minded person gets up in the morning and sets out to get it wrong. Particularly those in our flight crew community, who are, in 99.9% of cases, without doubt, their own harshest critics. Aviators set out to conquer the challenges of another day and to hopefully enjoy a pleasant day out. Of course, things do not always go to plan as we know, particularly when the Human is involved. Best intentions do not always come to fruition which is, of course, where the robust and effective Safety Investigation comes into play.

The Just Culture now features in EU Law through Regulation 996/2010 which covers Accident and Incident Investigation EU 390/2013 – Performance Regulation – and, of course importantly, EU 376/2014 – which outlines Occurrence Reporting. 'Just Culture means a culture in which front-line operators or other persons are not punished for actions, omissions or decisions taken by them that are commensurate with their experience and training, but in which gross negligence, wilful violations and destructive acts are not tolerated.'

It is encouraging to see that the aviation industry is taking this very seriously now. More pro-active Operators now measure not just numbers of reports, which could give a good or not so good message, but did they 'have' to report (is it reportable as Mandatory Occurrence Report and would they have been found out if they hadn't reported it)? Or was this something that may never have come to light?

The Company Safety Review Board should be actively seeking answers to the very important question – do more reports mean we are getting better or worse? Have we received more reports because more is going wrong, or is it that our colleagues feel safe in telling us what is really going on with our operations? This could be either, and without careful profiling of reports the wrong picture could be assumed – good or bad.

The very important point with a Just Culture, of course, is 'Do Your Workforce Believe In It?' An affirmative answer to that question is, of course, what is described as a Positive or Good Safety Culture. If your employees don't believe that they will be treated fairly in line with the Just Culture the Company has, no doubt eloquently, described in their Operations Manuals, then a lot of work is required to build up this vital trust. As in all walks of life this Trust is very hard to build up but can be destroyed very easily. One case of the Just Culture not being 'seen to be' adhered to can knock down years of work building it up.

'Not Being Seen To' is so relevant in this case because the rumour mill can destroy the Culture so easily in the guise of 'please don't confuse me with the facts...' Unfortunately, rumour is often a far more exciting story than reality, and this supposition and idle chat can so easily break down that trust which took so long to build up. The entity can do little to stop this as the outcome of the Confidential Investigation cannot, quite rightly, be discussed openly.

This demonstrates the importance of as many personnel as possible, especially those in Management and Safety positions, 'Role Modelling' the Just Culture and demonstrating that reporters will not only be treated fairly, in line with this policy, but will in fact be actively praised for this behaviour. Colleagues who have been pleasantly surprised at how they have been treated very fairly, will also go away and tell colleagues, though unfortunately, this is not always believed as easily as the negative stories.

We are aware that accidents in aviation have significantly reduced over recent years, and a positive and ever improving safety profile is widely described, particularly in Europe. It is often quoted that aviation is the safest form of transport, and 'much safer than driving a car' is often quoted. This must be attributed in a great part to the number of safety reports describing what is really going on out there.

Unfortunately, recent months have had a very sad downturn in the accident statistics with the investigations ongoing into the two accidents involving Ethiopia Airlines and the Lion Air aircraft. At the time of writing operations on this type of aircraft have been subject to a worldwide ban until more can be learned about the accidents and whether they have common causes.

Just Culture has been widely embraced in the world of Air Traffic Control with a Just Culture Task Force set up by Eurocontrol; this has sought to influence prosecutors and judges in European States. It has considered that fresh looks needed to be taken at not the law in itself, but by the way in which the law has been implemented and enforced.

Additionally, aviation and rail operators have worked together to promote the Just Culture as a transport, rather than just aviation, concept. This has recognised that Just Culture seeks to address two important areas – Safety and Justice – and should be addressed to ensure that the honest mistake is treated as just that and not punished in the way that a wilful act would be.

The Eurocontrol Task Force has developed a model policy to help national prosecution organisations to publish their own policies, which a number of states are undertaking. The UK and Netherlands already have an Aviation Prosecution Policy in place. How far any policy can limit prosecution in the case of gross negligence would depend on the law of the state. However, it is understood that even without a policy there is a tendency not to formally prosecute aviation incidents unless unacceptable behaviour, a pilot under the influence of alcohol for example, played a role.

So, do we have examples of where the Just Culture has been successful? And in different cultures?

This story of a large German Engineering company is worth looking at. The company had expanded its MRO (Maintenance, Repair & Overhaul) around Europe and on into Asia, both by growth and acquiring existing MRO facilities. The German company rotated its executives from the parent company into local management roles and in this case a German executive was rotated into the Asian work environment.

There was a significant maintenance error which occurred on the German executive's early days at this newly acquired MRO facility. An engineering crew caused extensive damage to a large engine cowling during removal using the hangar lift. The extant culture led all employees to expect that the lift operator would lose their job as appearing to be the most responsible party, as well as other long serving engineers.

The German expatriate took control of the safety investigation and looked at the work environment, how the workforce was trained for this task, the clarity of procedures, how adequate was the support equipment, and other relevant details.

His conclusion was that some aspects of the work environment, procedures, training and human factors approach, had not set up the workers for success, and that the maintenance event had been an honest mistake. The expatriate executive accordingly, did not fire anyone, but addressed all the contributing factors and arranged installation of a replacement cowl. He also asked the same engineer to operate the lift for a new cowling installation.

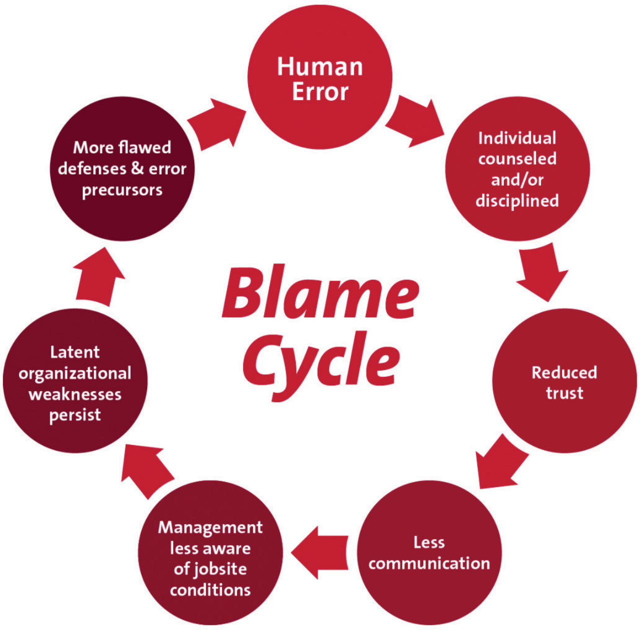
Subsequently, the entire workforce learned of this event and the fair treatment of the engineer. The example of Just Culture influenced the German-Asian collaboration and had an extraordinary long-term impact on not only safety but efficiency too. This shows that whilst written processes and procedures are important, the Just Attitude is as important.

I like to think that in Europe we now expect the Just Culture to be the norm. I am aware that Aircraft Operators now routinely include questions about the Just Culture in their recruitment for Flight Management and Safety personnel. A positive attitude from such personnel is vital for the Safety Culture.

But has the Just Culture moved into our lives without any problems and implementation issues? No, certainly not. I have a story of a large carrier whose leaders and Senior Managers saw the benefits of Just Investigations but wanted to test the voluntary reporting concepts. When an event occurred, everyone wanted to determine the root causes and find preventative actions. Reporting procedures and Just Culture policies were developed, with the co-operation of the Union, put in place and training delivered.

As a radically new programme there were, of course, those Management who were not convinced of the value and had concerns that accountability would be lessened, whilst many of the workforce were suspicious and feared that a reported error would trigger disciplinary action.

Very early on in the implementation of this programme there was a maintenance error that required expensive rework. A mistake had been made. The Supervisors and Middle Management understood the mistake and did not take action against the workers. However, when Senior Management saw the cost of this error immediate disciplinary action was taken against both the workers, and the Managers who had followed the Just Culture policy. This resulted in the Union involved pulling out of all future Just Culture participation, resulting in many years passing before confidence in the Just Culture was restored.



I believe that we have gone far away from those dark days in any sector of aviation, but this is a salient reminder of how far, and how important it is that we have moved forwards. The aviation industry is complex, where front of house operators work as an integral part of a wider system, and teams must interact continuously with procedures and equipment.

It is important therefore, that any investigation considers the total aviation system, which needs continuous attention and improvement, and can only be achieved with informed and pro-active reporting.

It is almost inevitable that when there is high workload people will find workarounds to achieve the goals required and find a way to put out a good performance, thinking that they must do so to avoid being reprimanded.

There is no doubt that the Just Culture has evolved and come a long way and been largely successful in the western world, but with a few caveats. There are still people who simply do not believe it, do not trust it. This is not irrational, paranoid behaviour, but ordinary people who need to see a lot of evidence of fair treatment before they are convinced.

So, is there anything we can do to improve this trust? I believe there is.

Remember that when conducting an investigation, there is an ideal opportunity to showcase the Just Culture, to prove that it is operating successfully by showing understanding of personal needs and how people would most appreciate being treated and supported.

When evaluating an event for the investigation, do we feel swayed by whether there was a negative outcome? Mindful of the Just Culture the result should not be any different whether an event had caused there to be significant cost to the Operator or it had come to light from a Voluntary Report.

The Just Culture should employ empathy and not judge but seek to understand when an error or mistake had occurred with the best of intentions. What occurred inevitably made sense to those involved at the time, we just need to discover Why?

It is important to look at how people judge themselves, as well as others, when an adverse event occurs. Often for flight crew this will be harshly, critical of their own performance, questioning their own competence and finding disappointment in themselves.

It is important to focus on the whole event and not just part of it, and whether there were systemic or extraneous issues. Everyone makes mistakes – it is important to drill into the Why – 5 Whys is such a good technique – keep asking Why until the real root cause has been established.

I believe so much has been learned from the pre-cursors, the minor incidents as well as the more serious, thanks to the Just Culture. But, and there always is a but, it needs constant care, attention, and transparent role modelling to ensure consistency and fairness with laid down boundaries, is seen to be alive and flourishing.

Thinking Things Through

by Clarence E. Rash and Sharon D. Manning

A pilot's cognitive processes – thinking and decision-making skills – often are the key to successfully overcoming in-flight safety risks.

On the chilly afternoon of Jan. 15, 2009, having lost power from both engines of their Airbus A320 minutes after takeoff from New York's LaGuardia Airport, the crew of US Airways Flight 1549 landed the aircraft in the Hudson River.[1] Although the A320 was destroyed, all 155 people inside survived.

There is little doubt as to the role that the training and experience of the flight crew played in the successful emergency landing, but ultimately, it was their decision-making skill that turned a potential tragedy into a triumph.

When faced with a challenging situation, pilots must use their skills, abilities and knowledge to overcome the immediate circumstances. Cognitive psychologists consider decision making as the interaction between a *problem* needing to be solved and a *person* who wishes to solve it within a specific environment and set of circumstances.[2] Although making the right decisions does not always lead to success, making the wrong decisions makes success considerably less likely.

When the crew is faced with a threatening situation in the cockpit, the outcome is largely determined by three groups of factors:

- External factors, such as weather, runway conditions, takeoff weight and presence of birds;
- Aircraft and flight deck design factors, such as the structural limits of the aircraft and the human factors engineering design of flight deck displays and input controls that affect the workload; and
- Factors related to human capabilities, such as those that influence a pilot's level of cognitive processing and his or her decision-making capability.

The first two groups are largely predetermined and beyond the immediate control of the pilots. However, the third group of factors centers around the human performance of the pilots and is within their direct control.[3] This group includes high-profile factors that are recognized as important enough to be regulated, such as the amount of rest time provided and alcohol consumed within a specified preceding time period, as well as factors that frequently are overlooked, such as nutrition state, hydration level, smoking rate and ambient noise level. These and other seemingly unimportant factors can significantly degrade pilot performance by impairing cognition, and, as a result, problem-solving and decision-making capabilities.

Cognitive Capacity

Although philosophers have been interested in human thought for thousands of years, the field of cognitive science – the scientific study of the human mind or of intelligence – is barely more than 100 years old. Despite tremendous advances in the understanding of how the mind works, it remains difficult, even for cognitive specialists, to predict the cognitive capabilities of an individual in most sets of circumstances.

When cognitive demands exceed an individual's capacity – a condition referred to as cognitive saturation – newly presented information may not be perceived or understood.[4] This implies that individuals have a set amount of cognitive resources – a term that refers to information-processing capabilities and knowledge that can be used to perform mental tasks. Different cognitive tasks appear to involve different information processing systems, and the resources and limits of these systems determine the cognitive capability to perform a given set of tasks. One of the main goals of cognitive science is to identify the properties of these systems and characterize their limits.

Scientists have explored human cognition by studying its fundamental processes and how they are affected by internal and external factors called stressors.

Cognitive Processes

To make decisions that lead to doing the "right thing" at the "right time" requires pilots to acquire, process and act on information available within the immediate situation. This information is acquired through the five basic human senses – sight, hearing, smell, taste and touch – and the so-called sixth sense of proprioception, or the ability to sense the position and movement of the body and its parts (see "How Humans Obtain Information").

On the flight deck, there is an unusually broad unitization of the senses to continually update pilot information. For example, vision is used to monitor panel displays and to detect airspace and runway incursions. Hearing is used to detect aural warning signals and in communication. Smell – and in some cases, taste – can help detect the presence of fire, fuel leaks or chemicals. Proprioception supplies not only the sensations associated with "seat of the pants" flying but also a range of other signals from sensors in the skin, muscles, tendons and joints that aid in establishing awareness of the position of the body relative to the Earth.

As information is provided by the senses, it is interpreted by the respective cognitive processes of perception, attention, memory, knowledge, problem solving and decision making, after which a course of action is implemented. This defines just one cycle in the decision-action sequence, which is a continuous feedback loop of acquisition, processing, decision and action.

How Humans Obtain Information

Humans obtain information via a number of senses. Although most cognitive scientists have moved away from the historical concepts of physiological senses and their resultant sensations and toward the psychological concept of perception – the understanding of sensory information – these older concepts are useful in understanding how we obtain information to make decisions.

Our senses acquire information using specialized receptors (Table 1). The most basic sense modes are sight, hearing, touch, taste and smell.

Along with the sense of balance (equilibrioception, or vestibular sense), these senses sometimes are referred to as exteroceptive senses, because they relate to our perceptions of the world around us. However, scientists have identified a second group of senses called interoceptive senses that pertain to our sense of self. This group includes thermoception, or temperature; nociception, or pain; and proprioception, the sense of the orientation and position of oneself in space. Proprioception does not result from any specific sense organ but from the nervous system as a whole.

— CER, SDM

Table 1

HUMAN SENSES

Human Sense	Receptors	Sensations/ Perceptions
Sight (Vision)	Photoreceptors (Cones and rods)	Brightness and color
Hearing (Audition)	Hair cells (Vibration receptors)	Sound
Touch (Tactility)	Touch receptors (Mechanoreceptors)	Touch and pressure
Smell (Olfaction)	Chemoreceptors (Odor receptors)	Smell (Odor)
Taste	Taste buds	Salty, sour, sweet, bitter and umami[1]
Thermoception (Temperature)	Thermoceptors (Heat receptors in the skin)	Temperature (Heat and cold)
Proprioception	Muscle spindles, Golgi tendon organs, and joint receptors	Self orientation and position
Nociception (Pain)	Nocioptors (Pain receptors)	Pain
Equilibrioception (Vestibular sense)	Otolith organs	Balance (Direction of gravity)

Note: 1. Umami, the lesser-known "fifth taste," is described as savory or "meaty."

Source: Clarence E. Rash and Sharon D. Manning

Perception

Perception is a series of conscious sensory experiences. It is a combination of the information from the stimuli, or sources of information, in the world around us producing sensations in the sense organs – via sensory receptors – and cognitive processes that interpret those sensations. Perception deals with the psychological awareness of objects in the world, based on the effect of those objects on the sensory systems. It often is defined as the mental organization and interpretation of the visual sensory information with the intent of attaining awareness and understanding of the objects and events in the immediate environment.

Because perception is an interpretation by the cognitive processes of the information obtained by the senses, it is possible for an interpretation to be wrong. These misperceptions are called "illusions" and are attributed to all of the senses. The flight environment is known for inducing a host of sensory illusions in pilots. When not recognized as incorrect interpretations of the current state of the aircraft, these illusions impair situational awareness and frequently lead to incorrect decisions and courses of action, often with disastrous consequences.

Attention

Because humans have limited cognitive processing capability, there is a distinction between the total information provided by the real world and the amount of this information that actually is processed. The mental process that is involved in producing this distinction is referred to as "attention." A stimulus can be processed very differently when attended to, compared with when it is unattended. For example, if someone is asked a question while he is busy attending to something else, he may not even hear the question.

Generally, attention involves a voluntary or intended focusing of concentration. It is believed that attention can be directed to different aspects of the environment. In reality, attention is not based on a single mechanism but involves the properties of many different cognitive systems.

Cognitive scientists distinguish between voluntary and involuntary attention.[5] Voluntary attention occurs when a person makes an obvious cognitive effort to remain focused on a particular task. Involuntary attention often is related to environmental stimuli, such as warning signals, that seem to automatically draw attention.

One attention condition that has been the subject of considerable interest in aviation is "cognitive tunneling." Cognitive tunneling refers to a difficulty in dividing attention between two superimposed fields of information – for example, head-up display (HUD) symbology as one field and see-through images as another field. It sometimes is referred to as "attentional tunneling" or "cognitive capture." In the aviation environment, such difficulty can lead to serious problems. Studies have found that pilots sometimes have failed to detect an airplane on a runway when they are landing while using a HUD system.[6,7] Cognitive tunneling is an extreme form of a trade-off between attending to displays and attending to the outside world. Several studies have shown that a HUD improves monitoring of altitude information in a simulated flight but at the expense of maintaining the flight path.[8,9]

Memory

Memory interacts with attention and perception. Indeed, many failures of attention are described as breakdowns in memory of recent events. Cognitive scientists have identified various components of memory, such as short-term memory, working memory and longterm memory.[10]

Short-term memory deals with memory of items for several seconds and generally has a relatively small capacity, holding only a few items before forgetting takes place. Working memory, which typically involves the manipulation of a piece of information – such as the mental comparison of two remembered airspeeds – is broken down into subsystems that process information in a variety of ways.[11]

Long-term memory refers to the important memories that are stored for long-term use. For example, training information, information about rules for behavior in specific situations and other developed forms of knowledge are stored in long-term memory. Closely related to this type of knowledge is a sort of mental model, a cognitive structure called a "schema," that helps interpret information about how particular situations typically play out; for example, of how a specific aircraft will behave under stall conditions. Schemas allow people to adapt to new situations by using knowledge about other similar situations.

The cognitive process of problem solving refers to an immediate distinction between the present state of circumstances and a goal for which there is no immediately obvious path to attainment.[12] The ability to solve a problem is interrelated with the previously discussed cognitive processes. Some problems are difficult because their solution requires retaining more information than can be held by working memory, and others are difficult because individuals lack the appropriate schemas to characterize and analyze the important issues of a problem.

One important aspect of problem solving is to identify the differences between expert and novice problem solvers. Pilots are specially trained for their duties and are thus experts at solving some aviation-related problems. As a result of their training, experts in a particular field solve problems faster and with a higher success rate than novices. The primary difference between expert and novice problem solvers seems to be that experts have more specific schemas for solving problems.

Experts also generally have more knowledge about their field of specialization than novices. Their knowledge is organized differently than novices' knowledge. In particular, experts often organize their knowledge in a way that reflects the fundamental aspects of solving a class of problems.

Decision Making

The culmination of the other cognitive processes is the decision-making process.

The major elements of decision making are: outcome selection, certainty and uncertainty, and risk. An outcome is what will happen if a particular course of action is selected. Training helps identify the list of possible outcomes and the courses of action that may lead to each outcome. Knowledge of possible outcomes is important when multiple courses of action are available. Certainty implies that decision makers have complete and accurate knowledge of the possible outcomes for each possible course of action, and that there is only one outcome for each course of action. This last condition is not always met.

Risk becomes a factor when there are multiple outcomes for one or more courses of action. Risk can be managed if a probability can be assigned to each outcome when a specific course of action is taken. Uncertainty is present when the probabilities cannot be assigned; such a decision situation is referred to as "decision under uncertainty."

Researchers at the U.S. National Aeronautics and Space Administration (NASA) Ames Research Center examined decision-making errors in aviation[13] and found most errors to be intentional – that is, they resulted from a positive selection of an incorrect course of action (a mistake) and not from a failure to take action (a lapse) or because an intended action was carried out incorrectly (a slip).[14]

However, as has been described, the decision-making process is the culmination of the other cognitive processes; if the other processes are degraded or go awry, then the decision-making process and the resulting selected course of action will be incorrect. The consequences can be disastrous.

To assist pilots with their decision-making skills, the U.S. Federal Aviation Administration (FAA) developed a six-step model for use in teaching the elements of decision-making. Known by the acronym "DECIDE," the six elements are:[15,16]

- *Detect* that a change has occurred;
- *Estimate* the need to counter or react to the change;
- *Choose* a desirable outcome;
- *Identify* actions that could successfully control the change;
- *Do* take the necessary action to adapt to the change; and,
- *Evaluate* the effect(s) of the action.

Decision making is a skill. Pilots, like other professionals, must learn to become better decision makers. The DECIDE model – one of many human factors approaches to teaching decision-making skills – has proved to be a successful resource for learning the crucial components of making more effective decisions.

Developing good decision-making skills is not just an academic exercise for pilots; it is a necessity. With lives at stake, making the right decision at the right time is imperative. From 1990 through 2002, decision errors were identified as a contributing factor in 30 to 40 percent of commercial and general aviation accidents.[17,18]

Clarence E. Rash is a research physicist with 30 years experience in military aviation research and development and the author of more than 200 papers on aviation display, human factors and protection topics. His latest book is Helmet-Mounted Displays: Sensation, Perception and Cognition Issues*, U.S. Army Aeromedical Research Laboratory, 2009.*

Sharon D. Manning is a safety and occupational health specialist at the Aviation Branch Safety Office at Fort Rucker, Alabama, U.S., and has more than 20 years experience in aviation safety.

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CHIRP
Reports for FOCUS

ATCOs' RT calls

Report Text: This report is a general one, the time and date given is the most recent example where the subject of the report recently occurred (it was during my annual Licence Proficiency check, after an ILS approach, with an examiner on board).

I operate a two-pilot helicopter based at a large and often very busy civilian airport. We fly to "Class A" performance and aim to operate in accordance with the sterile cockpit principle, for well publicised reasons.

A "Clear Area" (runway) approach for the type we operate has a Landing Decision Point (LDP) of 80 feet agl and 25 kts IAS. Beyond that point on the approach, an engine malfunction would require a landing on the runway because there is likely to be insufficient power to achieve a hover or to climb away. 80 feet agl is therefore a point where the pilot needs to fully concentrate on either landing or achieving a stable hover, from where either hover or ground taxiing can be commenced to clear the runway.

Increasingly often, ATC transmit our subsequent taxiing instructions on short finals, sometimes including a frequency change to "Ground". As instructions there is a requirement for these to be read back in full. This is an unacceptable distraction at a critical stage of flight.

The pilot flying calls "LDP" across the cockpit so that the other pilot is aware of what his immediate actions would be in the event of an engine failure. An untimely transmission from ATC completely disrupts this cross-cockpit communication. I have noticed that ATC certainly seem to totally understand the "sterile cockpit" environment of fixed wing aircraft but inexplicably, do not seem to consider this same factor for helicopters.

ATCOs should delay transmitting taxi instructions to helicopters until after they have cleared the runway, or at least after landing, certainly not on short finals.

British Helicopter Association Comment: This is a common one for helicopter operators. The solution is to go and have a liaison visit with the tower and tell them your concerns and how you operate. Because helicopters do not follow the normal instrument arrivals, ATC may not realise that crews need a 'sterile' period during the late stages of an approach. Very often we are turning onto the final approach heading, at a low height, having come from 90 degrees to the runway. Certainly, taxi instructions should not be given from the time the helicopter enters finals until it is in a stable hover. It makes no difference whether the aircraft is being flown multi or single pilot.

ATC Comment: This is a busy airport equipped with a single main taxiway running parallel to, and along the entire length of the runway. There are several aprons spanning the entire south side of the airport and entry/egress from these aprons is via a multitude of access points. As a consequence, aircraft are not generally allowed to choose the point at which they vacate, as this may well bring them into conflict with aircraft taxiing in the opposite direction for departure and there is an insufficient amount of safe space between the runway exits and the main taxiway to safely hold aircraft. We also have some exit points towards the mid-point of the runway that are also used as holds for departure. Consequently, if a specific exit is required, aircraft are usually given instructions on where to vacate prior to being given landing clearance, to allow them to plan for the required braking action and also to allow for an uninterrupted approach and landing. However, due to the dynamic nature of the traffic and the small traffic gaps that a single runway operation requires, it is sometimes necessary to instruct pilots upon completion of their landing roll where they are required to vacate and controllers are trained to time this call accordingly.

In the case of helicopters, it is not always apparent when the landing manoeuvre has been completed and taxi manoeuvre commences as helicopters seldom come to rest either in a hover or on the runway and often transition from landing straight into taxiing off the runway. In this instance Controllers will make a judgement as to when it is likely to be safe and prudent to issue taxi instructions but this may sometimes be prior to them vacating the runway if the traffic situation requires it.

It is not clear from the report at exactly what point the reporter received the taxi instructions but we would be surprised if this was 'late on the approach' and is far more likely to be when the aircraft is abeam the tower (approximately half way down the runway) which is where our ATCOs generally make the necessary call.

The report will be included in the next standards bulletin together with re-iteration of the importance of timely taxi instructions, in particular those relating to helicopter movements. Equally, pilots need to be aware that if they receive an instruction from ATC that is poorly timed or inappropriate, the use of "Stand-by" is always available. Working with many different operators, experience has shown that there is very little standardisation in cockpit procedures and very often, a period that is regarded as 'sterile' by one operator may well be considered to be 'opportune' by another.

We appreciate this kind of feedback and it's always good to hear the other side of the story.

CHIRP Comment: A sterile cockpit for critical phases of flight is a sound principle. In reality, controllers frequently issue instructions or guidance when on final approach. These transmissions may be helpful - for example a wind check, the position of marshallers or the location of the exit taxi way, which, taking into account the great flexibility of a helicopter, may allow the final approach to be modified to minimise a possible long hover-taxi. However, such calls should not be made during the critical final phase of the approach. Frequency changes in the late stage of flight or the hover can be a problem for single-pilot helicopters that do not have a cyclic frequency select button – or who have not pre-programmed their radio to the ground frequency! This report, and the two Comments above, provide a good reminder of the differences between fixed wing and helicopter operations. Also, that a bit of awareness can go a long way; if ATC procedures cause pilots a problem, and vice versa, it is a good idea to discuss them and find a solution that works for both parties.

Reporting CPDLC status

[CPDLC: Controller-Pilot Data Link Communications]

Report Text: On an extremely regular basis pilots report that they are either logged on to CPDLC or are equipped or that they are equipped but unable to log on. The whole point of CPDLC is to reduce R/T and these extra transmissions are entirely counterproductive. As radar controllers we can see equipage state and login status on our radar and our tools will only offer us the option of sending a message by CPDLC if all requirements have been met. If we can use it, we might. If we can't, we obviously won't. I don't know if it is aircrew procedures that require these reports or if it is just something that has evolved as the use of the new technology increases but it would be appreciated, especially as traffic levels build again next summer, if they stopped.

CHIRP Comment: CPDLC was originally mandated for February 2015 and many operators had started to equip and use CPDLC beforehand. During this period there was a requirement to state that you were using CPDLC as most aircraft were not so equipped and only a few ANSPs could use it. The mandate was subsequently delayed until February 2020; more ANSPs have come online since then and the requirement to state that you are equipped/using CPDLC has gone.

Because we have not reached the mandate date, the use of CPDLC is still variable and its usage is not yet as straightforward as it is likely to become over time. It is understood that in the UK it's use is still down to user-preference. Consequently, some ATCUs use it a lot and some not at all, as they are not required to. The same goes for most of Europe (probably with the exception of Maastricht who were one of the first and use it by default).

There is little guidance in CAP413 regarding CPDLC and operators have produced different SOPs regarding usage and reporting. An amendment of CAP413 for when the use of CPDLC is mandatory would appear to be the best solution. The CAA is aware of this report and the proposed solution.

HLA training/familiarisation

Report Text: My operator has been conducting HLA Oceanic training under the guise of "Familiarisation" for a while now. This used to be conducted by LTCs under a training programme following a lesson plan followed by sign-off, enabling the crew member to now fly with other qualified crew members on oceanic routes. They have since changed this from Training to Familiarisation meaning that once a Line Captain like myself has operated 6 sectors oceanic, we are now classed as "qualified" to conduct these famil flights. I, like a lot of others I have spoken to, am not comfortable conducting these flights with an unqualified crew member on these procedural more complex route structures plus the fact as these used to be training flights we have been supplied the same "lesson plan" (now changed name) as the LTCs would have used and have been notified by the training department via a "Training Instruction" memo, as to how to conduct these flights. Any words to do with Training or

Student have literally been scored out and replaced with Familiarisation and Observer.

Personally, as a Line Captain, I'd rather not fly with an "Observer" in the other crew seat. The company have said the regulator approved this process however have not provided this approval to us. I would be interested to learn if this Approval exists with the NAA and the legalities to flying oceanic airspace as a normal Line Captain with an unqualified or unfamiliar crew member. Procedures and Emergencies etc. in this airspace are more complex and demanding than the domestic alternative and I think it's unfair to lay this extra responsibility on us. Especially as we have not been trained to conduct these types of flights nor do we receive any further remuneration as LTCs would.

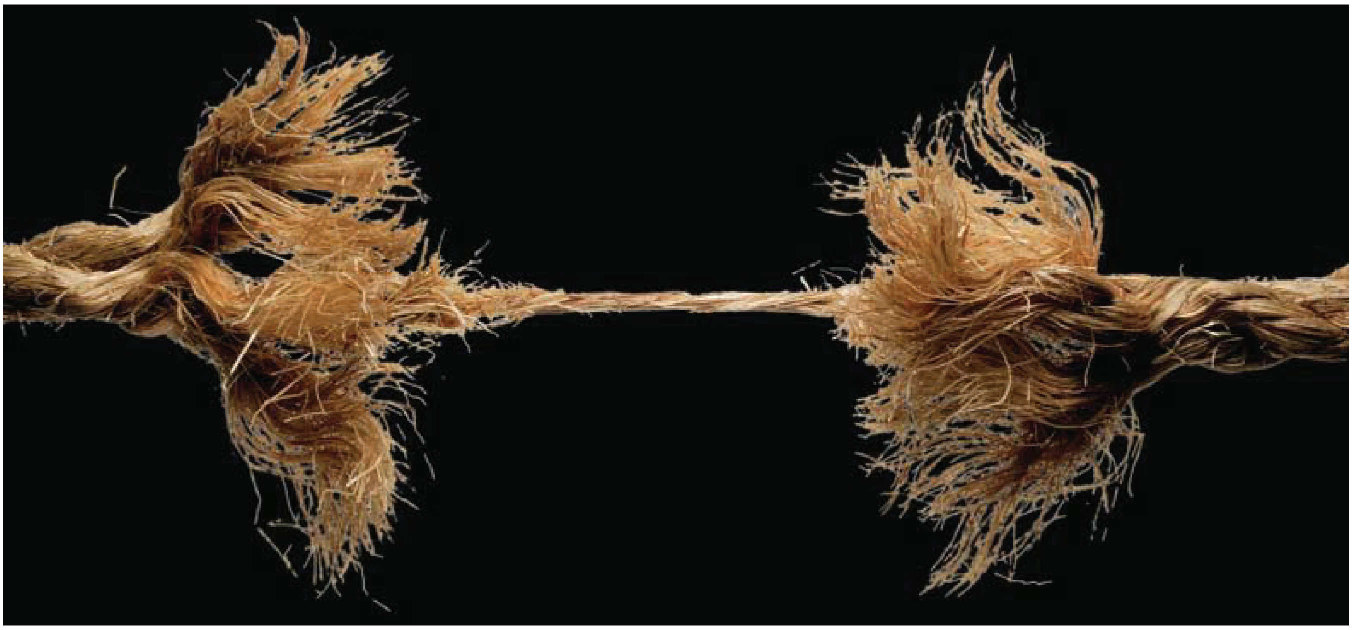
Operator's Comment: There are no grounds for raising the Company's NAA-approved procedures for pilot NAT HLA Route Familiarisation training as a safety issue. The approval process for this change considered the difficulty and safety implication of the task and the Company was satisfied that the new training procedure was suitable and did not compromise safety. This process was discussed in detail with the NAA at the time of the relevant Training Instruction proposal.

CHIRP Comment: We have been unable to find any formal training requirements for flights in North Atlantic High-Level Airspace; ICAO Doc 007 provides little guidance but operators should detail their training requirements in their Ops Manuals. Operating 'Tango routes' is generally straightforward but there is the potential for complications and many operators include an aide memoire in the QRH. Pilots who do not gain experience of HLA ops during their line training should have little difficulty learning the procedures during routine flights with a non-training Captain. The experience can be likened to operating into an unfamiliar airport for the first time.

Concerning the issue of legality when flying these routes with an unfamiliar crew member (CHIRP would not consider them to be 'unqualified'), reference should be made to an article on Vicarious Liability which appeared in Air Transport FEEDBACK 126.

Stressed Out

by Clarence E. Rash and Sharon D. Manning



A range of physical and emotional factors can interfere with a pilot's cognitive process and degrade his decision-making skills.

Whenever pilots step onto a flight deck, they should ask themselves if they are fully capable of making the right decisions during the upcoming flight and taking the actions required in case of an emergency.

Decision making – the final step in the cognitive process[1] – is a factor in 30 to 40 percent of all commercial and general aviation aircraft accidents.[2,3] Any physical, physiological or emotional factor that degrades any portion of the cognitive process ultimately will degrade decision-making skills. When considered in the context of their effect on cognitive function in the operational flight environment, these factors often are referred to as "stressors."[4]

'Wear and Tear'

The term "stressor" is derived from "stress," a concept first identified in the early 20th century by Austrian endocrinologist Hans Selye. He identified what he believed was a consistent pattern of mind-body reactions that he called "the nonspecific response of the body to any demand."[5] He later referred to this pattern as the "rate of wear and tear on the body."

The definition of stress is necessarily broad: Stress is a normal, nonspecific physical, psychological and physiological response of the body to any demand placed upon it.

Prolonged stress may affect cognition – the process of perception, attention, memory, knowledge, problem solving and decision making – just as it affects emotions and behavior. This is a serious issue for pilots, because problems with judgment, attention or concentration present a great risk to the aircraft and the people in it. For example, under high-stress conditions, there is a tendency to oversimplify problem solving and decision making and to ignore important, relevant information – to "take the easy way out."

Many individuals under high-stress conditions tend to forget learned procedures and skills and revert to old habits that may not be appropriate. For example, they apply the techniques and knowledge acquired during previous training in other aircraft types.

Another stress-related cognitive error is perceptual tunneling – in which a pilot or an entire aircrew under high stress becomes focused on one stimulus, such as a warning signal, and neglects to attend to other important tasks or information.

Perceptual tunneling was at the heart of the Dec. 29, 1972, crash of an Eastern Air Lines Lockheed L-1011 in the Florida Everglades. The three-member flight crew declared a missed approach because they had no indication that the nose landing gear had extended, and then became so engrossed in identifying the problem with the position light system that they failed until seconds before the crash to notice that their airplane was no longer in level flight at 2,000 ft.[6]

In addition to affecting memory, judgment and attention, stress also can decrease hand-eye coordination and muscle control.

It is important to control stress by identifying and managing potential stressors. Stressors often are categorized as either external or internal.[7]

External stressors originate outside the individual and may be divided further into environmental and psychosocial subcategories (Table 1). In aviation, examples of environmental stressors are adverse flight conditions, cabin temperature extremes, glare or insufficient lighting, high noise levels and altitude effects.

Table 1

CLASSIFYING STRESSORS

EXTERNAL		INTERNAL	
Environmental	**Psychosocial**	**Physiological**	**Cognitive**
Poor flight conditions	Workplace conflicts	Poor diet (Nutrition)	Lack of information
Extreme heat or cold	Family conflicts	Tobacco	Information overload
High noise level	Insufficient flight time	Muscular fatigue	Mental fatigue
Excessive vibration	Low job satisfaction	Sleep deprivation	Fear
Altitude effects	Feeling of lack of support	Alcohol	Feeling of helplessness
Crowded space	Lack of control	High blood pressure	Boredom
Air pollution	Spousal conflict	Prescription or over-the-counter medications	High workload
Humidity extremes	Family illness or death	Caffeine	
	Unrealistic expectations	Decreased vision	
	Financial problems	Hearing loss	
	Loneliness	Diseases	
	Devalued self-worth	Hunger	
		Thirst (Dehydration)	

Source: Clarence E. Rash and Sharon D. Manning

Psychosocial stressors relate to events or conditions that are linked to individual and family social characteristics, positions and roles, and include workplace conflict, a feeling of a lack of support from coworkers, and family-related stressors such as spousal conflict, problems with children, and illness or death of a relative.

Internal stressors originate within the individual and typically are considered to be within the individual's control. They may be divided into physiological and cognitive subcategories. Physiological stressors include poor diet, tobacco use, muscular fatigue, sleep deprivation, alcohol use and hearing loss. Cognitive stressors include boredom, high workload, information overload, a lack of information and emotions such as fear and hopelessness.

Making Rules

A few of these stressors have long been recognized for their degrading effects on cognitive function and, therefore, on decision-making skills. For this reason, civil aviation regulatory bodies have established rules regarding some of the more obvious stressors, including alcohol consumption and drug use, and continue to wrestle with the best methods of handling others, such as fatigue.

In the past, fatigue was addressed almost exclusively with rules limiting the number of hours worked in a given period. In recent years, however, specialists have begun to recognize other equally important contributors to fatigue such as inadequate sleep time, poor sleep quality, disruption of circadian rhythms, irregular work hours and the effects of commuting time.

Fatigue typically causes an increase in reaction time, a decrease in accuracy and a reduction in attention. Fatigued pilots may exhibit a tendency to overlook or misplace sequential task elements, such as leaving out items on a checklist, or become so preoccupied with a single task that they neglect more critical tasks.

Fatigue also impairs memory. Although long-term memory is reasonably well preserved in the presence of fatigue, short-term memory and cognitive processing capacity are greatly reduced.[8] Communication also is impaired by fatigue; speech may become less clear, and fatigued pilots may be prone to misunderstanding messages. Fatigue invariably degrades decisionmaking skills, sometimes resulting in incorrect responses to emergency situations.

Hidden Stressors

A host of other factors – often misunderstood or ignored – have more subtle effects on cognitive performance. These factors include inadequate nutrition and exercise; use of prescription and over-the-counter medications; dehydration; tobacco use; exposure to heat and cold; noise; and vibration. As a result of their exposure to these factors, pilots may not be at their best while flying. Consequently, in an emergency, pilots may be unable to respond with the necessary reaction time, hand-eye coordination, communication skills or decisionmaking ability.

Poor nutrition and lack of exercise are stressful and make it more difficult to deal with other stresses. A proper diet provides the body with the essential vitamins and minerals and helps maintain cognitive function.

Medication

Most civil aviation regulations prohibit flying while taking any medication that might affect pilot performance and flight safety. Medical conditions and medications – even those that present no problems on the ground – can have adverse side effects that may vary with altitude.

Many common over-the-counter medications can significantly impair cognition, judgment or sensory inputs. For example, some medicines for colds and allergies contain ingredients that can cause drowsiness, short-term memory loss and blurred vision. Pilots should ask aeromedical specialists about the appropriateness of medications for use during flight and read all labels carefully.

When researchers from the U.S. Federal Aviation Administration (FAA) Civil Aeromedical Institute (now the Civil Aerospace Medical Institute) examined pathology samples from 1,683 pilots killed in aviation accidents from 1994 to 1998, they found over-the-counter medications more frequently than any other drugs.[9] Over-the-counter drugs were found in 301 samples, and prescription drugs in 240.

Smoking

The use of tobacco is widespread, although numerous studies have demonstrated an association between smoking and cardiovascular disease, various cancers, pulmonary disease and other ailments.[10]

As a stimulant, nicotine has been found to improve cognitive performance on attention and memory tasks,[11,12] and it appears to improve visual attention – both important in aviation.[13] Other studies have shown that nicotine may improve the ability to focus on auditory information and filter out background noise.[14,15]

However, other studies have found that:

- Cigarette smoking contributes to hypoxia – a problem that increases with altitude. Three cigarettes smoked at sea level increase the physiological altitude to between 5,000 and 8,000 ft. At altitude, complex tasks requiring decision making, use of mental strategies and memory retention can be more difficult than they are at sea level; for a pilot who is at an artificially high physiologic altitude because of smoking, the problem is compounded.[16]

- Smoking reduces visual acuity at night, and the effect increases with altitude. Night vision has been reported to decrease by 5 percent at 3,500 ft, by 20 percent at 10,000 ft and by 35 percent at 13,000 ft, if supplemental oxygen is not provided.[17]

- Cigarette smokers are nearly two times more likely than non smokers to experience hearing loss, especially at high frequencies.[18]

- The nicotine in cigarettes also is associated with transient dizziness and nausea, which can be aggravated by motion.[19]

Dehydration

Dehydration is a major contributor to fatigue and an accompanying decrease in mental and physical performance, and dehydrated pilots are at a higher risk than others for decompression sickness, spatial disorientation, visual illusions, airsickness and loss of situation awareness.[20]

Pilots with health problems and those in small aircraft without air conditioning are most susceptible, but the problem also can affect pilots who operate on the low-humidity flight decks of air carriers.

The first common indication of dehydration is thirst. By the time an individual senses thirst, however, he or she already is about 1.5 qt (1.6 L) low on water – or about 2 percent dehydrated – and more if he has been drinking caffeinated beverages or if he consumed alcohol the previous day. At a dehydration level of 3 percent, he may experience sleepiness, nausea, mental impairment, and mental and physical fatigue.

Psychosocial Stressors

Psychosocial stressors are those that involve relationships, career and finances, as well as the factors that influence these three areas, such as physical health. Psychosocial stress can be either positive – such as a promotion at work, marriage or the birth of a child – or negative – such as divorce or separation, death of a loved one or illness or injury to self or family. Good psychological health enhances pilot performance, and the presence of negative stressors affects performance. These stressors are distractions and can slow reaction times in assessments of critical situations and decision making.

While some stressors are well known to pilots, others go unrecognized. Civil aviation authorities and others have developed a number of personal checklists to aid pilots in evaluating themselves for stressors. For example, the FAA has developed an "I'm Safe" checklist for pilots to evaluate their readiness for flight (Table 2).[21]

Table 2

'I'M SAFE' CHECKLIST

Illness	Do I have symptoms of an illness?
Medication	Have I been taking prescription or over-the-counter drugs?
Stress	Am I under psychological pressure from the job?
Alcohol	Have I been drinking within eight hours? Within 24 hours?
Fatigue	Am I tired and not adequately rested?
Eating	Have I eaten enough of the proper foods to keep adequately nourished during the entire flight?

Source: U.S. Federal Aviation Administration; Clarence E. Rash and Sharon D. Manning

The mnemonic stands for being unimpaired by illness, medication, stress, alcohol, fatigue or eating (inadequate nourishment).

Dozens of stressors – originating from a variety of environmental, psychosocial, physiological and cognitive sources – may degrade cognitive processes and jeopardize decision-making skills. Vigilance by pilots can help prevent these stressors from putting flight operations at risk.

Clarence E. Rash is a research physicist with 30 years experience in military aviation research and development. He has authored over 200 papers on aviation display, human factors and protection topics. His latest book is Helmet- Mounted Displays: Sensation, Perception and Cognition Issues, U.S. Army Aeromedical Research Laboratory, 2009.

Sharon D. Manning is a safety and occupational health specialist at the Aviation Branch Safety Office at Fort Rucker, Alabama, U.S., and has over 20 years experience in aviation safety.

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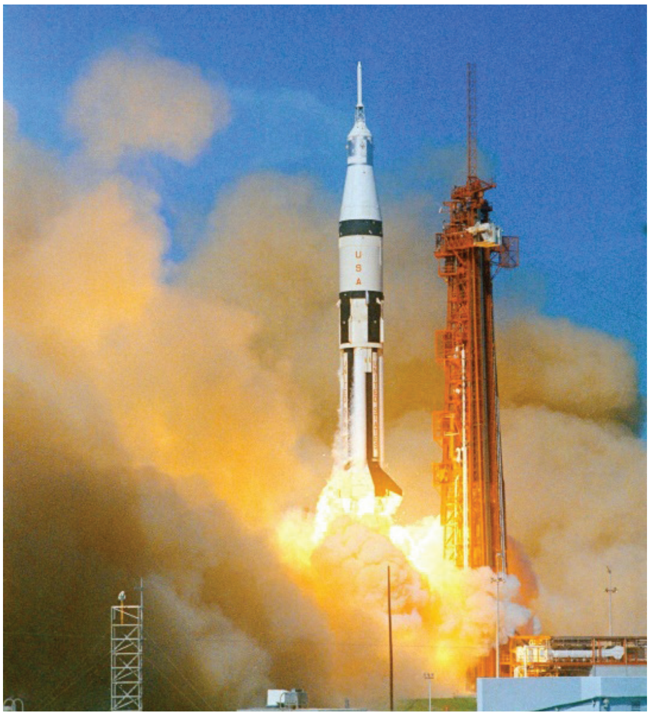
The Apollo 1 Disaster

by Dai Whittingham, Chief Executive UKFSC



The Context

With the 50th anniversary of the first moon landing fast approaching, it is worth recalling that manned spaceflight has always carried significant risk. With the benefit of hindsight, it is remarkable that those risks were so willingly accepted by the early astronauts and that the risks were also considered acceptable by the space programme managers and leaders.

The backdrop to the Apollo 1 accident was the 'Space Race' between the USA and the Soviet Union, who were both already deeply embroiled in the Cold War. The Soviets had gained a head start by launching Sputnik 1 into a low Earth orbit in October 1957, 3 months before the USA was able to reply with Explorer 1. Sputnik 1 operated for 3 weeks until its batteries were exhausted and burned up on re-entry 2 months later. The Americans were further shocked on 12 April 1961 when Yuri Gagarin flew Vostok 1 to become the first man in space and to orbit the planet; Alan Shephard's sub-orbital flight followed on 5 May.

In March 1961, the NASA Administrator, James E Webb, had submitted a budget request to fund a moon landing before 1970. At the time, President John F Kennedy rejected this out of hand as being unaffordable. He then asked Vice-President Lyndon Johnson to look at areas where the USA could take a lead, with Johnson subsequently advising that the two options were an orbiting space station and a moon landing. A possible moon landing was seen as being sufficiently far into the future that there was time to catch up and get ahead. The rest is history.

On 25 May 1961, Kennedy committed the USA to the goal of landing man on the moon and returning him safely before the end of the decade, thus putting enormous pressure on NASA to succeed in developing new technology and techniques against a hugely ambitious deadline and in a political environment dominated by an increasingly hostile Cold War. The 1963 assassination of Kennedy also placed further pressure on NASA through a perceived need to honour Kennedy's vision.

The Accident

At 1800 GMT on 27 January 1967, astronauts Virgil 'Gus' Grissom, Ed White and Roger Chaffee crewed into the Command Module of Apollo 1 (then known as Apollo 204) for a "Plugs-Out" test which was intended to prove that the internal electrical systems of their newly assembled space vehicle would function correctly without external connections.

The specific objectives shown in the Operational Checkout Procedure were:

- To verify overall spacecraft/launch vehicle compatibility and demonstrate proper function of spacecraft systems with all umbilicals and Ground Support Equipment disconnected.
- To verify no electrical interference at the time of umbilical disconnect.
- To verify astronaut emergency egress procedures (unaided egress) at the conclusion of the test.

(Gus Grissom, Ed White and Roger Chaffee)

The test sequence ran with various interruptions for several hours but by 23:20 GMT all final countdown functions up to the transfer to simulated fuel cell power were completed; the count was held at

T-10 minutes pending resolution of communications problems that included an open mic on Gus Grissom's helmet.

All systems appeared to be operating normally and there was no voice traffic from the Command Module until a short transmission of a single exclamatory remark at 23:31:04 followed shortly after by a call from Chaffee of "We've got a fire in the cockpit". A 7-second silence was broken by a garbled transmission along the lines of "We've got a bad fire – let's get out – Open 'er up (or 'we're burning up…)'" There were no further transmissions from the crew. The Command Module ruptured at floor level because of the build up of internal pressure and 3 seconds later all data and voice transmissions were lost.

Although the Pad Leader ordered crew egress procedures to be started, efforts to access the Command Module were hampered by flames, heavy smoke, and the absence of fire-fighting equipment and breathing protection. By the time the inner and middle hatches were opened, 5 minutes after the first report of fire, it was apparent that the crew had not survived. The autopsies showed that all 3 men would have been rapidly incapacitated by the carbon monoxide generated by the fire and which entered their suits once these were compromised by the flames.

The Investigation

NASA immediately launched a comprehensive investigation that sought to identify the source of the fire, understand its nature and severity, and examine contributory causes and organisational factors. (https://history.nasa.gov/Apollo204/summary.pdf).

The origin of the fire could not be determined but it was believed to have originated in wiring to the left of the Command Pilot (Grissom) and below the level of his couch. The fire burned in 3 stages, the first producing a rapid temperature rise and increase in pressure that lasted around 15 seconds. The flames moved quickly across the cabin from left to right, travelling along nylon net debris traps and Velcro strips.

The Command Module pressure vessel ruptured at 23:31:22, starting an intense conflagration, with gases and flames venting to the exterior. The pressure vessel was designed to withstand a differential pressure of at least 13psi (0.9 bar) but internal pressure was assessed to have dropped to local atmospheric within 5-6 seconds. The third stage of the fire lasted only a few seconds but produced heavy smoke and very high concentrations of carbon monoxide. It was estimated that the cabin atmosphere was lethal by 23:31:30, five seconds after the start of the third stage fire and only 27 seconds after the first crew report.

(Command Module – Post Fire)

The investigators determined that the fire had been particularly intense because it was in a sealed cabin that was pressurised with 100% oxygen and noted that there was 'an extensive distribution of combustible materials in the cabin' including 3.2 m^2 of Velcro. Wiring and plumbing was vulnerable, with the plumbing carrying a combustible and corrosive coolant.

Crew escape might have been possible but for the design of the hatches; the plug-style inner hatch opened inwards to help prevent pressure loss during space flight, but the 3-hatch combination took 90 seconds to open under normal conditions. Though Ed White was initially seen trying to operate the inner hatch, internal pressure during the fire would have prevented it from opening at all.

The choice of a 100% oxygen atmosphere at launch was aimed at preventing decompression sickness and had been used on all previous flights. Cabin pressure considerations in flight also required 100% oxygen to ensure adequate partial pressures at the lung while limiting differential pressure. There had been earlier accidents involving 100% oxygen atmospheres but these had not been recognised by NASA. The investigation determined that a deeper analysis of the test conditions would have led to its being categorised as hazardous, whereas it was treated as a non-hazardous test. A hazardous test would have prompted the provision of enhanced fire and rescue resources and probably other tests prior to the manned element of the programme. The investigators further observed that "Adequate safety precautions were neither established nor observed for this test".

(Command Module – external view)

The investigation also uncovered significant weaknesses in the management, control and documentation of the space vehicle construction and maintenance. It noted problems with programme management and relationships with the multiple work centres and the main contractor, opining that these had led in some case to an inadequate response to changing requirements.

The Aftermath

The investigation was largely NASA staffed and led but was later viewed as having been suitably self-critical. Subsequent investigations into space accidents have been conducted by independent Presidential Commissions.

The programme was delayed by around 18 months. The early (Block 1) Command Modules were restricted to unmanned flights. The Command Module underwent significant redesign, with all flammable materials replaced. The cabin atmosphere at launch was adjusted to a 60/40 oxygen/nitrogen mix and allowed to vent down to 5 psi during the ascent before being purged and replaced with 100% oxygen over the next 24 hours. Protective insulation was added to all plumbing and wiring. Nylon used in the construction of the space suits (which had contributed to their early breach by fire) was replaced with non-flammable Beta cloth, woven from fibreglass and Teflon. Importantly, the main hatch design was changed for subsequent Apollo missions to one that opened outwards and was operable within 5 seconds.

Multiple changes were made to management and oversight processes, with renewed emphasis on quality control.

Lessons for today

- Testing of anything, including post-maintenance flight checks, needs approaching with caution. Testing something new is a specialist job.
- Work with pressurised cabins brings a whole new batch of hazards into play for those in or near the platform being tested.
- Similarly with hydraulic systems – the maintenance procedures are there for good reason, so follow them.
- Use the right materials – ask yourself what the worst conditions might be (the lessons on flammability had not been properly absorbed until the Manchester B737 accident prompted changes in cabin design).
- Quality control matters.
- Political and commercial pressures can occasionally lead to unwise decisions. If you need more time, ask for it, don't assume things will work out in the end.
- Introduction to service for a new aircraft is a complex task that needs to be actively managed.
- Don't accept the status quo without questioning it at some stage.

And the last word to Gus Grissom:

"If we die, we want people to accept it. We're in a risky business, and we hope that if anything happens to us it will not delay the program. The conquest of space is worth the risk of life."

Photos provided by NASA.

Lessons Learned!

by Dai Whittingham, Chief Executive UKFSC

More years ago than I care to remember, I was a student on a 6-month course learning to fly and operate the Phantom FGR2 (F4M for the purists).

The aircraft itself was huge compared with my previous types. Almost 60 feet long and 32,000 lbs ZFW, it had blown leading and trailing edge flaps and an all-moving slab stabiliser. The combination of cranked dihedral wings and anhedral stab was a good indicator of some 'unusual' aerodynamic qualities; the adverse aileron yaw at higher angles of attack was so powerful that you rolled the aircraft on rudder alone. For the same reason, there was an interconnect system that provided a bit of rudder to go with aileron inputs when the flaps were down, more of which later. And it was a lot of fun to fly.

One fine but breezy afternoon, and with less than 60 hours combined experience on type between us, my student navigator and I were tasked to fly as part of a pair to practice the Low-Level Attack Re-Attack profile. One would fly as target, holding a straight course at 250 ft over the sea while the other manoeuvred for a simulated radar missile release head-on before breaking away and reversing at the right moment to position in the stern sector for a simulated heat-seeker shot.

After our second run we were down at 250 ft as target and flying at a steady 420 kts. As we turned inbound to start the exercise, I used a blip of stick-top aileron trim to counter a slight left-roll tendency. The rolling tendency became more pronounced and, assuming I had reacted incorrectly (I was new…), I tried again. This time it got much worse. Trim runaway. Deep joy.

I held the switch to counter the movement while simultaneously changing hands on the stick, climbing away from the sea, looking for and pulling the trim circuit breaker on the right console (trim runaway memory item), and explaining to my nav what was going on. The aircraft now required quite a bit of stick force to keep wings-level, the result of a fully-deflected aileron on one side. Time to go home.

I found I could relieve some stick forces with a combination of bank and rudder but the aircraft was still a bit of a handful. We did a handling check down to approach speed and decided we didn't need to jettison the aircraft at that stage. Naturally, the crosswind at base was from the most inconvenient direction possible. The aircraft was duly wrestled onto the ground, albeit with some difficulty (I was tiring quite fast), and we retired to the crew-room for a well-earned coffee and some ASR writing.

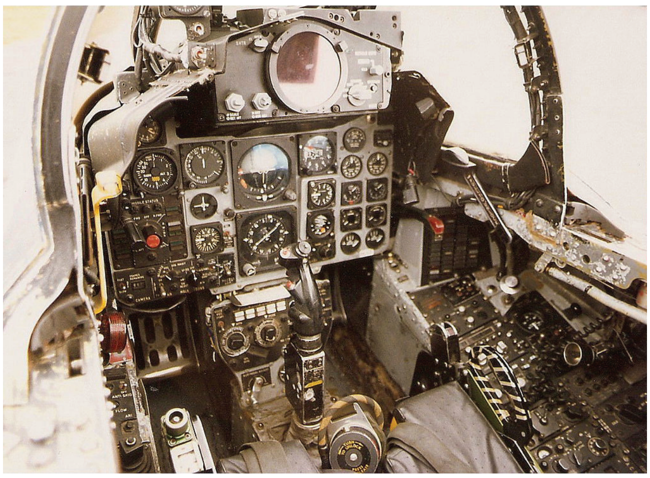
The following morning, I was invited into an office by one of the more senior staff members. I was half-expecting to get a metaphorical pat on the back for having sorted out a difficult situation. What I was not expecting was an opening threat followed by a demand. "How much do you want to pass this course?" "I need you to withdraw your report because it makes the engineers look complete ***** and we are not having it…"

To this day, I regret that I buckled under the pressure and agreed the report could be withdrawn. Nothing else was said, but I later found out what had happened.

The after-start functional checks included proving the aileron-rudder interconnect worked properly, and that the ailerons were trimmed to neutral. The 2-man see-off team were not on headsets, so there was a lot of arm-waving and hand-flapping involved. If the ailerons needed adjusting, the arms outside would be extended with thumbs indicating the required direction of aileron travel and the pilot would move the coolie hat until the 'neutral' signal was given.

For our aircraft, the wiring to the trim motor had been disturbed as part of a maintenance task but had been re-connected with reversed polarity. The work had been signed off by the tradesman, with a supervisor's signature that it had been completed correctly. It had already flown 3 times in that condition, all with staff pilots. Either the trim had not needed adjusting (quite possible), or pilots had assumed the groundcrew signal was wrong and moved the switch in the opposite direction for neutral, or simply not realised the groundcrew signal was correct and their trim input was incorrect but having the result desired outside the aircraft! Whatever, in 4 start sequences none of us picked up the fact that the trim motor had been cross-connected.

So, what lessons did I learn from the experience? That Just Culture matters. That bullying is unacceptable. That feelings of regret and shame over doing the wrong thing do not go away quickly, if ever. That I would never put someone else in the same position no matter how stupid it made me or anyone else look. That nothing is more important than flight control checks. And that whenever I was asked to produce a control surface deflection as part of a checklist I would first work out what control input I needed to achieve the desired effect, so that I would know immediately if there was something wrong.



(The office. Trim CBs are just visible on the extreme lower right of this photograph, below the wander-light.)

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